Assessment of Particulate Matter (PM2.5) pollution and Health risks associated with Coal Power Project Sahiwal (Pakistan)

By

Hafiza Asma Khan
00000171287

A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science

In

Environmental Sciences

Institute of Environmental Sciences and Engineering (IESE)

School of Civil and Environmental Engineering (SCEE)

National University of Sciences and Technology (NUST)

Islamabad, Pakistan

(2020)

Approval Sheet

It is certified that the contents and forms of thesis entitled

Assessment of Particulate Matter (PM2.5) pollution and Health risks associated with Coal Power Project Sahiwal (Pakistan)

Submitted by

Hafiza Asma Khan

Has been found satisfactory for the requirements of degree of Master of Science in Environmental Sciences

Supervisor: ____________

Dr. Salahuddin Azad.
Associate Professor

IESE, SCEE, NUST

Member: ____________

Dr. Zeshan Sheikh
Assistant Professor

IESE, SCEE, NUST.

Member: ___________

Dr. Aansa Rukya Saleem
Assistant Professor,
E&ES, BUIC Islamabad

THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of MS/MPhil thesis written by Miss **Hafiza Asma Khan** (Registration No. NUST 00000171287 of **IESE(SCEE)** has been vetted by undersigned, found complete in all respects as per NUST Statutes/Regulations, is free of plagiarism, errors, and mistakes and is accepted as partial fulfillment for award of MS/MPhil degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

Signature: ______________________________________

Name of Supervisor: Dr. Salahuddin Azad

Date: ____

Signature (HOD): ________________________________

Date: ____

Signature (Dean/Principal): _________________________

Date: ____

DEDICATION

“Fondly dedicate my research work to
My beloved parents
and
my Supervisor Dr. Salahuddin Azad”

ACKNOWLEDGEMENTS

All my humble gratefulness is for Allah Almighty for giving me strength, vision and capability to comprehend and conquer the science of universe He has created. No doubt, it’s because of His countless blessings on me.

I would like to express special thanks and gratitude to my Supervisor **Dr. Salahuddin Azad** for his continuous support throughout my thesis at IESE, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me through my research and writing of this thesis. I could not have imagined having a better advisor and mentor for my MS research work.

Many thanks to **Dr. Zeshan Sheikh** (IESE) and **Dr. Aansa Rukya Saleen** (E& ES, BUIC) for their guidance and support.

I am also very thankful to **Dr. Abdulwaheed** (NICE, SCEE) for his unfailing support and guidance throughout my research work.

I am also very grateful to several other individuals who assisted me during the data collection, processing and analysis stage and provided all the required technical support in a timely manner. Lastly, I would like to appreciate the endless support I received from all my friends.

“Hafiza Asma Khan”

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

AP	Affected Person
BHU	Basic Health Unit
CHP	Combined Heat and Power
CHS	Controlled Hazardous Substance
CO	Carbon Monoxide
CO_2	Carbon Dioxide
E&RT	Environment and Resettlement Team
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
EMC	Environmental Monitoring Cell
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
EPD	Environmental Protection Department
FGD	Flue Gas Desulphurization
FGMC	Flue Gas Mercury Control
HAPs	Hazardous Air Pollutants
HSE	Health Safety and Environment
IEE	Initial Environmental Examination
IUCN	International Union for the Conservation of Nature
LAA	Land Acquisition Act
LAC	Land Acquisition Committee
LBDC	Lower Bari Doab Canal
LES	Livestock Experiment Station
MCM	Million Cubic Meter
Mha	Million Hectares
MTPY	Million Ton Per Year

MW	Mega Watt
NCS	National Conservation Strategy
NEQS	National Environmental Quality Standards
NESPAK	National Engineering Services Pakistan
NO	Nitrous Oxide
NO2	Nitrogen Dioxide
NTDC	National Transmission and Dispatch Company
SO2	Sulfur Dioxide
SCPP	Sahiwal Coal Power Project
US EPA	United States, Environmental Protection Agency

ABSTRACT

Economic development comes at an unavoidable cost of environmental degradation. History suggests that Coal-Fired power plants are a symbol of economic development, at present 38% of world electricity generated by Coal-fired Power Plants. Following the examples of economically stable countries, to overcome energy shortages, Pakistan is also installing coal-based power plants under CPEC. Sahiwal Coal Power Project is the first major coal power plant with the installed capacity of 1320MW, operational since July 3, 2017. While the plants bring jobs and prosperity to the surrounding region, they also pose a serious threat to the locals residing nearby as they are more vulnerable to the immediate impacts. Exposure to the pollutants' emissions from coal power plants cause adverse respiratory problems (i.e. asthma), cardiovascular diseases (i.e. Heart attacks) and effects on nervous system such as ischemic strokes as well as skin, eyes, nasal allergies etc... Thus, the aim of the study was to assess the impact on ambient air quality and the status of health problems in the vicinity aroused after the installation of Sahiwal coal power plant. Surveys were conducted (Nov-Dec, 2018) in the vicinity, ambient air quality monitoring at 3 stations (Chak 75/5R, Chak 76/5R, Chak 77/5R) to assess the 24-hr avg. concentrations of various air pollutants (SPM, PM10&2.5, SO2, NO, NO2, CO, O3) was performed. Health assessment via questionnaires (Modified ATS-DLD 78A) and respiratory tests (Spirometry) were undertaken during the surveys. Reported symptoms for common illnesses was dominated by Nasal irritation and allergies 80.4%, followed by throat irritation and allergies (77.2%) and eyes related issues 65.6%, skin problems 58.4% and ear related problems with 46%. Headaches and nausea related complaints were reported with 63.6% and 37.6% respectively. Predominant type of respiratory complaint was cough (80% frequent and 44.4% chronic) followed by shortness of breath with (49.6% Grade I, 43.6% Grade II, 38.8% Grade III, 20.8% Grade IV, and 11.2% for Grade V), wheeze (37.6% frequent and 24% chronic), phlegm (36.8% frequent and 13.6% for chronic). Majority of respondents with preexisting illness complaint about worsening of their condition after the installation and operation of Sahiwal coal power plant. The spirometry analysis, of selected participants suggested that the Obstructive pattern on spirometry was 56 % (Mild: 29.2%, Moderate:15%, Severe:9.3%, Very Severe: 2.5%) and restrictive pattern was 17.4 %. A trend of reduced lung function (predicted FVC, FEV1 and FEV1/FVC ratio) was observed among participants with chronic respiratory symptoms compared to those without symptoms. The observed ambient 24-hr average concentrations of air pollutants in the study area of Sahiwal Coal Power Plant were well below the PEQS except for SPM and PM2.5 which are quite high than the standard values. This was a pilot study with a small sample size and short sampling period, however, as a preliminary research, this study significantly adds to the scarcely available data in this field. It is recommended that repeated, longitudinal, quantitative health monitoring with professional consult be provided to truly mitigate persistent health problems. Further work be done, with longer sampling periods for each season in order to capture a seasonal profile of concentrations of particulate matter. NGOs, Educational Institutes and researchers should be allowed to visit inside the plant.

1 CHAPTER 1: INTRODUCTION

1.1 Background

Electricity provides many health benefits worldwide and is a significant contributor to economic development, a higher standard of living, and an increased life expectancy (Markandya and Wilkinson, 2007). The use of coal to produce electricity has been shown to increase illness and death in the general population through air pollution. When coal is burned in power plants to generate steam which spins turbines and creates electricity, it produces air-borne pollutants of particulate matter, sulfur dioxide, oxides of nitrogen, carbon dioxide, mercury, arsenic, chromium, nickel, other heavy metals, acid gases (HCL, HF), hydrocarbons (PAHs) and varying levels of uranium and thorium in fly-ash (US EPA, 2009). These emissions contain 84 of the 187 Hazardous Air Pollutants (HAP) regulated by the US EPA (dirtykilowatts.org). In addition to the stack emissions from the coal-fired power plant, coal handling may also emit pollutants into the atmosphere and thus degrade the air quality in the vicinity near the power plant (Aneja *et al.*, 2012).

While the plants bring jobs and prosperity to the surrounding region, they also pose a serious threat to the locals residing nearby. Exposure to the pollutants' emissions from coal power plants cause adverse respiratory problems (i.e. asthma), cardiovascular diseases (i.e. Heart attacks) and effects on nervous system such as ischemic strokes (Lockwood *et al*., 2009). The Hazardous air pollutants (HAPs) released from coal-fired power plants can influence environmental quality and public health on a local, regional and global scale. A number of factors can influence the range or extent of a given pollutant or facility on these scales but principally the atmospheric residence time of a pollutant, physical attributes of power plant (i.e. Stack height), weather conditions and the proximity of human population determine whether human and environmental impacts of a power plant related to HAPs are generally local or can extent to regional or global scale.

However, potential exposures to these HAPs can be elevated in areas surrounding a coal-fired power plant. For instance, a study of coal-fired power plants in new England found that public health damages are two to five times greater for communities near the facilities than for population living at a greater distance from the plants (Levy and Spengler, 2002). Moreover, two of the major greenhouse gases carbon dioxide (CO_2) and nitrous oxide (N_2O) are products of coal combustion contributing to global warming and ultimately to climate change.

Despite the adverse environmental and public health impacts of coal as fuel source, Coal-fired power plants have been widely used for energy production worldwide. At present the world energy mix shows that 38 percent of the world electricity is produced by coal, 24 percent each from natural gas and renewable sources, 11 and 4 percent from nuclear and oil resources respectively (Worldcoal.org). Whereas Pakistan's energy mix is quite the opposite as the use of coal for power generation is negligible despite the fact that it is the cheapest nonrenewable fuel source.

1.2 Pakistan Energy Generation and Coal.

1.2.1 Pakistan Energy Mix and Power shortages

Pakistan's economic growth has been severely affected by the energy shortages in last few decades. The electricity shortfalls reached to a peak of 8,500 MW in June 2012, 40% more than the national demand (NBR, 2013). In 2017, Pakistan's total installed electricity generation capacity was 25,100 MW, Power production was 16000-17000MW, average energy demand was 22,000MW, which means an average shortfall of 5000-6000MW. According to IEA forecast total energy demand will be 49,078 MW by 2025. No wonder, because the energy mix of Pakistan is mainly based on imported oil and natural gas resources (Figure 1.1). As compare to the neighboring countries especially China and India (Figure 1.2). Coal based energy production of various developed countries around the world has been described in Annex…

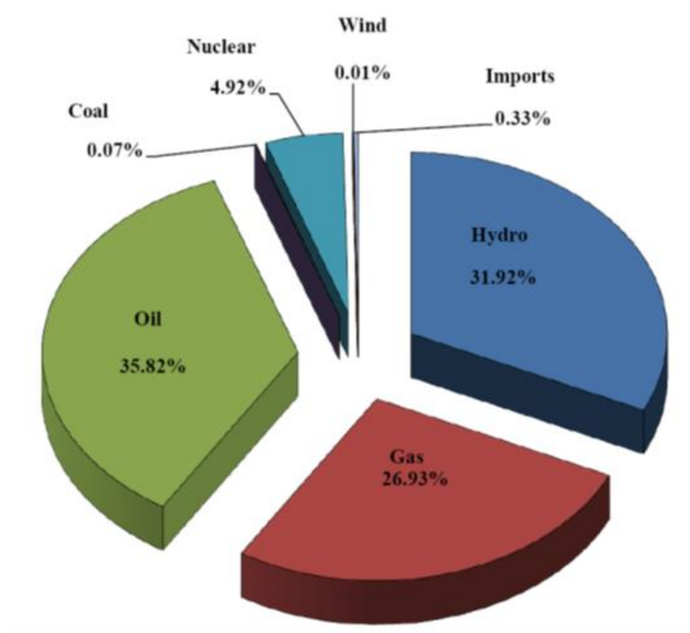

Figure 1-1: The energy generation of Pakistan by fuel type

Source: Power System Statistics 2011-2012 - NTDC

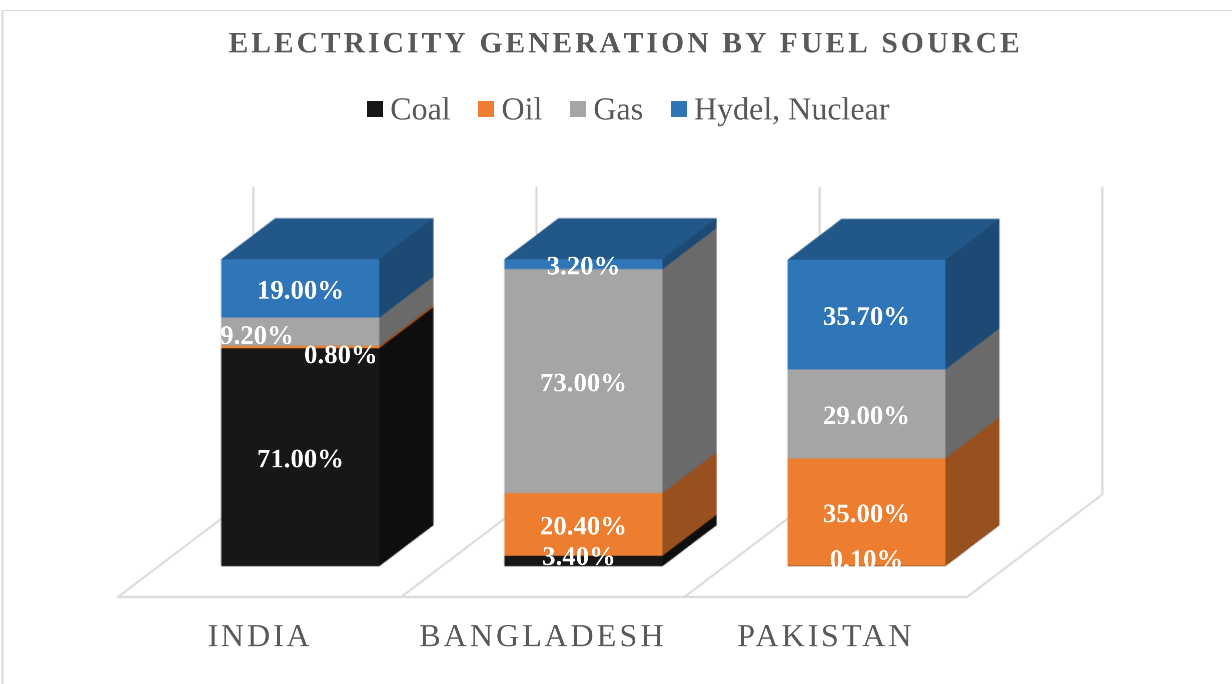

Figure 1-2: Pakistan Energy generation by fuel type and comparison with India and Bangladesh

Source: Economic Survey of India, Bangladesh and HDIP (2012)

In order to meet the increasing energy demands of the country, China-Pakistan-Economic-Corridor (CPEC) has assigned a major part of its funds to energy generation and transmission. Including Coal-fired power plants, solar parks, hydro-power projects, wind farms throughout the country. To overcome the energy deficiencies for domestic and industrial use, Pakistan's very first mega Coal-fired power project has been installed in district Sahiwal, Punjab with installed capacity of 1320MW. It has been operational since July, 2017. The other coal based power projects along with their capacity and operational status have been listed below in table 1.1

Table 1-1: Pakistan's Coal-fired power projects under CPEC at their current status

Sr. no.	Coal Power Projects	Capacity	Status
1	Sahiwal Coal-fired Power Plant, Punjab	2x660MW	Operational, July 2017
2	Coal-fired Power Plants at Port Qasim Karachi	2×660MW	Operational, April 2018
3	Engro Thar Coal-fired Power Plant and Surface Mine in Block II of Thar Coal Field	2x330MW	Operational, July 2019
4	Imported Coal Based Power Project at Gwadar, Pakistan	300MW	70%

5	2 x 660MW Hubco Coal Power Plant, Hub Balochistan	2x660MW	Operational, Oct 2019
6	Thar Coal Block I and 2x660MW Mine Mouth Power Plant	2x660MW	90%
7	Rahimyar Khan Coal Power Plant	2x660MW	15%

Pakistan's current scenario of energy generation by fuel type is illustrated in Fig. (source: International Energy Agency, IEA) which clearly depicts the shift in fuel for electricity generation by cutting off its oil needs and moving towards coal since few coal based power plants has been operational since 2017.

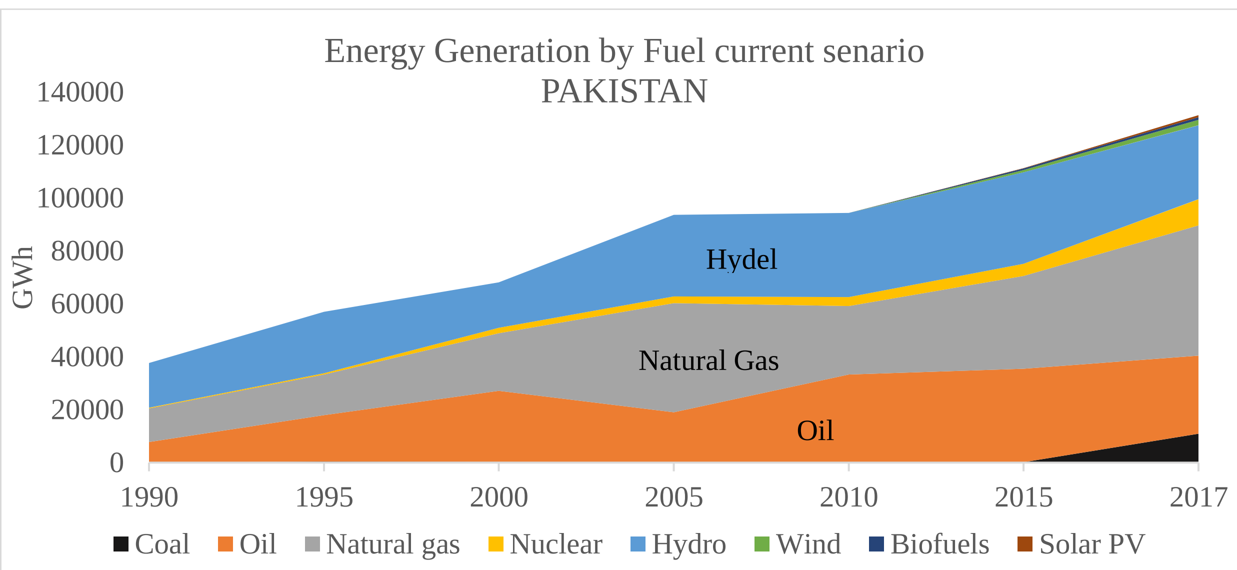

Figure 1-3: Current scenario of Pakistan's energy generation by fuel type

1.2.2 Sahiwal Coal Power Project (SCPP)

The power plant is located about (12 mi) from Sahiwal city and (9.3 mi) from Okara cantonment in the province of Punjab. The power plant site (Figure 1.4) primarily falls within the area of Chak

No.75/5-R and is located on a single-track road at a distance of 1-2 Km from Qadir Abad on left hand side of the main dual track of National Highway-N5 from Sahiwal to Lahore. Dual main railway track also exists near the project site. Sahiwal coal power plant is Pakistan's first supercritical power plant, and it consists of two 660-megawatt (890,000 hp) plants for a combined capacity of 1320MW. Each plant consists of one boiler, steam turbine and generator operating at temperatures of up to 580-degree Celsius.

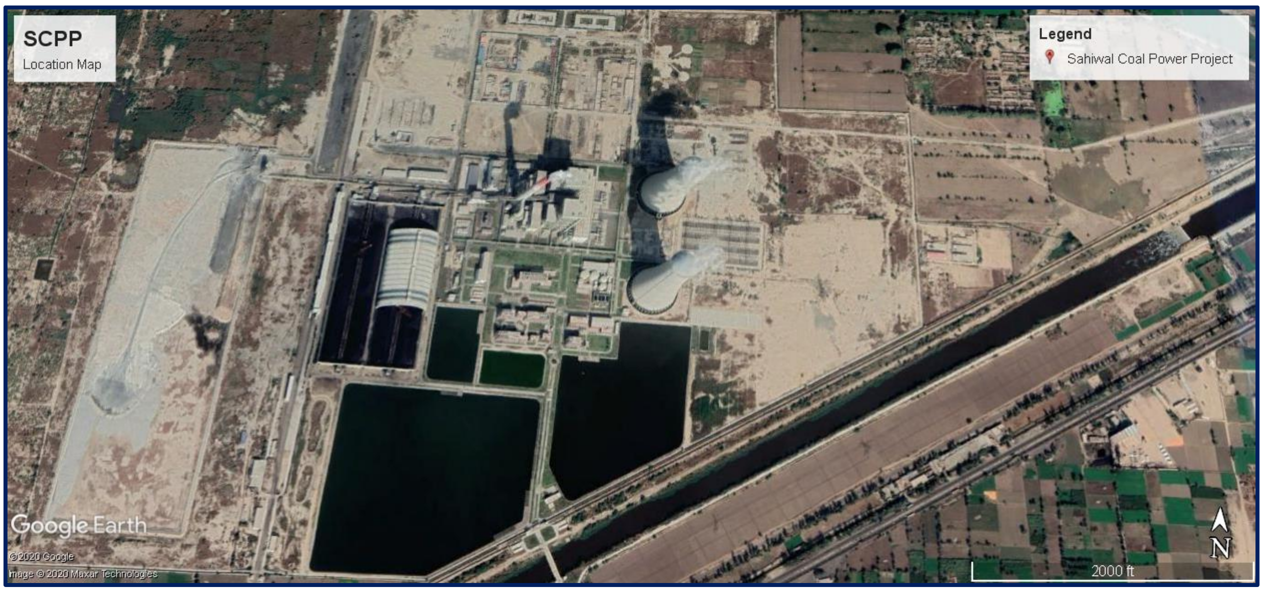

Figure 1-4: Sahiwal Coal Power Project (SCPP) Arial View

Sahiwal Coal Power Project was started in February 2015 and completed in 2017. It has been operational since July 3, 2017, Owned by Chinese state enterprise; Huaneng Shandong Rui Group. Punjab Power Development Board (PPDB) is the supervisory agency under the Ministry of Water and Power. The company utilizes supercritical technologies and imported bituminous coal. The Plant operates on imported coal, transported from Karachi through railway.

1.2.2.1 Environmental Protection Measures at Sahiwal Coal Power Project.

The Sahiwal coal power plant has an air quality monitory system to monitor the air emissions. It also utilizes Flue Gas Desulfurization (FGD) and Electrostatic Precipitators (ESP) technologies to reduce the ash and sulfur emissions from plant in order to protect the environment. Following is a list of Environmental Protection measures the plant administration claimed to have installed.

1. **Dust Control Measures:**

   Electrostatic Precipitators (ESPs) along with Limestone-Gypsum wet desulfurization technology has been installed as dust removal system.

2. **SO_2 Control Measures:**

   The Sahiwal power plant has Limestone-Gypsum Flue Gas Desulfurization (FGD) designed to remove SO2. After being treated in an electrostatic precipitator (ESP) flue gas from boiler enters the FGD system.

3. **Wastewater Treatment:**

   The wastewater treatment system is designed keeping in mind the "No Wastewater Discharge" Techniques to treat the regular and irregular wastewater from the plant.

4. **Seepage control measures "Ash Yard"**

   Given Pakistan has no regulations to control ash seepage and permeability, the ash yard is designed according to Chinese standards, dam slope and ash fields laying of polyethylene geo-membrane (two cloths one membrane) and 1.5M thick clay layer to control seepage.

5. **Coal Dust control measures "Coal Yard"**

   Spray guns are installed to timely sprinkle the water on the top of coal pile to ensure the surface moisture remains at about 6% to effectively reduce the volume of coal dust.

6. Tree Plantation

In order to improve the ecological environment, the Power Plant has aimed to Plant 30,000 trees. As 1200 trees were cut down to clear the site for SCPP (IEE Report of SCPP, 2014).

1.3 Socio-Economic and Climate conditions of district Sahiwal

1.3.1 Socio-Economic condition of Locale

According to recent censes in 2017 approximately 80 percent of the population resides in rural areas of district Sahiwal (84 percent in 1997 censes). Agriculture is important to the local economy, particularly cotton and grain crops, most of the population is dependent on agriculture related activities for their livelihood. Since the annual rainfall is too low in this region, groundwater is the sole source of water for domestic, agricultural and industrial use. There are transport connections via road and Pakistan railways to Lahore, and a regional airport under construction. The literacy rate is alarmingly low, about 30 percent overall and 51 percent in the city of Sahiwal.

Civil Hospital is the largest hospital of Sahiwal, other notable and renowned hospitals include the Christian Hospital, Bhagwan jee Children Hospital etcetera. Shaukat Khanam Lab, Agha Khan Lab, Bhagwan Lab, Shafqat Lab and numerous other private laboratories are functioning in Sahiwal city. The rural areas however lack health facilities and are suffering from poverty, illiteracy, water scarcity plus environmental degradation after the installation of coal-fired power plant.

1.3.2 Weather and climate conditions of District Sahiwal

The climate of Sahiwal is called a desert climate, classified by the Köppen-Geiger system as BWh. Which is extremely hot, reaching 47-50°C in the summer and cold in winter, down to 12°C. The average annual mean temperature is 32 °C and the annual rainfall is approx. 200 mm. The driest month is October with 1 mm of precipitation. Most precipitation falls in July, with an average of 89 mm. The rainy season lasts from July to September. June is the warmest month with an average temperature of 47 °C.

1.4 Relevance to National Needs

Economic development comes at the unavoidable cost of environmental degradation. Innumerable amounts of pollutants are released in to the environment causing damage to

environment and ultimately human health. It is important to understand the consequences of any technology before installation. In order to meet the national demands for electricity Pakistan has initiated installation of Coal-based Power Generation Plants under CPEC. Sahiwal Coal Power Project is the first operational plant in Pakistan at present. This study is aimed to assess the impacts on air quality and public health after the installation of coal power plant. As coal has been known as dirty fuel and release many pollutants having harmful impacts. In order to protect the environment and human health, this study could serve as baseline to understand the impacts and to estimate the potential impacts of other planned coal fired power plants as well. Successful outcome of the proposed research offers many advantages to Policy makers and stake holders involved in this project. Efforts could be made accordingly to prevent or mitigate the adverse impacts.

1.5 Significance of the study

This is a pilot study to assess the ambient air quality and public health impacts in the vicinity of Sahiwal Coal Power Project. The results from the proposed research could be used by Policy makers, environmentalists, Public health safety specialists, Social scientists and all other stakeholders and concerned citizens. Students and researchers in this field could use it as baseline study to correlate the impacts of other coal-based projects in Pakistan. This research could help understand the current situation of ambient air quality and health in the area. Future and recommendations could be made to combat the impacts.

1.6 Objectives of the study

- → To Assess the Impacts of Coal Wastes from power plant on the Socio-demographic Environment
- → To assess the ambient air quality impacts (Particulate Matter PM 10, PM2.5, SPM) of Sahiwal coal power project.
- → To evaluate the health/respiratory risks associated with the coal power plant emissions in the vicinity.

2 CHAPTER 2: REVIEW OF LITERATURE

2.1 Introduction

Although Coal fired power plants offer many advantages by producing electricity which is essential in order to gain economic stability in this modern world. Historically it is well known that Coal power plants have devastating impacts on the environment by polluting the atmosphere and other environmental matrices as well as on public health, which in turn burdens the economy of a country. Guttikunda *et al.*, (2014) estimated pollution emissions from 111 operational coal thermal plants in India with an installed capacity of 121 GW, consumption of 503 million tons of coal, generated an estimated 580 ktons PM2.5, 2100 ktons SO2, 2000 ktons NOx, 1100 ktons CO, 100 ktons of VOCs, and 665 million tons of CO2. Those emissions resulted in an estimated 80,000-115,000 premature deaths and 20 million asthma cases from PM2.5 pollution exposure, and estimated health costs of INR 16,000 to 23,000 crore (USD 3.2 to 4.6 billion). This study also stated that pollution control technologies such as installation of flue gas desulfurization systems could reduce the PM2.5 concentrations by 30-40% by eliminating the formation of the secondary sulfates and nitrates. 2,130 premature deaths and $18 billion in health burdens were caused by Particulate Matter pollution from burning coal and gas in Ohio power plants in 2015 alone (Krieger, E, *et al.*, 2016). According to Berkeley Earth estimates, air pollution from coal-fired power plants is responsible for 0.7 to 2.2 million premature deaths per year in China. The life expectancy has also been reduced by 5.5 years in northern China and a general reduction of 3-years in life expectancy of the population (Chen *et al*., 2013). A strong correlation between the concentration of pyrite in coal and the occurrence of black lung disease in United States was demonstrated by Huang *et al.*, (2005). Mumford *et al*. (1987) first noted the carcinogenicity of coal smoke in Xuan Wei county of China with the highest rate of female lung cancer mortality. In

2013, exposure to PM2.5 caused 2.9 million premature deaths worldwide; 916,000 deaths alone in China (Guan *et al.* 2014; Ma *et al.* 2017).

Exposure to high concentrations of HAPs can lead to a number of adverse health effects such as damage to the eyes, skin, lungs, kidneys and the nervous system, and can even cause cancer, pulmonary disease and cardiovascular disease (MacIntosh, D. & Spengler, J., 2011). Particulate matter with an aerodynamic diameter of 2.5 microns or less, is also a dangerous atmospheric pollutant due to its small size, which can travel deep into people's lungs and lead to a number of severe health effects. Elevated concentrations of PM2.5 are known to be associated with cardiovascular issues (heart disease, heart attacks, etc.) as well as respiratory issues, reproductive issues and even cancer (Pope, C.A., III., *et al.* 2006). According to Environmental Protection Agency US, PM2.5 is the likely cause of developing respiratory symptoms and asthma, and effects on lung function in children. The respirable Particulate Matter (PM2.5 or below) have been particularly linked to causing cardiovascular disease and death (US EPA, 2009).

Exposure to the emissions from coal-fueled power plant vicinity depends on weather conditions i.e. Temperature, precipitation, wind speed and direction and the topography of locale. The pollutants can also be transported to long distances, contributing to health impacts globally, affecting the people living far away from the power plants. Susceptibility to coal-fired power plant emissions depends on available medical facilities and age and health status of the individual. Children, pregnant women, the elderly and people with lung diseases for example asthma or chronic obstructive pulmonary diseases are more susceptible to health impacts from air pollution (Burt E. *et al*., 2013).

In addition to harming human health, coal-fired power plants can also lead to a number of environmental impacts as well, such as acidification of the environment, bioaccumulation of toxic metals, the contamination of water sources, reduced visibility due to haze as well as degradation of buildings and monuments. Before coal can be used in power plants, it first must be mined, washed, and transported. After being burned in power plants, the remaining ash must be stored or disposed of. Each of these steps in the coal life cycle, in addition to coal combustion, generates pollution. In the mining of coal, excess oil and slurry from the washing process contains hazardous substances such as heavy metals that can leach out of storage containers or infill, contaminating surface and ground water. After being washed, coal is transported from mines to power-plants via train, truck, ship, or barge. Diesel emissions from coal transport can be a significant contribution to local air pollution. After combustion, some coal ash is recycled into cement and other engineering products, but most of it is disposed of in dry or wet landfills. Landfills that leak fly-ash waste can contaminate ground and surface water with arsenic, cadmium, barium, thallium, selenium, and lead.

The ‘external costs’ of electricity generation from coal are the burdens to society that are not included in the electricity’s monetary price. Estimates of the external costs of electricity generation from coal suggest that 95% of the external cost consists of the adverse health effects on the population. Most of coal’s health burden results from its combustion in power plants, with the rest of the health burden consisting of the effects caused from the other steps of coal’s life cycle (Rabl, A., & Spadaro, J. V., 2006).

2.2 The Cost of Health Burden from Use of Coal for Energy Production

The impacts of coal combustion can be described in economic terms, and several papers have attempted to estimate the cost of using coal by assigning value to the environmental and public health damage caused during each stage of coal’s extraction, transportation, combustion, and disposal. An article published in 2007 in a medical journal, *The Lancet*, summarizes the burden of the health effects of generating electricity from coal and lignite (a type of coal). The authors estimate that for every TWh (Terrawatt-hour) of electricity produced from coal in Europe, there are 24.5 deaths, 225 serious illnesses including hospital admissions, congestive heart failure and chronic bronchitis, and 13,288 minor illnesses. When lignite, the softest and most polluting form of coal, is used, each TWh of electricity produced results in 32.6 deaths, 298 serious illnesses, and 17,676 minor illnesses (Markandya, A., & Wilkinson, P., 2007). According to International Energy Agency (IEA), world-wide coal-based energy production was 8,572 TWh in 2010. Using the health effects per TWh estimates in *The Lancet* article, the worldwide health toll from air pollution due to coal combustion is 210,000 deaths, almost 2 million serious illnesses, and over 151 million minor illnesses per year, not including the effects of climate change. This calculation is based on European pollution standards and population density. In countries with fewer air pollution standards, higher use of coal, or poorer quality coal, the health burden is even greater.

However, the compliance with regulations can greatly reduce the external costs. In 2011 the US EPA estimated the benefits and costs of the Clean Air Act, a law which regulates emissions of sulfur dioxide, oxides of nitrogen, carbon monoxide, and particulate matter in the United States. The EPA calculated that the ratio of health care cost savings to compliance costs was 25:1 in 2010. This means that for every dollar spent complying with the Clean Air Act, twenty-five dollars were saved in health care costs due to lower disease burden, including a reduction in premature deaths, and cases of bronchitis, asthma, and myocardial infarction (US EPA; Report 2011). Thus, it is important for coal power plants to keep in check, the compliance of regulations set by authorities.

2.3 Ambient Air quality and Health Assessment

2.3.1 Assessment of Ambient air quality

The stack emissions from coal-fired power plants and coal handling emit numerous hazardous pollutants into the atmosphere, degrading the air quality in the vicinity, which is a direct threat to the workers and the people living nearby. Several studies have been conducted on the relationship between Particulate matter and emissions from coal-fired power plants. For example, in 2017, Bray, C. et al. carried out a study called "Characterization of Particulate Matter (PM2.5 and PM10) Relating to a Coal Power Plant in the Boroughs of Springdale and Cheswick, Pennsylvania, USA" to monitor the 24-hour average ambient concentrations of Particulate matter in the residential areas nearby. The sampling was carried out at three stations within a mile and a half of the coal power plant using a High-volume sampler. The average concentrations of PM10 observed during the periods were 20.5 ±10.2 μg/m³ (Station 1), 16.1 ±4.9 μg/m³ (Station 2) and 16.5 ±7.1 μg/m³ (Station 3). The average concentrations of PM2.5 observed at the stations were 9.1±5.1 μg/m³ (Station 1), 0.2 ±0.4 μg/m³ (Station 2) and 11.6 ±4.8 μg/m³ (Station 3). The ambient 24-hour average concentrations of both PM2.5 and PM10 were found to be at levels lower than what is permitted by the US EPA 24-hour National Ambient Air Quality Standards (NAAQS). These low concentrations were attributed to a number of factors: Short study period, local scale meteorological conditions based bias in the results, errors in the Instrumentation, improved emission control technology that were added to the Cheswick power plant such as wet lime Flue Gas Desulfurization (FGD), low NOx burner technology with separated over fire air selective catalytic reduction and an Electrostatic Precipitator ESP (Bray, C., *et al*. 2017). Another study conducted in Malaysia to assess the Particulate matter concentrations in ambient air near a coal fired power plant concluded that, 58.25 % from total inhalable dust exceeded the outdoor PM10 24 hours Malaysia Standard. The study also found that the percentage ratio of respirable (PM2.5) towards inhalable dust (PM10) was at 51.7%. High temperature with low relative humidity causes the dispersion of plumes from the stack at a higher level (Din, S. A. M., *et al*., 2013). A monitoring of gaseous air pollutants Carbon monoxide (CO), Nitrogen oxide (NO), and Sulfur dioxide

(SO_2) near (1000 meters) an industrial area was carried out in Malaysia to assess the concentrations of these pollutants in ambient air. The observed CO concentrations fell within the (Recommended Malaysian Air Quality Guidelines (RMAQG) at all three stations monitored. The SO2 concentration was high at Station 3 (Closest to industrial area), with 0.66 ppm which was exceeded the RMAQG of 0.13 ppm. All three stations recorded high concentration of NO, which the peak concentration occurred at the afternoon sampling. The nearest Station 3 (300 meters from the industries) has recorded the highest level of NO, SO2 and CO compared to the other stations (Station 1 at1000 meters, Station 2 at 500 meters). The monitoring data has contributed some highlights to the authority and awareness about possible long risk effect of the air pollutants at the case study (Mohamed, R. M. S. R., *et al*., 2016).

2.3.2 Respiratory health assessment via questionnaires and spirometry

Spirometry is recommended as basis for diagnosing compromised lung function (Buist, A. S., *et al.,* 2008, Celli, B. R., *et al.*, 2004) but lack of spirometry equipment and expertise to use it in primary care settings of developing countries make it an unfeasible option (Duvall, K., & Frank, G. W., 2010). In these settings, respiratory symptom-based questionnaires can be a simple and cost-effective tool enabling identification and diagnosis of patients with respiratory illnesses. A number of respiratory questionnaires containing questions about symptoms of chronic obstructive pulmonary disease (COPD) and asthma have been developed [(Martinez, F. J., *et al.,* 2008), (Shin, B., *et al.*, 2010), (Fiechter, R., & Marks, G. B. 2006), (Leite, M., *et al.*, 2008), (Mahesh, P. A., *et al.*, 2009)]. American Thoracic Society Division of Lung Disease questionnaire (ATS – DLD-78A) (Ferris, B. G., 1978) is a commonly utilized questionnaire for identifying the respiratory symptoms.

It contains questions regarding frequent and chronic respiratory symptoms including cough, phlegm, wheeze and shortness of breath. It has been used after interpretation into local languages in a number of studies [(Brodkin, C. A., *et al*., 1993), (Moran-Mendoza, O., *et al*., 2008), (Nafees, A. A., *et al*., 2011), (Bandyopadhyay, A. 2011)]. When used in conjunction with spirometry, symptoms-built questionnaires can be a useful adjunct in the screening of population for respiratory illnesses (Price, D. B., *et al*., 2006).

A study aimed to test the reliability (internal consistency) of the ATS-DLD-78A for respiratory symptoms and diseases among older people (55 years and above) found the questionnaire to be reliable and admissible with an overall Cronbach's alpha coefficient of $\alpha = 0.74$ (Nkosi, V., & Voyi, K., 2016). Thus, the questionnaire is a reliable instrument for data collection and can be a useful tool for collecting data in a developing country. However, a study to assess respiratory symptoms and lung function 8–10 months after community exposure to chlorine gas was conducted in 2013. The comparative analysis between self-report of respiratory symptoms via questionnaire and quantitative spirometry results represented a net 16.8% underreporting of symptoms. The study determined that relying upon the self-report questionnaire was not adequate to objectively assess the lung health of our population following irritant gas exposure (Clark, K. A., *et al.*, 2013).

To determine the association of spirometric lung pattern with respiratory symptoms and to validate the American Thoracic Society respiratory questionnaire for lung function assessment among textile workers. A cross-sectional survey was conducted among adult textile workers of Karachi. The combination of chronic respiratory symptoms was best correlated with decrements in lung function (Jamali, T., & Nafees, A. A., 2017). Another study aimed to determine the correlation of respiratory symptoms and spirometric lung patterns and to validate the (ATS-DLD-78A) questionnaire was carried out in a rural setting of Khairpur, Sindh Pakistan. The study concluded that respiratory symptoms of cough, wheeze, dyspnea and phlegm are significantly correlated with reduced lung function and should be strongly emphasized for assessment of respiratory health. These symptoms are important predictor of obstructive and restrictive lung function, independent of risk of smoking (Abbasi, I. N., *et al*., 2012). Thus, symptoms based respiratory questionnaires are a valuable and cost-effective tool for screening of respiratory symptoms.

3 CHAPTER 3: MATERIAL AND METHODS

3.1 Research Methodology

This Chapter describes the procedure adopted for the conduct of Research work in the field, collection of data, experimental material used in the field, study area, Medical and Laboratory services and statistical tools practiced identifying the problem areas. The overall research methodology adopted for this study is represented in following figure 3.1.

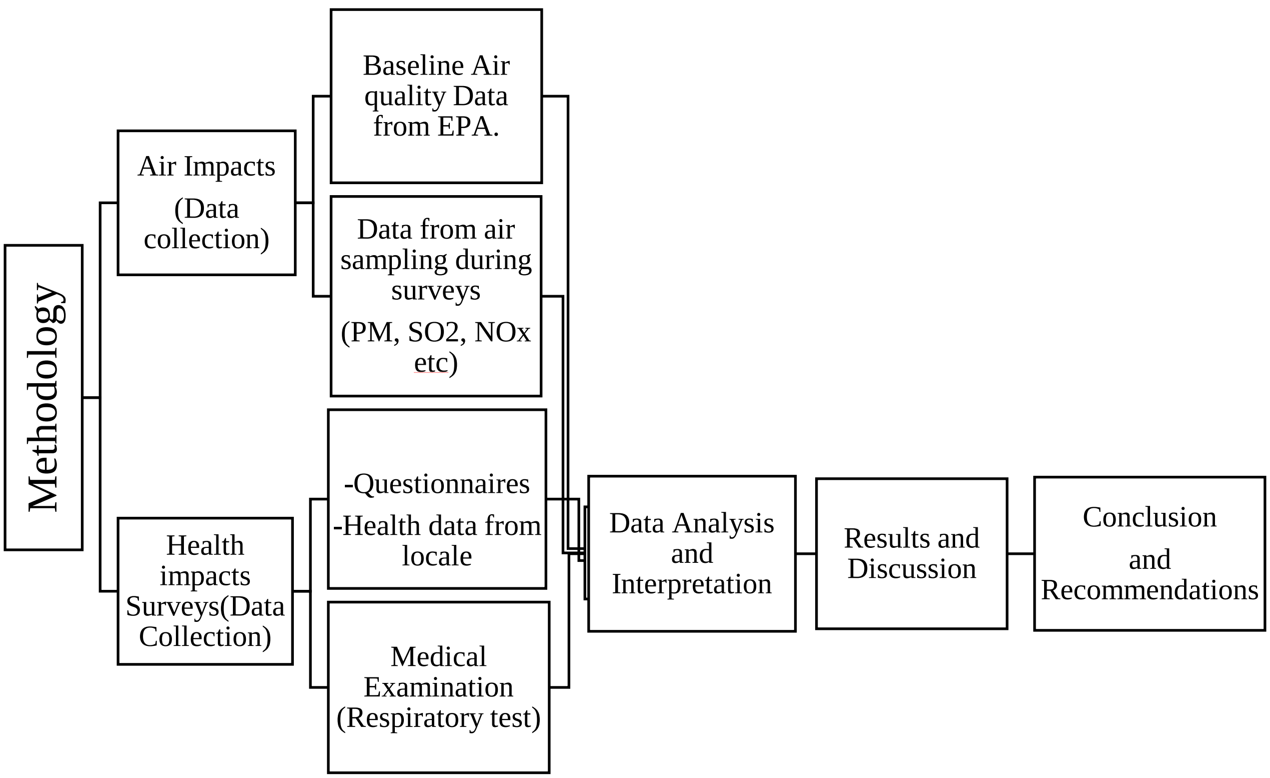

Figure 3-1: The overall Methodology flowchart adopted for Research work

3.2 Study area

The study area selected for this project to assess the impacts are the closest three villages (Chak 75/5-R, Chak 76/5-R, 77/5-R). As these villages are located within 1-2 km distance from the Sahiwal Coal Power Plant and being so close to the plant make this area more vulnerable and the people living this close are directly affected from the pollution of the plant. The study area and sites are presented in following map (Figure 3.1). The vegetative cover and greenery in the vicinity before the installation of Sahiwal Coal Power Project is depicted in figure 3.2. The difference is clearly visible in the figures below.

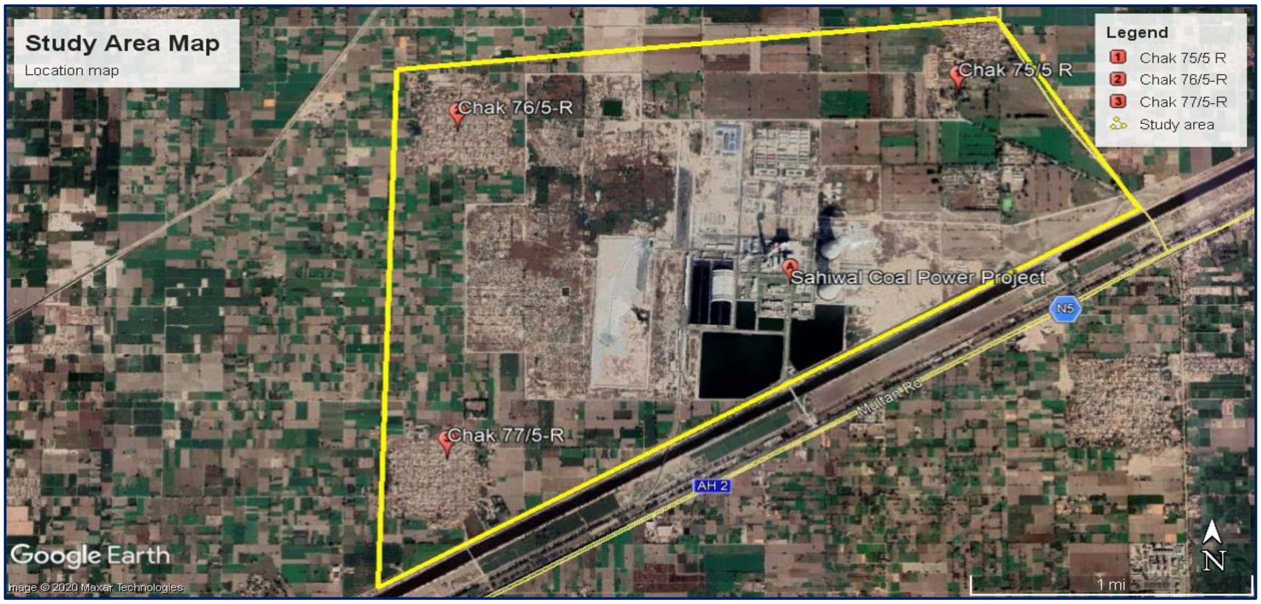

Figure 3-2: Collection of Data at various points within 500 meters of Sahiwal Coal power plant (Google Earth pro plus image taken in Dec, 2019)

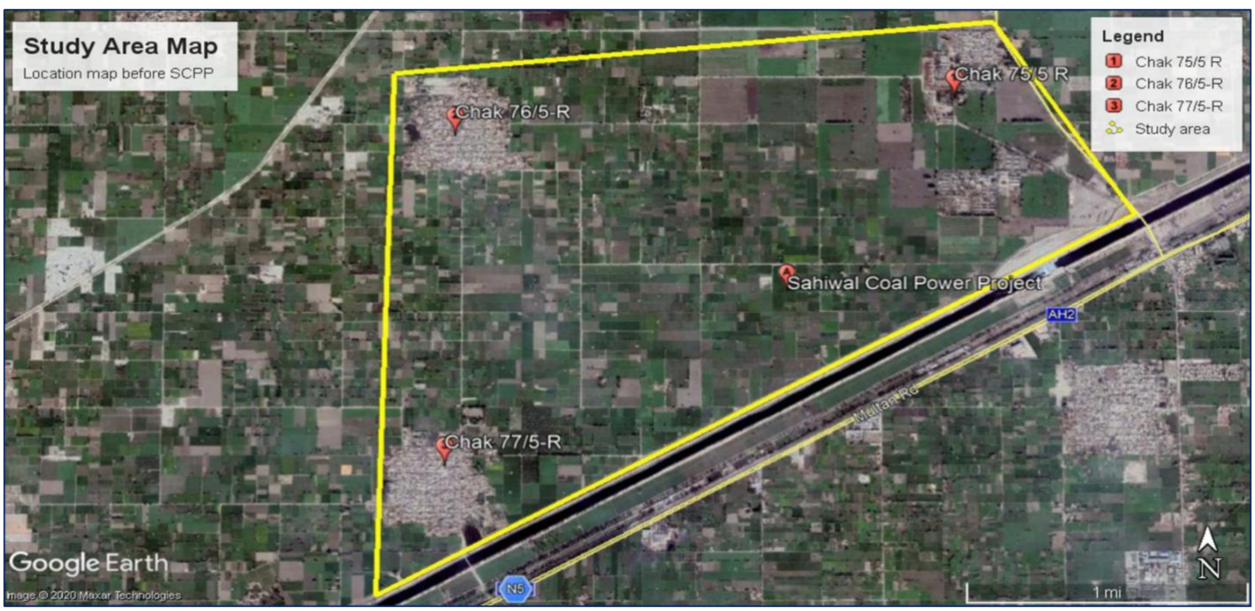

Figure 3-3: Study Area before the installation of Sahiwal coal power plant (Google Earth Pro image taken in Feb 2015.

3.3 Data Collection and analysis.

Field surveys was conducted in the study area to collect the data for impact assessment from 17, November to 9, December, 2018. To assess the ambient concentrations of particulate matter and other gaseous air pollutants in the vicinity of Sahiwal coal power plant, a reasonable site (Figure-3.1 and 3.2) were selected within 500 meters' range. The criterion for finalization of sampling locations on the site was done considering the area, present environmental conditions, weather, potential receptors/polluters on the site and sampling constraints from Plant. A monitoring plan was developed to achieve precision and accuracy. Twenty-four hours monitoring was performed from 3 Dec,2018 to 9 Dec, 2018. To identify the symptoms of respiratory illnesses among the residents near the coal power plant, a questionnaire-based survey along with peek flow meter Vitalo-graph a manual apparatus was used. Health assessment data was collected from 17-29 November, 2018.

3.4 Ambient Air Quality Monitoring

3.4.1 Identification of Monitoring Location

Following criterion was used to finalize the sampling locations on the given site and have been marked in Figure 3.2.

- Area where there will be project activities
- Present environmental conditions at the site
- Potential environmental receptors/polluters

3.4.2 Monitoring Plan

On the basis of identified sampling locations, a monitoring plan was developed in order to achieve precision and accuracy in the monitoring of the required environmental parameters. Monitoring was performed for Twenty-Four hours (Ambient Air) on December 3, 2018 to December 9, 2018.

3.4.3 Sampling Method

The environmental monitoring was conducted at advised location for following environmental parameters. Ambient Air (CO, SO_2, O_3, NO, NO_2, SPM, PM2.5, PM10). Location for monitoring of required environmental parameters was identified Outside the boundary wall of power plant and environmental factors including wind direction on the particular day and amount of turbulence in the air etc. A High Volume (Hi Vol 3000) fiber glass filter papers were used to analyze mass concentration of Particulate matter. Filter weighing measurements took place inside a temperature/relative humidity-controlled ISO Class 6 (<1000 PM0.5/cf) clean room employing a draft-shielded microbalance with anti-static wand. Temperature and relative humidity were controlled to 21 ◦C and 35%, respectively. The filter mass was determined through five weightings of the filter, with each weight bracketed by a reading of the internal zero of the balance. A buoyancy correction was applied to the mass and the average of the zeros bracketing the mass was the n subtracted from the result.

3.4.4 Air quality monitoring for Pollutants in ambient air.

Ambient air quality monitoring was conducted to assess the concentration of priority pollutants (Nitrogen Dioxide (NO_2), Oxides of Nitrogen (NO) Sulphur Dioxide (SO_2), Carbon Monoxide (CO), Ozone (O_3), Suspended Particulate Matter (SPM), PM2.5, PM10. Selection of sampling location was based on the environmental factors including wind direction and amount of turbulence in the air etc.

3.4.4.1 Oxides of Nitrogen

Oxides of Nitrogen (NOx) were monitored using AC32e Chemiluminescent NO-NO_2 & NOx Analyzer. The analyzer measures NO, NO_2 and NOx using chemiluminescence

(CLD) method with the help of chemical reaction between NO and O3. Measurement range of the analyzer is 0-10 ppm. Continuous data was recorded for 24 hours.

3.4.4.2 Sulphur Dioxide (SO_2)

Sulphur dioxide was monitored using AF22e UV Fluorescent SO_2 Analyzer. The SO_2 analyzer measures SO_2 using UV fluorescence method that operates on the principle that when the SO_2 molecules contained in the sample gas are excited by ultraviolet radiation they emit a characteristic fluorescence. This fluorescence is measured and the SO_2 concentration is obtained from changes in the intensity of the fluorescence. Measurement range of the analyzer is 0-20 ppm. Continuous data was recorded for 24 hours.

3.4.4.3 Carbon Monoxide (CO)

Carbon monoxide (CO) was monitored using CO12e Non-Dispersive Infrared CO Analyzer. The analyzer measures CO concentration by measuring the quantity of infrared light the sample gas absorbs as it flows through a multi-reflection chamber. Measurement range of the analyzer is 0-300 ppm. Continuous data was recorded for 24 hours.

3.4.4.4 Ozone (O_3)

The O_3 analyzer module continuously measures ozone in ambient air. Air is actively sampled by pump and travels through a glass and Teflon coated inlet system to the analyzer module. The ozone analyzer module incorporates a gas sensitive semiconductor (GSS) sensor. This sensor is a tungsten oxide (WO3) formulation that is particularly sensitive to O_3 when operated at elevated temperatures.

3.5 Data collection for Particulate Matter (SPM, PM10, PM2.5)

A High-Volume Air Sampler (HiVol 3000) was used to collect the truly representative sample of ambient air for the monitoring of Particulate matter concentrations as suspended particulate matter (SPM). Sampling was conducted for period of 24 hours using fiber glass filter paper for each parameter. The sampler incorporates advanced programming functions and electronic volumetric flow control to maintain a consistent flow. The sampler draws a large known volume of air through a pre-weighted filter. After sampling the filter is reweighted and the difference in filter weight is collected particulate matter mass. Dividing the mass by the volume of sampled air gives the concentration of particulate matter.

Mass concentration =<u>*Filter Paper Weight after - Weight before (mg)*</u>

$$1\ m^3 \ x\ \underline{Flow\ Rate}\ x\ Duration\ of\ sampling\ (min)\ 1000L\ min$$

Later, statistical approach being used to analyzed the attained data.

3.6 On Field Health Assessment

To identify the symptoms of respiratory illnesses among the residents near the coal power plant, a questionnaire-based survey along with peek flow meter Vitalo-graph a manual apparatus was used. Health assessments were obtained through respiratory symptom and exposure questionnaires, simple spirometry, and physical exam. Simple spirometry was used as the standard to identify continued breathing problems. Sensitivity, specificity, positive and negative predictive values were applied to evaluate the validity of the respiratory questionnaire. Generalized estimation equations were applied to determine prevalence ratios for abnormal spirometry based on the presence of participant persistent respiratory symptoms. Covariate adjustment was made for participant age, sex, race, smoking and educational status.

3.6.1 Collection of Data from nearby dispensaries/Hospitals

To assess the health impacts due to coal fired power plant, health care centers like dispensaries and hospitals were visited through structured questionnaire.

3.6.2 Statistical analysis

Data was entered and analyzed using SPSS 20 for windows. Descriptive statistics were calculated for socio-demographic variables, respiratory symptoms and lung volumes. Percentage predicted lung volumes were entered as continuous variables and independent samples t-test was applied to determine significant differences in lung function decrements according to presence and absence of respiratory symptoms.

3.7 Collection of Socio-economic and Cultural data

The basic objective of the social surveys was to observe and document the existing socio- cultural settings, get feedback from community, and to evaluate the possibilities of addressing their grievances. Social assessment of the people of the Study Area was carried out through socio-economic baseline surveys public/stakeholders and consultations/focus group discussions. A total of 250 respondents from the Study Area were selected for interviews. Punjabi is the pre-dominantly spoken language with major castes as Arain, Khokar, Bhatti etc. Most of the population is Muslim. The educational situation in few villages is worse as compared to the other villages of the Study area and majority are illiterate or have primary education. Occupational distribution indicates that majority are working in agriculture sector. Most of houses are pacca and semi-katcha in nature while rest of the structures are made of mud bricks and mud. Groundwater is being used for drinking purposes by pumping through electric and hand pumps. The area is irrigated by canal water supplemented with ground water pumping by peter engines and tube wells. Main canal in the Study Area is LBDC while several irrigation minors are off taking from LBDC. Wastewater is being disposed of in the open spaces just outside the houses and in few villages such as 75-5R, 76-5R and 77-5R, water ponds exists for wastewater. Street lights and play grounds are absent in the area with no public water supply. Health facilities are generally very meager in the villages.

Due to existence of N-5 and Peshawar-Karachi railway line near the Project Area, communication facilities are better. Women in the Study Area are also vulnerable through economic, social and psychological poverty. No indigenous or vulnerable social group of people was identified in the entire Study Area. Locals are very warm hearted and fun loving. People of the Study Area have strong beliefs on pir-faqeers, jogi, taweez, manat-ka-dhaga, reputable saints, black magic, and other superstitions, however recently due to increase in literacy, people have become somewhat rational. No Historical and Archaeological site fall in the Study Area. Only one national level NGO Punjab Rural Support Program (PRSP) is working in few villages.

The Population statistics, education and health facilities in the study area are described in Table 3.1, Table 3.2, Table 3.3.

Table 3-1: Population and Number of Houses in the Study Area

Sr. no.	**Name of Village/ Chak**	**Population Census 2017** **NH: Number of Houses**
1	Chak 75/5R	2.081 (NH-339)
2	Chak 76/5R	7,716 (NH-837)
3	Chak 77/5R	6,323 (NH-1047)
Total		16,120 (NH-2223)

Table 3-2: Education facilities in the Study Area

Sr. no.	Name of Village/ Chak	Govt. Primary School	Govt. Middle School	Govt. High School	Private School	Govt. College	Vocational Training Centers	Deeni Madrasas
1	75/5R	Girls	Boys and Girls	Boys and Girls	_	_	_	_
2	76/5R	Boys	Boys and Girls	Girls	High School	_	_	Boys
3	77/5R	Girls and Boys	Boys and Girls	Boys and Girls	_	_	_	_

Table 3-3: Health facilities in the Study Area

Sr. no.	Name of Village/ Chak	Dispensary	Hospital
1	Chak 75/5R	1 Private	_
2	Chak 76/5R	_	_
3	Chak 77/5R	1 Govt.	_

3.7.1 The Cost of the Health Burden from Use of Coal for Energy Production

The impacts of coal combustion can be described in economic terms which means that for every penny spent complying with the regulations, certain money can be saved in health care costs due to lower disease burden, including a reduction in premature deaths, and cases of bronchitis, asthma, and myocardial infarction. Data was collected for comparison purpose.

3.8 Ecological Environment of Study Area

The study has been conducted using standard ecological assessment technique based on primary and secondary information, verification and incorporating additional information collected during site visit, discussion with Government departments and meeting with groups of communities/public living in and around the Project Area and expert visual observations. Following is the description of the baseline ecological environment of the area.

3.8.1 Flora

Sahiwal District has a hot semi-arid climate intermediating between Desert climate and Humid climate in ecological characteristics and agricultural potential. The climate tends to have hot, sometimes extremely hot, summers and mild warm winters. The soils are very fertile and climate tends to support short or scrubby vegetation. A significant area is dominated by grasses, shrubs and forests.

Sahiwal District of Indus basin plain, falls under Tropical Thorn Forests type. Vegetation of the area can be termed as open and pronouncedly xerophytic forests in which thorny leguminous species predominate. This type occupies the whole of the Indus plain except the driest parts.

3.8.2 Trees, Bushes and Shrubs

Although no compact plantation or woodlot exist in the Study Area, but trees do exist on farmlands mostly in linear pattern. The indigenous species of the area are xerophytic in nature and include Kikar, Frash, Jand, Peelu, Ber,Simal, Mulberry, Bohar, etc. Common trees and shrubs in the area are given in Table 3.4

Table 3-4: Trees and Shrubs in the Area

Sr. #	Name	Botanic Name
1.	Kikar	*Acacia nilotica*
2.	Shisham	*Dalbergia sisso*
3.	Mulberry	*Morus species*

4.	Ber	*Ziziphus mauritiana*
5.	Frash	*Tamarix aphylla*
6.	Wan/Peelu	*Salvadora oleoides*
7.	Jand	*Prosopis cineraria*
8.	Pipal	*Ficus religiosa*
9.	Barh/Bohar	*Ficus bengalensis*
10.	Karir	*Caparis decidua*
11.	Semal	*Bombax ceiba, Syn; Salmalia malabarica*
12.	Poplars	*Populus species*
13.	Mango	*Mangifera indica*
14.	Jaman	*Syzygium cumini*
15.	Sufeda	*Eucalyptus species*
16.	Neem	*Azedarachta indica*
17.	Bakain/Dhrek	*Melia azedarach*

Source; Field work and EPAP Report 2014

3.8.3 Mammals/Reptiles

On account of anthropogenic interventions mainly agriculture, no habitat is left to support wildlife in the Study Area. Construction of roads, infrastructure by the Livestock Department and vehicular traffic further deteriorated the overall environment leading towards destruction of wildlife habitat. In general, following mammals and reptiles are found in the area as native ones but not in large number.

Table 3-5: Mammals and Reptiles in the Area

Mammals	**Reptiles**
Jackal *(Canis* sp.*)*	Snakes *(Vipera /Elapidae* sp.*)*

Fox (*Cannis vulpes*)	Lizards *(Sauria* sp.*)*
Rabbit (*Rodentia* sp.*)*	Rats/Mouse *(Rodentia* sp.*)*
Pig *(Artiodactyla* sp.*)*	Frog *(Anura ranidae)*

Source; Field work and EPAP Report 2014

3.8.4 Birds – Avifauna

Due to inadequate habitat cover, not many birds are found except in small orchards, scattered tree groves and trees along canals and roads where ample food and shelter is available. No conspicuous avifauna was observed in the Study Area during field visit except common crows, kites, sparrows, bulbul, hoopoe, myna, tateeri and dove. Common resident birds of the area as per information supplied by the Wildlife department are given below in Table 3.6

Table 3-6: Popular Birds in Study Area

Sr. #	**Name**	**Scientific Name**
1.	Ring Dove	*Zenaida sp.*
2.	Rock Pigeon	*Columba livia*
3.	Myna	*Acridotheres tritis*
4.	Crow	*Corvous corone*
5.	Parrot	*Phaethontida sp.*
6.	Paddy bird/ Pond Heron	*Ardeola grayii*
7.	Common Snipe	*Gallinago gallinago*
8.	Grey Patridge	*Perdix perdix*
9.	Quail	*Coturnix coturnix*
10.	Hoopoe	*Upupa epops*
11.	Koel	*Eudynamys scolopacea*

12.	Common Bulbul	*Pycnonotus barbatus*
13.	Sparrow	*Spizella sp.*
14.	Tree Pie	*Dendrocitta vagabunda*

Source; Field work and EPAP Report 2014.

3.8.5 Agriculture and main crops

The Project Area consists of fertile land of high productivity. It comprises of 2 main categories i.e., (a) Government Land (b) Private Land. Sugarcane, Wheat, Rice, Maize and Cotton are the main crops grown. Besides Guar seed, Bajra, Moong, Mash, Masoor, Jawar, Oil Seeds are also grown in minor quantities in Sahiwal Area. Average yield of the important crops in the Study Area is given in Table 3.7 below. Cotton, sugarcane, maize and rice are kharif (autumn harvest) crops while maize and wheat are rabbi (spring harvest) crops. Potatoes, Onion, Cauliflower, Tomato and Turnip are main vegetables grown in the area. Besides, Carnot, Peas, Garlic, Chilies and Lady Finger are grown on smaller scale. Citrus, Guavas and Mangoes are the main fruits grown in the district. Besides, Pomegranate, Litchi, Falsa and Banana are also raised on minor scale.

Table 3-7: Important Crops and their Average Yield

Sr. #	Crop	Yield/Acre (in Tons)
1.	Cotton	1.05
2.	Sugarcane	22.7
3.	Maize (Spring)	3.83
4.	Maize (Autumn)	3.08
5.	Rice	0.83
6.	Wheat	1.54
7.	Potato	10.58

Source; Field work and EPAP Report 2014.

4 CHAPTER 4: RESULTS AND DISCUSSION

4.1 INTRODUCTION

Power is a lifeline for the economic development of any country. Pakistan is facing acute power shortages. It has been reported that the shortfall in power generation has increased to about 8,000-10,000 megawatt (MW) and power shortage is estimated to cost the economy 2% of Gross Domestic Product (GDP) each year. Pakistan has faced immense challenges in power sector. The ever-increasing demand of electricity with only marginal addition of generation capacity in the recent years has resulted in long load shedding hours causing resentment in the public in general and has hampered the economic growth of the country. The main issues confronting the power sector include expensive generation mix, inefficient operation of the aging thermal power generating units, high losses of distribution companies and seasonal reductions in hydropower generation. Another factor is the rapidly depleting gas reserves that have compelled the supply of gas to be cut down for power generation. This has resulted in greater reliance on alternate expensive fuels such as Heavy Furnace Oil (HFO) and High-Speed Diesel (HSD). The substantial increase in the electricity price can be mainly attributed to increase in oil prices in the international market and greater utilization of fuel oil instead of natural gas. It is, therefore, vital to bridge this gap by alternative means, coal fired Power Plants is a step in this direction.

4.2 Socio-Environ Impacts

Due to the acquisition of the private land required for railway track, some families experienced direct impact in terms of losing their livelihood. Based on the field survey most of the farmers belonging to the village/Chak 76/5-R had small land holdings less than 1.7 Hectares (4 acres). The bread and butter of these families are dependent on the agriculture of these lands. Loss of livelihood is a significant adverse social impact of the Project with the acquisition of these lands. The compensation of power shortages through such resource, in addition to other impacts, have environmental and social implications as well. Other than complaints of distress by the citizens, there have been impacts on the educational, health and other sectors. The shortage of power results in the use of firewood, kerosene and biomass resulting in deforestation and deterioration of air quality. The power outages also result in the use of small generators in cities and surrounding areas and their emissions of Oxides of Nitrogen (NO_x), Oxides of Sulphur (So_x), Particulate Matter (PM) and other pollutants have led negative impacts on environment. Though the other aspects are not part of the study but have been viewed to commit and depict the overall picture of coal fired power plant impacts at Sahiwal. The General Impacts have been tabulated below in table 4.1

Table 4-1: Socio-Environ Impacts of Sahiwal Coal Power Plant

Sr. no.	**Parameter**	**Impacts Envisaged**	**Field investigation/ Observations**
1	Aesthetic Impacts	It was envisaged that during all phases the outlook of the area will remain Unchanged or beautified with adequate plantation. (3000 Trees)	Approximate 1200 Trees were cut down for SCPP. Despite being a fertile land, the study area gave a barren and deserted look, during the survey, no requisite measures have been taken.
2	Biodiversity	No change was suspected	A substantial reduction in the presence of common mammals/reptile and migrants' birds has reported during field study
3	Socio-demographic aspects	It was estimated that there will be no drastic changes in the area because of Coal power plant.	Displacement of huge population, the three villages had a population of 21,059 persons (Censes 1997) which has now reduced into 16,120 persons (censes, 2017). contamination of water and agriculture land, livestock and other livelihoods have not been supported by the plant

4	Contamination of Ground/Irrigation water	Ground water supplies need to be tapped to meet campsite requirements both drinking and irrigation. The Contamination through seepage from canals adjacent to power plant and coal Ash Will contaminate the water bodies like tube wells, Ground water. It may affect the quality of surface water bodies. Furthermore, any chemicals, oil spillage or runoff from drainage can contaminate water channels and agricultural land in the Vicinity. This is a potentially significant adverse impact as the wastewater can drain from the Project Area into the nearby canals carrying water for the agricultural field in the Study Area. Such contamination has highly adverse impacts on agricultural productivity.	The suspected impacts have been observed during the current study. A detailed water and soil analysis will provide an insight of the contamination of ground/irrigation water.
5	Impacts on Ecological Environment	Loss of vegetative cover in the form of removal of trees, shrubs and fruit plants will occur at a medium level while clearing land for plant installation and commissioning of entrance gate along main road and other structures, which will lead towards medium negative impact. It was estimated that a good quantity of trees will be removed.	Plantation of tall trees like Shisham, Neem, Simal, Kachna and Kikar in some areas near the plant. However, the loss of vegetation covers by cutting down 1200 trees is brutal. As trees provide suitable Habitat for Birds and other fauna, in addition to acting as shelter belts against Noise pollution. Establishing adequate number of Health Care units/Centers in the residential area and in nearby population to Cure the spread of epidemic diseases have not been observed during field visits.
6	Solid Waste (Coal, bottom and fly Ash)	One of the major solid wastes generated from the power plant's	The project is generating adequate quantity of coal combustion wastes, including

	from Power Plant Operations	operation is the residual coal ash (Fly and Bottom Ash). This coal ash is a product of coal combustion. The handling and ultimate disposal of coal ash will be an important issue which can have a potential impact on the water, health and land fertility	both fly ash and bottom ash which is spread out into atmosphere and leach into water and numerous health and environmental impacts have been observed.
7	Wastewater impact	With the operation of coal-based power plant, wastewater will not affect the local waterbodies.	The envisaged impacts on community and crops have been observed during field work.
8	Particulate matter and sulfur salts	Over-emission of particulate matter NOx, Cox, Sox etc. because of Coal power plant will not affect the area or the people in the vicinity.	Over-Emission particulate matter has been noted during field work and serious impacts have been registered by respondents, especially health impacts have been registered.
9	Impacts on Air Resources	It was estimated that the Impact on overall health and living of people will not be severe.	The concentrations of Suspended Particulate matter and PM2.5 are slightly on higher side and their impact has also been observed separately in subsequent paras.

4.3 Impacts of Coal Wastes on Socio-demographic Environment

Coal and coal waste products release a number of toxic metals including arsenic, selenium, mercury, etc. in the ambient environment, in addition to the oxides of carbon (CO_2), sulfur (SO_2) and nitrogen (NO_x), etc. All these pollutants are detrimental to Fauna (Avi-fauna and terrestrial) and Flora including trees and agricultural crops. Since the emissions are in high concentration so the exposure has become the continuous phenomena. With the operation of coal-based power plant, wastewater is generated. The disposal of wastewater without proper treatment has impact on the local community. The wastewater is partially becoming the part of Minor 75/5-R and has damaged the crops of the farmers utilizing this water. The power plant wastewater is also becoming the part of the natural drain which is consumed by the livestock or local population of surrounding villages and also use the drain for recreational purpose. In both the cases significant adverse impact on the locals and livestock has been observed. The changing state of water Quality observed during the surveys can provide the justification for rising trends in hospitals /dispensaries reporting of local's due waterborne diseases like cholera, diarrhea, hepatitis etc.

The function of the Ash Handling System is to collect, store and transport solid wastes resulting from the combustion of coal in the boiler. Solid waste products are bottom ash from boiler furnace and fly ash from ESP ash hoppers and Economizer hoppers. The ash quantity generated during plant operation is shown in Table 4.2.

Table 4-2: Quantity of ASH & Pyrites

		Ash quantity per hour (t/h)			**Pyrites per hour (t/h)**
Coal Type.	**Production**	**Fly**	**Bottom**	**Total**	**Total**
Design coal	1x660 MW	14.91	2.63	17.54	0.60
	2x660 MW	29.82	5.26	35.08	1.20
Worst coal	1x660 MW	66.62	11.77	78.39	0.77
	2x660 MW	133.24	23.54	156.78	1.54

The emissions of the power plant should have been controlled by use of technologies as described earlier. Large scale planting with suitable indigenous trees, shrubs, grasses and ornamental plants in the form of Tree Groves, wide Strips and Belts and Linear plantation to carried out in accordance with the Tree Plantation Plan to improve aesthetic value and offset the effect of removal of vegetation but adequate measure has not been taken. Abnormal operation of waste circulation system has corresponded to a situation in which the treatment system of waste is unable to operate at its rated capacity and/or the effluent quality has adversely affected. Abnormal operation has also created a situation in which excessive quantities of wastewater are being generated. About 6 million metric tons of coal is used annually to fire the super critical boilers and coming into the plant via train tracks every day. One of the major solid wastes generated from the Power Plant's operation is the residual coal ash (Fly and Bottom Ash). The dust from the coal piles in the form of fly ash, slurry and dirt which was supposed to be controlled by a combination of water sprays, and wind screens has become the source of suspended particulate matter and adversely affecting the health of population, livestock, land and drinking water as well. The handling and ultimate disposal of coal ash and limestone slurry is also an important issue and have significantly high health impacts due to acid mine and leaching into water channels, harming not only the health of people but fertility of land as well.

4.4 Impacts of the ambient air quality caused by coal power plant.

Air quality is adversely affected by the emissions of SO2, NO_x, CO, CO_2, VOCs, PM, HC. Gaseous and fugitive dust emissions have resulted an impact of high significance. Air quality is impacted from emissions of Particulate Matter and Mercury which are typical air pollutants from coal combustion. Nitrogen oxides are formed when combustion temperatures exceed 1,300 degrees Celsius in the super critical boilers. Oxides of Sulphur, ash and other contaminants are emitted depending upon the fuel characteristics. If the emissions of VOCs and mercury are not under control, Mercury exposure can impair neurological development, Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system have been reported. Key signs or symptoms associated with exposure to VOCs observed during study include conjunctional irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue, dizziness.

4.4.1 Atmospheric Dispersion model based predictions for pollutant concentrations.

Air dispersion modeling was performed by Environmental Protection Agency Punjab (PEPA) for the Initial Environmental Examination Report (IEE Report 2014) of Sahiwal Coal Power Project. The objective was to determine the ground level concentrations of SO2, NO2, and PM in order to check the compliance with the standards and assess the impacts on receptors. The model was used to estimate the maximum ground-level concentrations and the distance to the maximum by examining the full range of meteorological conditions, including all stability classes and wind speeds to find maximum impacts. The modelling setup for Air Dispersion Modelling is given in annex C and the dispersion modelling results are given in annex D.

The predictions based on Atmospheric Dispersion Model for Annual Average concentrations of NO2, SO2 and PM are illustrated in Figures 4.1, 4.2, and 4.3.

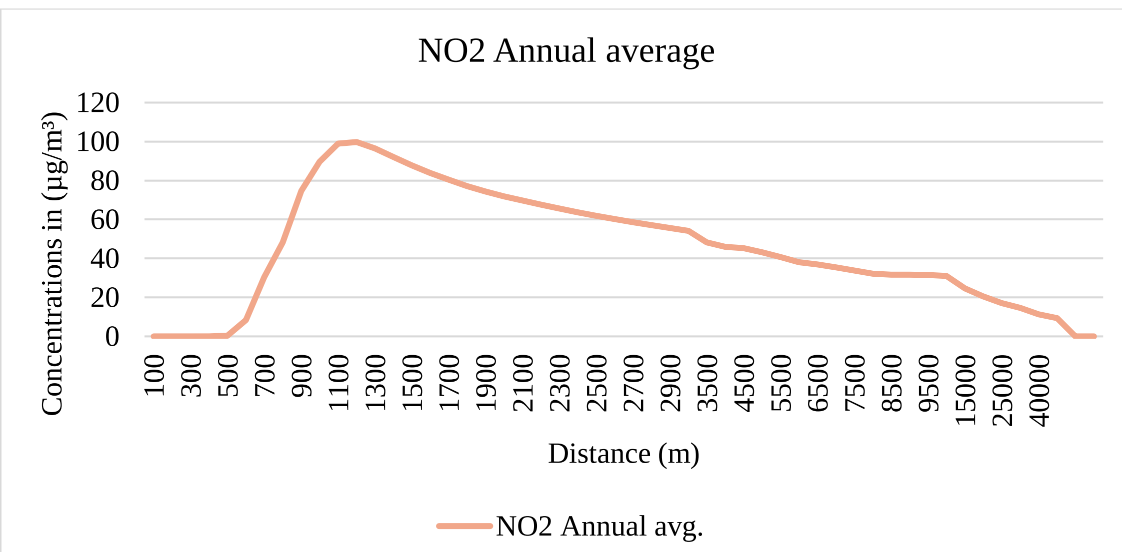

Figure 4-1 NO2 Average Annual Concentrations

The graph for annual average concentrations for NO_2 indicates a peak value of 99.76 µg/m³ at a distance of about 1,200 m from the Power plant. Beyond 1,200 m the concentrations decrease significantly. However, if compared with ambient air quality NEQS requirements (which is 40 µg/m³), the NO_2 is exceeding the maximum permissible values at a distance of 750m to 5,500m from the stack.

The graph for annual average concentrations for SO_2 (Figure 4.2) indicates a peak value of 47.30 µg/m³ at a distance of about 1,200 m from the power plant. Beyond 1000 m the concentrations decrease significantly. If compared with NEQS for ambient air quality, the SO_2 limits are well within the ambient air quality of 80 µg/m³.

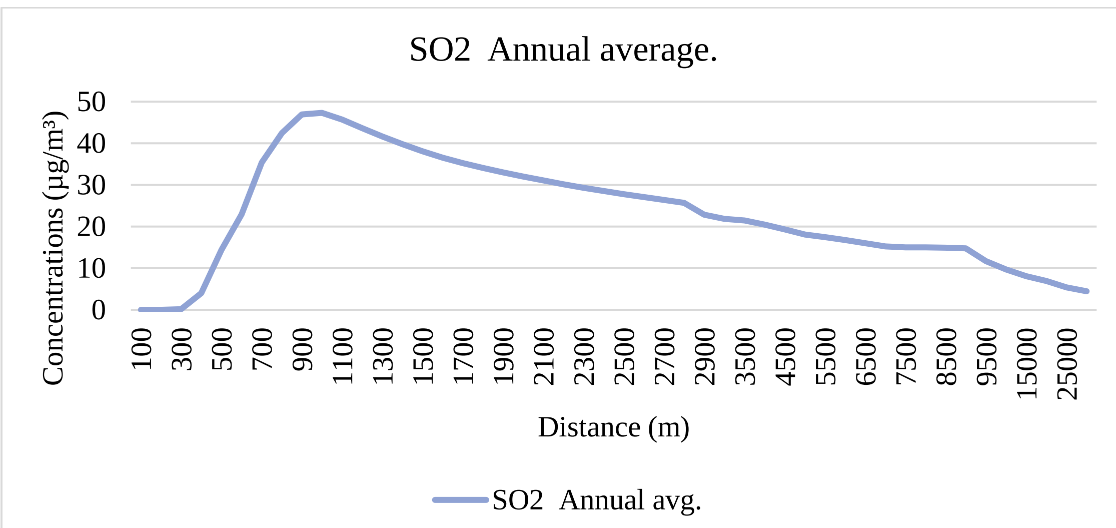

Figure 4-2: SO_2 Average Annual Concentrations

The graph for annual average concentrations for PM (Figure 4.3) indicates a peak value of 11.82 µg/m³ at a distance of about 1,200 meters from the Power Plant. Beyond 1,200 meters the concentrations decrease significantly. Since the NEQS state ambient air limits for PM_{10} as 120 µg/m³ for annual average, and 150 µg/m³ for 24 hours, the estimated concentrations are most likely within the NEQS limits.

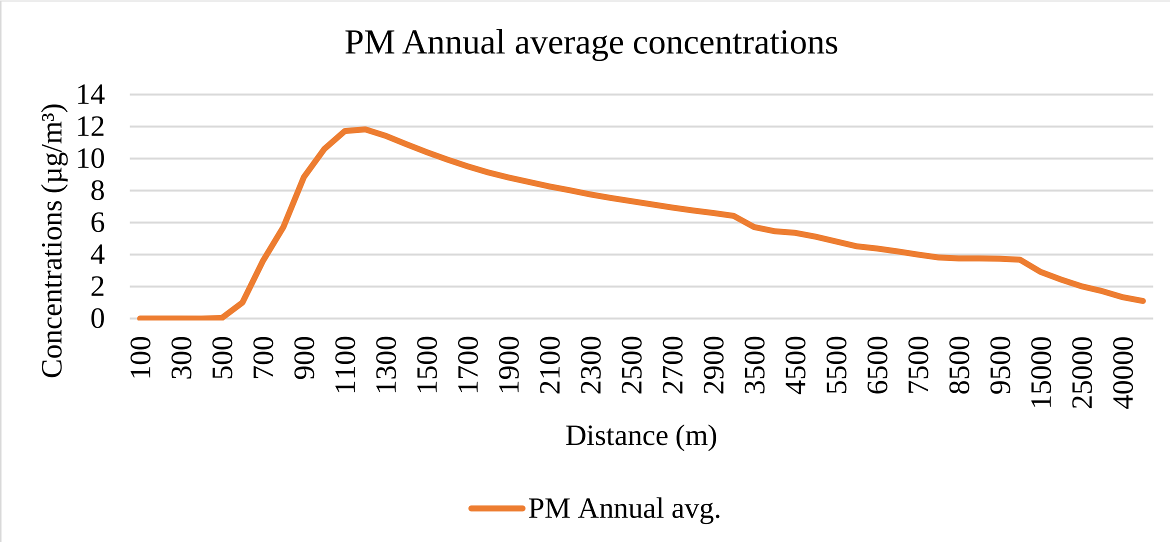

Figure 4-3: Particulate Matter Average Annual Concentrations

4.4.2 Ambient Air Quality Monitoring Results from field surveys.

Ambient air quality monitoring to observe the 24-hour average concentration of various air pollutants (NO, NO2, SO2, CO, O3, SPM, PM10 and PM2.5) at the selected sites (Station 1: Chak 75/5-R, Station 2: Chak 76/5-R, and Station 3: Chak 77/5-R) is described in this section. The results indicated that the ambient concentrations of pollutants such as NO, NO2, SO2, CO, O3, and PM10 are well below the air quality standards except for SPM and PM2.5. The 24-hour average concentrations of NO, NO2, SO2, CO, O3, SPM, PM10 and PM2.5 and their comparison with Pakistan National Environmental Quality Standards have been illustrated in Figure 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 4.10. 4.11.

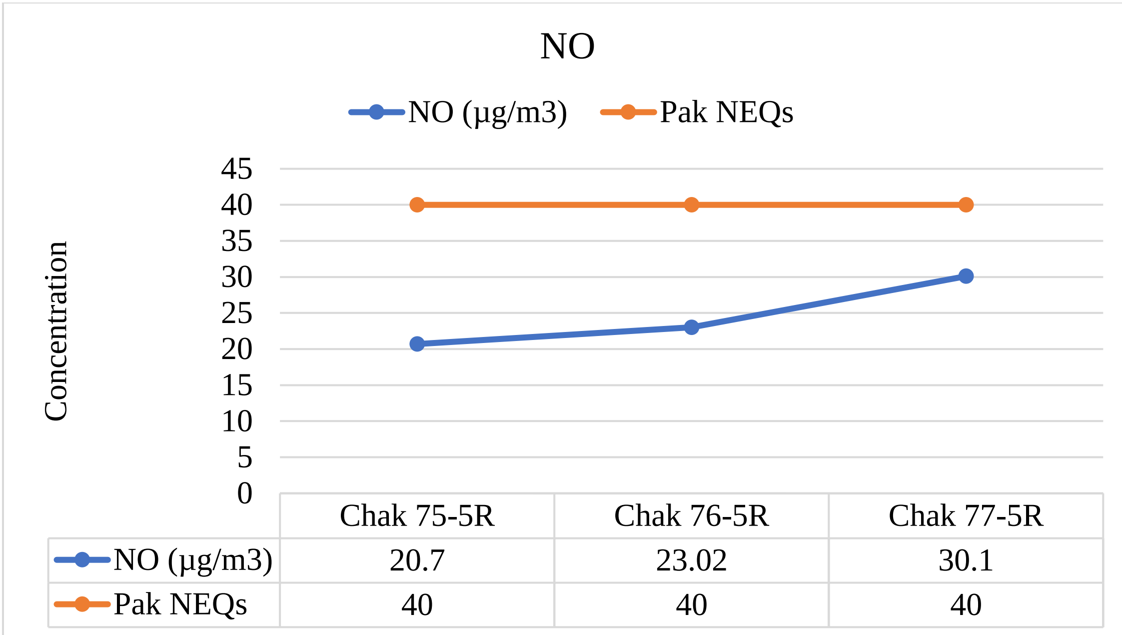

Figure 4-4: 24-hour average concentrations of Nitrogen oxide at the selected sites with respective Pak-NEQs

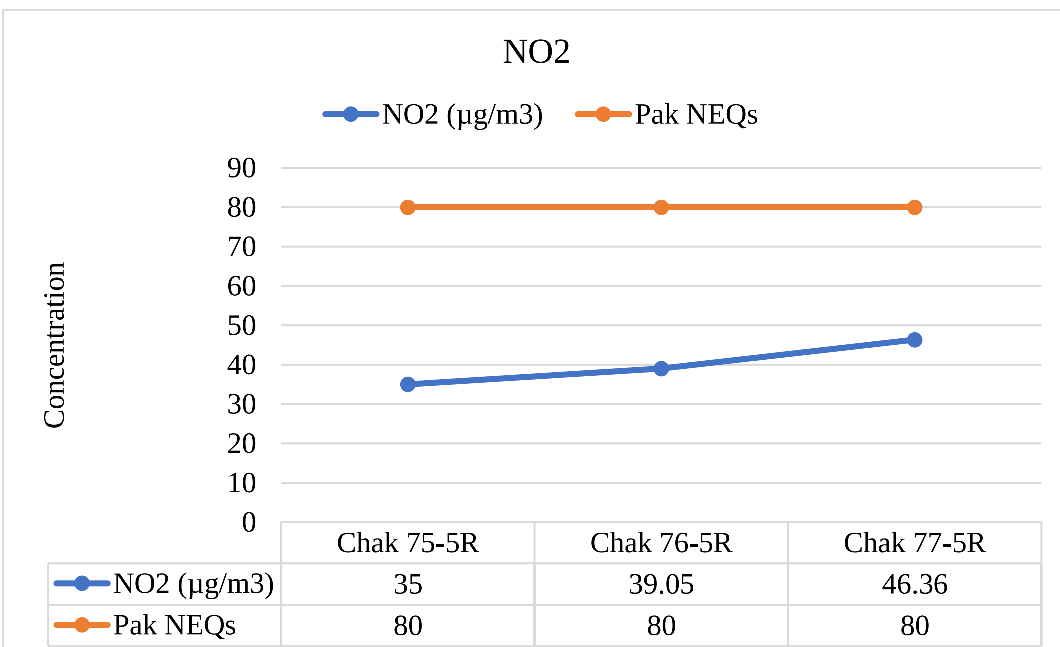

Figure 4-5: 24-hour average concentrations of Nitrogen Dioxide at the selected sites with respective Pak-NEQs

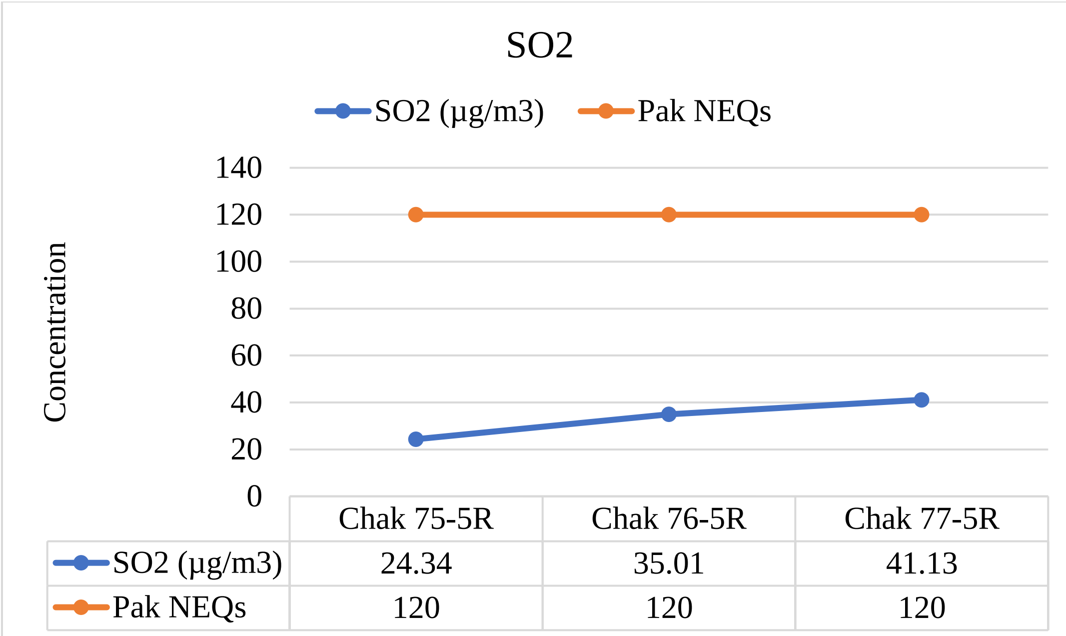

Figure 4-6: 24-hour average concentrations of Sulfur Dioxide at the selected sites with respective Pak-NEQs

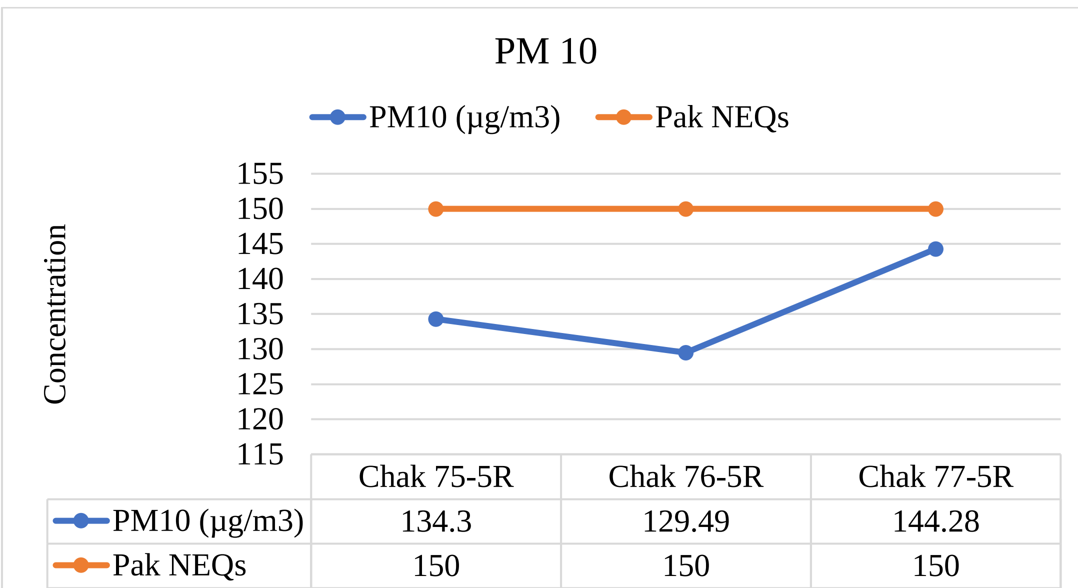

Figure 4-7: 24-hour average concentrations of PM10 at the selected sites with respective Pak-NEQs

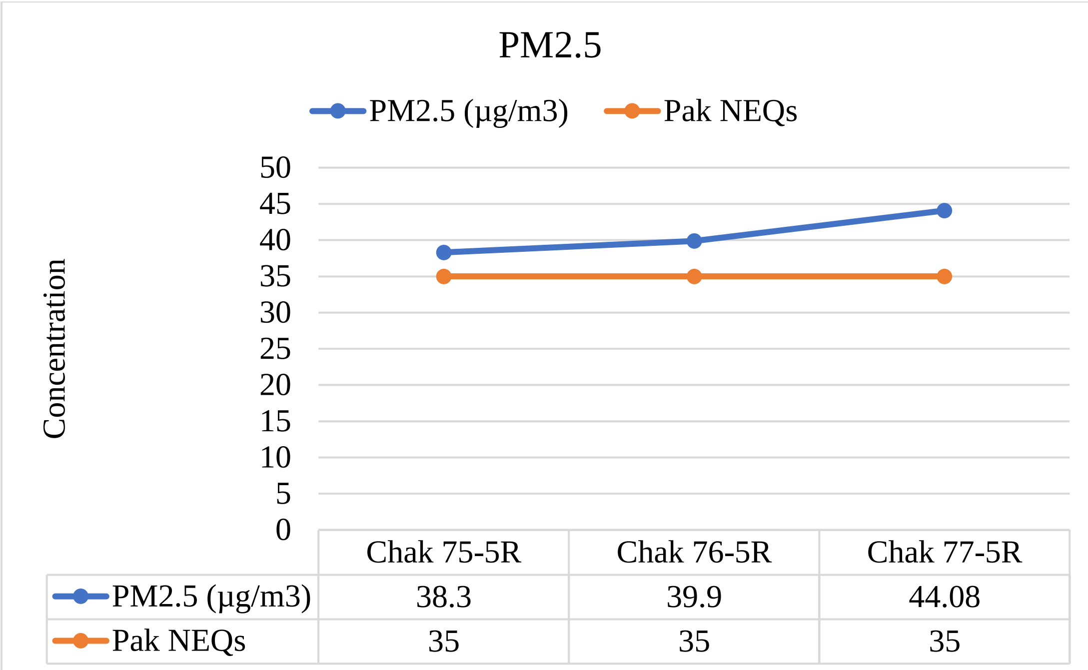

Figure 4-8: 24-hour average concentrations of PM2.5 at the selected sites with respective Pak-NEQs

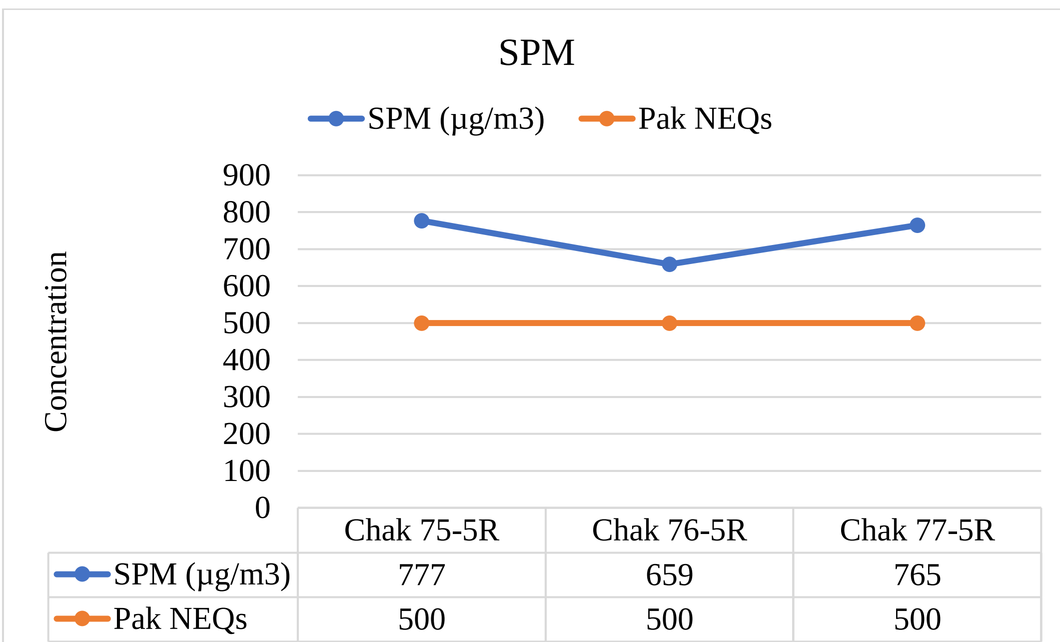

Figure 4-9: 24-hour average concentrations of Suspended Particulate Matter at the selected sites with respective Pak NEQs

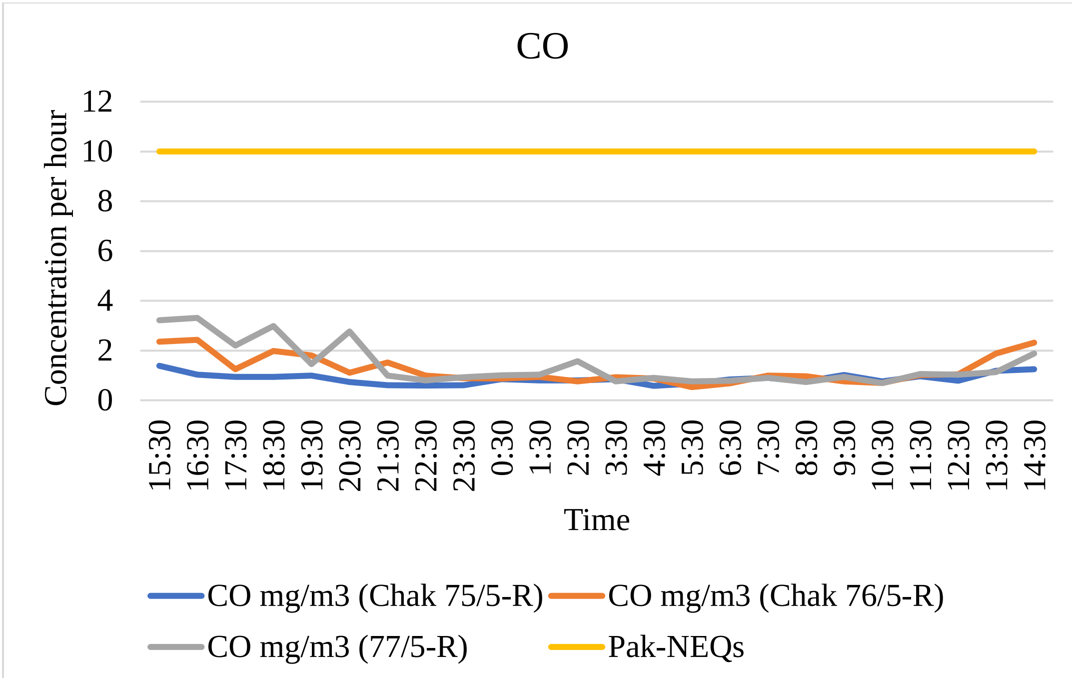

Figure 4-10: The 1-hour average concentrations of Carbon monoxide at the selected sites with respective Pak-NEQs

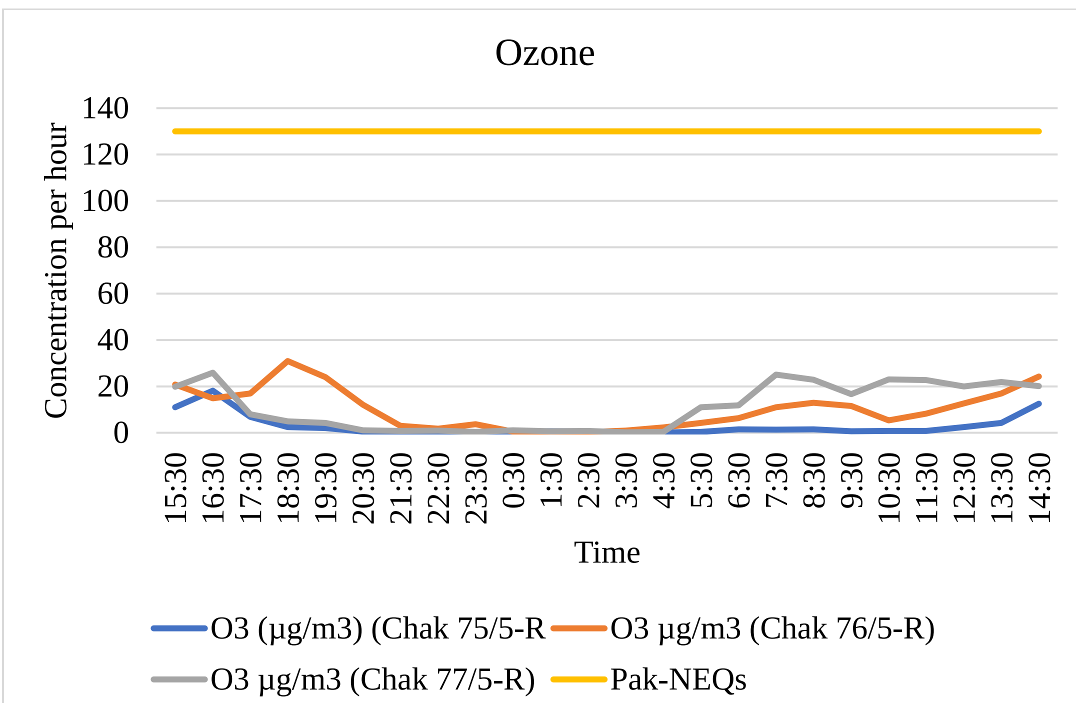

Figure 4-11: The 1-hour average concentrations of Ozone at the selected sites with respective Pak-NEQs

4.5 Health assessment results and analysis

A modified version of the American thoracic society division of lung disease questionnaire (ATS-DLD 1978A) was used to record the presence of respiratory symptoms. A copy of the questionnaire is attached in Annex__. It included questions regarding frequent cough (defined as presence of cough on most days for 3 consecutive months or more during the year), chronic cough (defined as presence of cough for 3 consecutive months in 2 consecutive years), frequent phlegm (defined as bringing up phlegm on most days of month, for 3 consecutive months or more in a year), chronic phlegm (presence of phlegm for 3 consecutive months in 2 consecutive years), frequent wheezing (whistling sound heard on expiration within 2 years), chronic wheezing (whistling sounds heard on expiration more than 2 years), shortness of breath Grade I (shortness of breath, when hurrying on the level or walking up a slight hill) and Grade II (dyspnea defined as: walk slower than people of the same age on the level because of breathlessness , Grade III (dyspnea defined as: to stop for breathing when walking at own pace on level), Grade IV (dyspnea defined as: ever having to stop for breath after walking about 100 yards/after a few minutes on the level), Grade V (dyspnea defined as: being too breathless to leave the house or breathless on dressing or undressing). Physician diagnosed respiratory and cardiovascular illnesses defined as illness confirmed by a doctor. The respondents were also asked about worsening of their pre-existing/physician diagnosed illness after the installation of power plant. Symptoms for other common illness such as, irritation and allergies of skin, eyes, nasal and throat areas and other common headaches, nausea etcetera were also asked in the questionnaire. Questions pertaining to socio-economic status (monthly income and expenditure on health related illness), education, occupation, type of kitchen, type of fuel used for cooking and smoking cigarettes or huqqa (local name for water-pipe) were added to the questionnaire. The questionnaire was translated into Urdu and back translated into English. During the data collection it was ensured that the respondents were able to truly comprehend the meaning of all questions, especially those pertaining to presence of respiratory symptoms, such as wheeze. The vital graph was used to ascertain the initial symptom of diseases.

4.6 Outcome of field study

The socio-demographic characteristics of study participants are given in Table 4.3. Majority of the participants were uneducated (52%) and predominant type of occupation was farmers and laborers (60.4%). The mean monthly income was (14388±9019) and monthly health expenditure was (1290±904.22) Pakistani rupees Table 4.4. Approximately 62.8% were smokers Table 4.5, predominant type of fuel used for cooking was bio- mass i.e. firewood and cow dung, while the commonly prevalent type of kitchen was open air and sheltered (roofs commonly made of wood/straws).

Reported symptoms for common illnesses was dominated by Nasal irritation and allergies with approximate 80.4%, followed by throat irritation and allergies (77.2%) and eyes related issues with 65.6%, skin problems with 58.4% and ear related problems with 46%. Headaches and nausea related complaints were reported with 63.6% and 37.6% respectively Table 4.6 and figure 4.12.

Predominant type of respiratory complaint was cough with 80% for frequent and 44.4% for chronic cough. followed by shortness of breath with (49.6% for Grade I, 43.6% for Grade II, 38.8% for Grade III, 20.8% for Grade IV, and 11.2% for Grade V, wheeze (37.6% frequent and 24% chronic), phlegm (36.8% frequent and 13.6% for chronic) Table 4.8. Majority of respondents with preexisting illness complaint about worsening of their condition after the installation and operation of Sahiwal coal power plant. Frequency of physician diagnosed pre-existing illness and worsening of their condition is demonstrated in Table 4.9.

On the basis of quality assessment of spirometry, the mean of % predicted for selected 161 participants were recorded is shown in Table: 4.10 and Table 4.11. The obstructive pattern on spirometry was 61.5% and that of restrictive pattern was 17.4%. A trend of reduced lung function (predicted FVC, FEV1 and FEV1/FVC ratio) was observed among participants with respiratory symptoms compared to those without symptoms.

During the study and respiratory analysis, it has been revealed that the respiratory symptoms of cough, phlegm, wheeze and shortness of breath are significantly correlated with reduced lung function and this trend was found consistently for all lung volumes (FVC, FEV1 and FEV1/FVC). This correlation suggests that the presence of respiratory symptoms is an important predictor of impaired lung function.

Table 4-3: Socio-demographic characteristics of the study population

Parameters	Male n (%)	Female n (%)	Total n (%)
Study Population	180 (72)	70 (28)	250 (100)
Age Group			
13-29 (Young age)	47	13	60 (24)
30-45 (Middle age)	92	33	125 (50)
>45 (Old age)	41	24	65 (26)
Marital status			
Single	55	10	65 (26)
Married	118	52	170 (68)
Widowed	4	7	11 (4.4)
Divorced/Separated	3	1	4 (1.6)
Education level			
No education	95	35	130 (52)
Primary	46	20	66 (26.4)
Secondary	29	11	40 (16)
Higher secondary or above	10	4	14 (5.6)
Occupation			
Student	21	5	26 (10.4)
Housewife	0	23	23 (9.2)
Farmer/Laborer	116	35	151 (60.4)
Govt./ Private service	8	0	8 (3.2)

Private Business	24	3	27 (10.8)
Retired/unemployed	11	4	15 (6)

Table 4-4: Average monthly income and expenditure on health related issues

Income status	**Mean (SD) PKR**
Monthly Income	14388 (9019.25)
Monthly Health Expenditure	1290 (904.22)

Table 4-5: Smoking Status of the respondents

[1]**Smoking Status**	**Total n (%)**
Ever smoker	93 (37.2)
Current smoker	157 (62.8)
Cigarettes per Day: *Mean (SD)*	16 (±3.7)

1. Smoking status defined as ever/never or current smoker of cigarette or huqqa.

Table 4-6: Prevalence of symptoms for common illnesses among the respondents

Common symptoms of other illnesses/diseases	**Total n (%)**
Eye problems	164 (65.6)
Skin problems	146 (58.4)
Ear problems	115 (46)
Headaches	159 (63.6)
Nausea	94 (37.6)
Nasal irritation/allergies	201 (80.4)
Throat Irritation/allergies	193 (77.2)

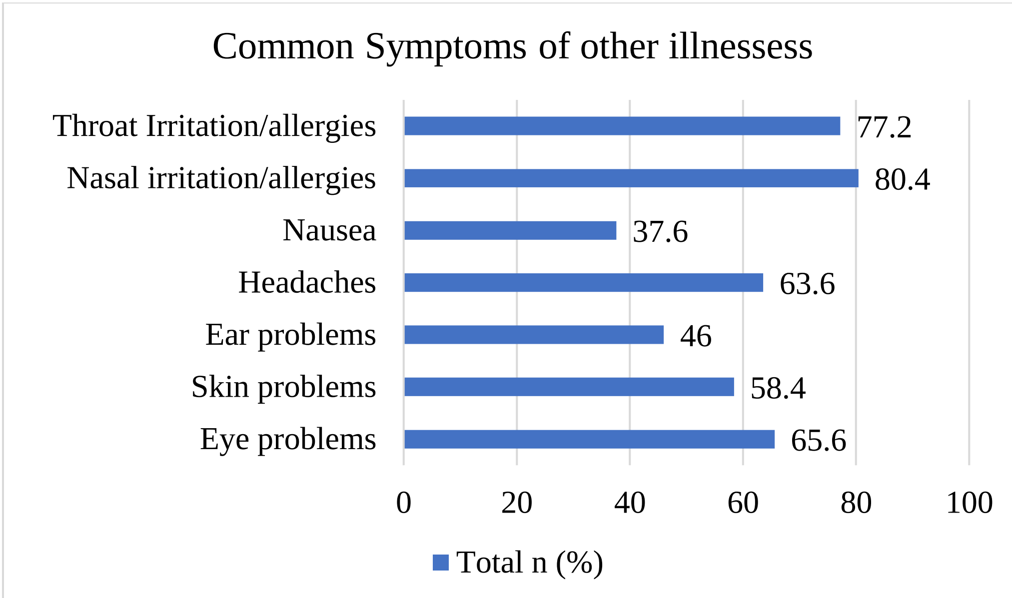

Figure 4-12: Frequency percentage for symptoms of common illnesses

Table 4-7: Prevalence of Respiratory Symptoms among the respondent

Prevalence of respiratory symptoms	**Total n (%)**
Cough	
[2]Frequent Cough	201 (80.4)
[3]Chronic cough	111 (44.4)
Phlegm	
[4]Frequent Phlegm	92 (36.8)
[5]Chronic Phlegm	34 (13.6)
[6]Episodes of Cough and Phlegm	98 (39.2)
[7]Chronic Bronchitis	36 (14.4)
Wheezing	
[8]Frequent Wheezing	94 (37.6)
[9]Chronic wheezing	60 (24.0)
Attacks of wheezing/self-reported Asthma	15 (6.0)
Breathlessness/ Dyspnea	
[10]Dyspnea Grade 1	124 (49.6)
[11]Dyspnea Grade 2	109 (43.6)
[12]Dyspnea Grade 3	82 (38.8)
[13]Dyspnea Grade 4	52 (20.8)
[14]Dyspnea Grade 5	28 (11.2)

2. Frequent cough defined as presence of cough on most days for 3 consecutive months or more during the year.

3. Chronic cough defined as presence of cough for 3 consecutive months in 2 consecutive years.
4. Frequent phlegm defined as bringing up phlegm on most days of month, for 3 consecutive months or more in a year.
5. Chronic phlegm defined as presence of phlegm for 3 consecutive months in 2 consecutive years.
6. Episodes of cough and phlegm defined as presence of episodes of increased cough and phlegm for 3 or more weeks in a year.
7. Chronic bronchitis defined as presence of these episode for most days of a week for 3 consecutive months in last 2 years.
8. Frequent wheezing defined as whistling sound heard on expiration within 2 years.
9. Chronic wheezing defined as whistling sounds heard on expiration more than 2 years.
10. Dyspnea Grade I defined as shortness of breath, when hurrying on the level or walking up a slight hill.
11. Dyspnea Grade II defined as: walk slower than people of the same age on the level because of breathlessness.
12. Dyspnea Grade III define as: having to stop for breathing when walking at own pace on level.
13. Dyspnea Grade IV defined as: to stop for breath after walking about 100 yards (or after a few minutes) on the level.
14. Dyspnea Grade V defined as: being too breathless to leave the house.

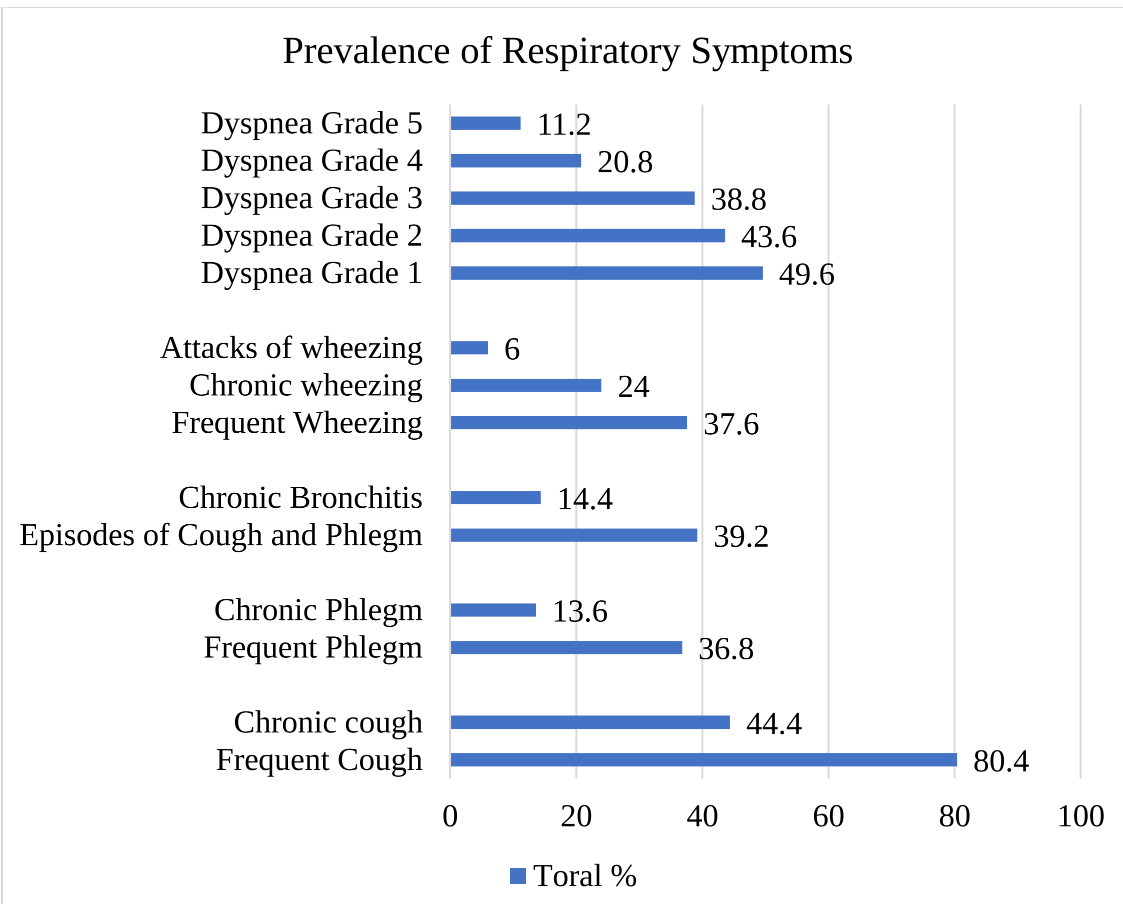

Figure 4-13: Frequency Percentage for symptoms of respiratory illnesses

Table 4-8: Physician diagnosed/Pre-existing illness and worsening condition of respondents

Physician diagnosed/ Pre-existing illnesses	**Total n (%)**	**Worsening of pre-existing condition n (%)**
Pulmonary/respiratory		
Bronchitis	18 (7.2)	15 (6.0)
Chronic Bronchitis	10 (4.0)	9 (3.6)
Pneumonia	4 (1.6)	3 (1.2)
Emphysema	3 (1.2)	1 (0.4)
Asthma	13 (5.2)	12 (4.8)
COPD	6 (2.4)	6 (2.4)
Heart Trouble/ illness	12 (4.8)	9 (3.6)
Hypertension/ High blood pressure	23 (9.2)	20 (8.0)

Table 4-9: Spirometry variables and lung volumes of respondents

Variables	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Age	161	13	64	35.70	11.298
Height (cm)	161	149	189	174.32	10.642
Spirometric Lung Volumes in Litters					
[15]FEV1	161	1	5	3.04	0.959
FEV1_P	161	2	5	4.03	0.835
%FEV1	161	25	95	74.56	13.788
[16]FVC	161	2	6	4.16	0.988
FVC_P	161	2	6	4.90	0.999
%FVC	161	52	100	84.73	9.040
FEV1/FVC	161	37	87	71.60	9.965
FEV1/FVC_P	161	77	88	81.78	3.083
Valid N (listwise)	161				

15. FEV1: Forced expiratory volume in 1 second.
16. FVC: Forced Vital Capacity

Table 4-10: Lung function/ Air flow pattern results/diagnosis of respondents

Lung function/ Air Flow Pattern Results	**n (%) N = 161**
[17]Normal	43 (26.7)
[18]Obstructive	90 (56)

[19]Mild	47 (29.2)
[20]Moderate	24 (15)
[21]Severe	15 (9.3)
[22]Very Severe	4 (2.5)
[23]Restrictive	28 (17.4)

17. Normal defined as: FEV1 and FVC ≥ 80% and FEV1/FVC ratio ≥ 80%.
18. Obstructive: FEV1/FVC ratio < 70%.
19. Mild: FEV1% predicted > 70%
20. Moderate: 50% < FEV1 < 70% predicted.
21. Severe: 30%< FEV1 <50% predicted.
22. Very Severe: <30% predicted.
23. Restrictive: FEV1/FVC Ratio > 70%.

4.7 Evaluation of health/respiratory risks associated with the coal power plant emissions in the vicinity.

The adverse health impacts Air pollutants and other effluents of Coal power plant were evaluated through a structured Questionnaire (ATS-DLS 78A) during the field work from respondents including the representative of dispensaries/hospital or other medical facility in study area (Chak 75,76, 77-5R), Civil and District hospital of Qadirabad and Sahiwal). The problems have been reported from all over the study area are summarized and tabulated in below table 4.12. The risks associated with coal power plant which has been observed/reported are the impacts like impair neurological development, Eye, nose, and throat irritation; headaches, loss of coordination, nausea; damage to liver, kidney, and central nervous system have been associated with Mercury exposure. Key signs or symptoms associated with exposure to Particulate Matter, Volatile organic compounds (VOCs) observed during study include conjunctional irritation, nose and throat discomfort, headache, allergic skin reaction, dyspnea, nausea, emesis, epistaxis, fatigue, dizziness**.** The impacts from the particulates matter towards the well- being of human health of people living in/expose to area of coal power plant with high particle levels emitted from the coal-fired power plant are summarized in Table 4.12. During the field work, people who are exposed to, are likely with the risk of facing the development of chronic bronchitis, and even at later stage the decreased lung function and the cardiovascular mortality is also expected. However, the current study has revealed that they are exposed to short-term coal particulates matter pollution either in hours or days. They are facing risk towards respiratory symptoms, exacerbation of chronic respiratory, mild problems associated with inhaling PM2.5 are found to include shortness of breath (dyspnea), chest discomfort and pain, and coughing and wheezing heartbeat irregularities, increased hospital admissions, increased respiratory symptoms. These detrimental health impacts shall affect at greater risk towards elderly, children and people with heart or lung disease.

Table 4-11: Coal's contributions to health effects

Sr #	**Type of Disease**	**Symptoms**	**Vulnerable population**	**Coal pollutants implicated**
1	Asthma exacerbations	*Coughing and wheezing *Heartbeat irregularities, *Increased hospital admissions * shortness of breath (dyspnea) * chest discomfort and pain Irritation in eyes *Phlegm	All most 65% of affected areas. It includes Adult and Children	PM2.5 PM10 NO2 SPM Ozone
2	Asthma Development	* Coughing and wheezing * shortness of breath *Breathlessness * conjunctional irritation, nose and throat *discomfort, headache,	All most 45% of affected areas. It includes Smokers and Adult	Ozone NO2 PM2.5
3	*Waterborne diseases *Over-exposure of VOC and Coal Effluents	* Ulcer, diarrhea, cholera, hepatitis B and C * allergic skin reaction * declines in serum cholinesterase levels, nausea, emesis, epistaxis, fatigue, dizziness. * loss of coordination * Neurological development	All most 35% of affected areas. It includes Adult	Coliform Arsenic VOC

5 CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

No Doubt the Power Generation through Coal plays an important role in Developing Countries GDP, but at the same time the Countries have to pay back in terms of huge health burden and Climate Change Issues because of Coal Emissions, particularly this burden increases manifold if the Coal Power Plants are constructed in the hub of City like Sahiwal. Coal power Plant also poses the Economic burden in terms of imported Coal and costly power Generation. Climate change that offers by coal as the source of electrical supply leads to high emissions of fine particulates matter, greenhouse gases and Coal effluents to the atmosphere. These later provide adverse health impact towards not only human but livestock directly or indirectly, and with short term or long-term exposure. The Over emission have left impacts on Sociodemographic and Socio-environment life of the area. The adverse impacts have been observed on water, agriculture land and crop as well.

Due to limited resources and time constraints the field study was curtailed to short sampling period of air quality monitoring, no control group was included for comparison in the health survey and did not have personal exposure estimates for each participant. The people located within 2 km of the power plant were included due to limited resources and budget. Reported symptoms for common illnesses was dominated by Nasal irritation and allergies 80.4%, followed by throat irritation and allergies (77.2%) and eyes related issues 65.6%, skin problems 58.4% and ear related problems with 46%. Headaches and nausea related complaints were reported with 63.6% and 37.6% respectively. Predominant type of respiratory complaint was cough (80% frequent and 44.4% chronic) followed by shortness of breath with (49.6% Grade I, 43.6% Grade II, 38.8% Grade III, 20.8% Grade IV, and 11.2% for Grade V), wheeze (37.6% frequent and 24% chronic), phlegm (36.8% frequent and 13.6% for chronic). Majority of respondents with preexisting illness complaint about worsening of their condition after the installation and operation of Sahiwal coal power plant. The spirometry analysis, of selected participants suggested that the Obstructive pattern on spirometry was 56 % (Mild: 29.2%, Moderate:15%, Severe:9.3%, Very Severe: 2.5%) and restrictive pattern was 17.4 %. A trend of reduced lung function (predicted FVC, FEV1 and FEV1/FVC ratio) was observed among participants with chronic respiratory symptoms compared to those without symptoms.

The observed ambient 24-hr average concentrations of air pollutants in the vicinity of Sahiwal Coal Power Plant are well below the PEQS except for SPM and PM2.5 which are quite more than the standard values. The highest concentration of PM2.5 was observed at station 3 (Chak 77-5R) and of SPM at station 1 (Chak 75-5R). Based on the results of this study, it is not possible to predict a concrete conclusion on the role of Sahiwal Coal Power Plant in concentrations of particulate matter in the region. These inconclusive results can be attributed to a number of factors like, Meteorological/instrumental bias, short sampling period and lack of cooperation from SCPP management. The poor population for the provision of commodities and hygienic living have been left on Gods Mercy. The cost of Power Generation through imported coal is unaffordable by poor nation and health burden is envisaged too. Time to come when the health burden and cost benefit ratio will exceed the limit where operation of this coal power plant through C-PEC will become mere dream and Power Generation by SCPP will be so expensive that it will have to be stopped. Though the plant was operational in July 2017, but the initial impacts on health and Environment are quite evident and if it remains at the current pace, it is going to be aggravated multifold.

This was a pilot study with a small sample size and short sampling period, however, as a preliminary research, this study significantly adds to the scarcely available data in this field.

5.2 RECOMMENDATIONS

- It is recommended that repeated, longitudinal, quantitative health monitoring with a professional consult be provided to truly mitigate persistent health problems.
- Further work be done, with longer sampling periods occurring in each season in to capture a seasonal profile of concentrations of particulate matter in this region.
- Improved implementation of the emission control technologies and environmental protection measures must be ensured.
- A detail health study should be conducted to assess the exact health burden and to suggest the measures to overcome in future.
- The citing of the coal plant within the periphery of densely populated area was based on political gain. Fair investigation and accountability should be done by the Government.
- Since SCPP is the first of its kind and many to come in future through CPEC so efforts should be made to avoid planning of such projects in agricultural and residential areas.
- Population at stake must be compensated for their lost land, property or any other asset as per existing market rates. This step will reduce any future social impacts or political strains due to power plant Project implementation.
- If Worst Coal is utilized at the Power Plant (mentioned in Feasibility Report of SEPCOIII) then it must be ensured that the air and wastewater emissions are in compliance with the NEQS.
- NGOs, Educational Institutes and researchers should be allowed to visit, to see what is exactly going on inside the plant.

6 REFERENCES

Abbasi, I. N., Ahsan, A., & Nafees, A. A. (2012). Correlation of respiratory symptoms and spirometric lung patterns in a rural community setting, Sindh, Pakistan: a cross sectional survey. *BMC pulmonary medicine*, *12*(1), 81.

Aneja, V.P.; Isherwood, A.; Morgan, P. Characterization of Particulate Matter (PM10) Related to Surface Coal Mining Operations in Appalachia. *Atmos. Environ*. **2012**, *54*, 496–501.

Bandyopadhyay, A. (2011). Pulmonary function studies in young healthy Malaysians of Kelantan, Malaysia. *The Indian journal of medical research*, *134*(5), 653.

Billings, P. (2007). Emission of hazardous air pollutants from coal-fired power plants. *Environ. Health & Eng*.

Bray, C., Battye, W., Uttamang, P., Pillai, P., & Aneja, V. (2017). Characterization of Particulate Matter (PM2. 5 and PM10) Relating to a Coal Power Plant in the Boroughs of Springdale and Cheswick, PA. *Atmosphere*, *8*(10), 186.

Brodkin, C. A., Barnhart, S., Anderson, G., Checkoway, H., Omenn, G. S., & Rosenstock, L. (1993). Correlation between respiratory symptoms and pulmonary function in asbestos-exposed workers. *American Journal of Respiratory and Critical Care Medicine*, *148*(1), 32-37.

Buist, A. S., Vollmer, W. M., & McBurnie, M. A. (2008). Worldwide burden of COPD in high- and low-income countries. Part I. The Burden of Obstructive Lung Disease (BOLD) Initiative [State of the Art Series. Chronic obstructive pulmonary disease in high-and low-income countries. Edited by G. Marks and M. Chan-Yeung. Number 6 in the series]. *The international journal of tuberculosis and lung disease*, *12*(7), 703-708.

Celli, B. R., MacNee, W. A. T. S., Agusti, A. A. T. S., Anzueto, A., Berg, B., Buist, A. S., ... & Fein, A. (2004). Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. *European Respiratory Journal*, *23*(6), 932-946.

Clark, K. A., Chanda, D., Balte, P., Karmaus, W. J., Cai, B., Vena, J., ... & Svendsen, E. R. (2013). Respiratory symptoms and lung function 8–10 months after community exposure to chlorine gas: a public health intervention and cross-sectional analysis. *BMC Public Health*, *13*(1), 945.

Din, S. A. M., Yahya, N. N. H. N., & Abdullah, A. (2013). Fine particulates matter (PM2. 5) from coal-fired power plant in Manjung and its health impacts. *Procedia-Social and Behavioral Sciences*, *85*, 92-99.

Dirty Kilowatts. America's most Polluting Power Plants 2006. Available online: http://www.dirtykilowatts.org/dirty_kilowatts.pdf (accessed on 15 September 2018).

Duvall, K., & Frank, G. W. (2010). Identifying chronic obstructive pulmonary disease in primary care of urban underserved patients: tools, applications, and challenges. *Journal of the National Medical Association*, *102*(7), 570-578.

Ferris, B. G. (1978). Epidemiology Standardization Project (American Thoracic Society). Recommended respiratory disease questionnaires for use with adult and children in epidemiological research. *Am Rev Respir Dis*, *118*, 7-53.

Fiechter, R., & Marks, G. B. (2006). Reliability and validity of a German asthma quality of life questionnaire. *Swiss medical weekly*, *136*(0506).

Jamali, T., & Nafees, A. A. (2017). Validation of respiratory questionnaire for lung function assessment among an occupational group of textile workers in Pakistan. *JPMA. The Journal of the Pakistan Medical Association*, *67*(2), 239.

Leite, M., Ponte, E. V., Petroni, J., D'Oliveira Júnior, A., Pizzichini, E., & Cruz, A. A. (2008). Evaluation of the asthma control questionnaire validated for use in Brazil. *J Bras Pneumol*, *34*(10), 756-63.

Levy, J. I., & Spengler, J. D. (2002). Modeling the benefits of power plant emission controls in Massachusetts. *Journal of the Air & Waste Management Association*, *52*(1), 5-18.

Lockwood, A. H., Welker-Hood, K., Rauch, M., & Gottlieb, B. (2009). Coal's assault on human health. *Physicians for Social Responsibility Report*.

MacIntosh, D.; Spengler, J. Emissions of Hazardous Air Pollutants from Coal Fired Power Plants. 2011. Available online: http://www.lung.org/assets/documents/healthy-air/coal-fired-plant-hazards.pdf (accessed on 20 August 2019).

Mahesh, P. A., Jayaraj, B. S., Prahlad, S. T., Chaya, S. K., Prabhakar, A. K., Agarwal, A. N., & Jindal, S. K. (2009). Validation of a structured questionnaire for COPD and prevalence of COPD in rural area of Mysore: A pilot study. *Lung India: official organ of Indian Chest Society*, *26*(3), 63.

Markandya, A., & Wilkinson, P. (2007). Electricity generation and health. *The lancet*, *370*(9591), 979-990.

Markandya, A., & Wilkinson, P. (2007). Electricity generation and health. *The lancet*, *370*(9591), 979-990.

Martinez, F. J., Raczek, A. E., Seifer, F. D., Conoscenti, C. S., Curtice, T. G., D'Eletto, T., ... & Phillips, A. L. (2008). Development and initial validation of a self-scored COPD Population Screener Questionnaire (COPD-PS). *COPD: Journal of Chronic Obstructive Pulmonary Disease*, *5*(2), 85-95.

Mohamed, R. M. S. R., Rahim, A. F. H., & Kassim, A. H. M. (2016). A Monitoring of Air Pollutants (CO, SO2 and NO) in Ambient Air Near an Industrial Area. In *MATEC Web of Conferences* (Vol. 47, p. 05022). EDP Sciences.

Moran-Mendoza, O., Pérez-Padilla, J. R., Salazar-Flores, M., & Vazquez-Alfaro, F. (2008). Wood smoke-associated lung disease: a clinical, functional, radiological and pathological description. *The International Journal of Tuberculosis and Lung Disease*, *12*(9), 1092-1098.

Nafees, A. A., Kazi, A., Fatmi, Z., Irfan, M., Ali, A., & Kayama, F. (2011). Lung function decrement with arsenic exposure to drinking groundwater along River Indus: a comparative cross-sectional study. *Environmental geochemistry and health*, *33*(2), 203-216.

Nkosi, V., & Voyi, K. (2016). Reliability of an adult respiratory symptom questionnaire in a community located near a mine dump in South Africa: pilot study. *Southern African Journal of Infectious Diseases*, *31*(3), 103-105.

Pope III, C. A., & Dockery, D. W. (2006). Health effects of fine particulate air pollution: lines that connect. *Journal of the air & waste management association*, *56*(6), 709-742.

Price, D. B., Tinkelman, D. G., Halbert, R. J., Nordyke, R. J., Isonaka, S., Nonikov, D., ... & Østrem, A. (2006). Symptom-based questionnaire for identifying COPD in smokers. *Respiration*, *73*(3), 285-295.

Rabl, A., & Spadaro, J. V. (2006). Environmental impacts and costs of energy. *Annals of the New York Academy of Sciences*, *1076*(1), 516-526.

Shin, B., Cole, S. L., Park, S. J., Ledford, D. K., & Lockey, R. F. (2010). A new symptom-based questionnaire for predicting the presence of asthma. *J Investig Allergol Clin Immunol*, *20*(1), 27-34.

United States. Environmental Protection Agency. Office of Air and Radiation. (2011). *The Benefits and Costs of the Clean Air Act from 1990 to 2020: Final Report, Rev. A*. US Environmental Protection Agency, Office of Air and Radiation.

ANNEX A

RESPIRATORY QUESTIONNAIRE FOR IMPACT ASSESSMENT OF SAHIWAL COAL POWER PROJECT

[Modified] ATS-DLD-78-A

ADULT QUESTIONNAIRE
(for those 13 years of age and older)

Thank you for your willingness to participate. You were selected by a scientific sampling procedure, and your cooperation is very important to the success of this study. This is a questionnaire you are asked to fill out. Please answer the questions as frankly and accurately as possible. ALL INFORMATION OBTAINED IN THE STUDY WILL BE KEPT CONFIDENTIAL AND USED FOR MEDICAL RESEARCH ONLY

SECTION 1

(IDENTIFICATION, SOCIAL AND DEMOGRAGIC INFORMATION OF RESPONDANTS)

IDENTIFICATION NUMBER: ____________

NAME: ________________________________

UNION COUNCIL: ______________________

CITY: _______________________ DISTRICT: ______________________

DATE: _____________________

===

1. AGE: ________________

2. Gender:
   1. Male
   2. Female

3. Marital Status:
   1. Single
   2. Married
   3. Widowed
   4. Separated/ Divorced

4. Education level:
   1. No Education
   2. Primary Education
   3. Secondary Education
   4. Higher Secondary or above

5. Occupation:

1. Student 2. Housewife 3. Farmer/ laborer 4. Govt. / Private service 5. Private Business 6. Retired/ Unemployed

6. Monthly Income and expenditure on health:

Average Monthly Income (PKR)	Expenditure on Health issues

==

SECTION 2

(SYMPTOMS OF RESPIRATORY AND OTHER COMMON ILLNESSES)

COMMON SYMPTOMS OF OTHER ILLNESSES:

These questions are mainly about your external organs related illness. Please answer yes or no if possible and check does not apply space if the question is not applicable to you. If you are in doubt whether your answer is yes or no, record no.

7. Do you experience any of these health problems on going outdoors?

Common illness	1.Yes	2.No	3. Does not apply
Eye problems			
Skin problems			
Nasal irritation/allergies			
Throat irritation/allergies			
Headaches			
Nausea/ dizziness			
Fatigue			

RESPIRATORY SYMPTOMS

These questions pertain mainly to your chest. Please answer yes or no if possible. If a question does not appear to be applicable to you, check the does not apply space. If you are in doubt about whether your answer is yes or no, record no.

8. COUGH

A. Presence	Do you usually have a cough? (Count a cough with first smoke or on first going out-of-doors. (Exclude clearing of throat.)	1.Yes	2. No	3. Does not apply
B Frequent	Do you usually cough as much as 4 to 6 times a day, 4 or more days out of the week?			
C. Chronic	Do you usually cough like this on most days (≥5 days) for 3 consecutive months or more for last 2 or more years?			

9. PHLEGM

A Presence	Do you usually bring up phlegm from your chest? (Count phlegm with the first smoke or on first going out-of-doors. Exclude phlegm from the nose. Count swallowed phlegm)	1.Yes	2. No	3. Does not apply
B Frequent	Do you usually bring up phlegm like this as much as twice a day, 4 or more days out of the week.			
C Chronic	Do you bring up phlegm like this on most days for 3 consecutive months or more during the year for last 2 or more years?			

10. EPISODE OF COUGH AND PHLEGM

A. Episodes of Cough & Phlegm	Do you have periods or episodes of (in-creased*) cough and phlegm lasting for 3 weeks or more each year? *(For individuals who usually have cough and/or phlegm)	1.Yes	2. No	3. Does not apply
B. Chronic Bronchitis	Do you have these episodes for most days (≥5 days) of the week for 3 consecutive months or more in a year for 2 or more years?			

11. WHEEZING

A Frequent	Does your chest sound wheezy or whistling on expiration most days of the week in last 3 months?	1.Yes	2. NO	3. Does not apply
B Chronic	Does your chest sound wheezy or whistling on expiration in last 2 years?			
C. Attacks of Wheezing	Have you ever had 2 or more Attacks of wheezing that made you short of breath in past 5 months			

12. BREATHLESSNESS/ DYSPNEA

If disabled from walking by any condition other than heart or lung disease, please describe and proceed to Question 13A

Nature of condition:________________________

A. Grade 1	Are you troubled by shortness of breath when hurrying on the level or walking up a slight hill?	1.Yes	2. No	3. Does not apply
B. Grade 2	Do you have to walk slower than people of your age on level because of breathlessness?			
C. Grade 3	Do you ever have to stop for breath when walking at your own pace on the level?			
D. Grade 4	Do you ever have to stop for breath after walking about 100 yards (or after a few minutes) on the level?			
E. Grade 5	Are you too breathless to leave the house or breathless on dressing or undressing?			

===

SECTION 3

(PHYSICIAN DIAGNOSED CARDIOVASCULAR/PULMONARY ILLNESSES, SMOKING, OCCUPATIONAL AND FAMILY HISTORY)

13. PHYSICIAN DIAGNOSED PAST ILLNESSESS

	Pre-existing condition diagnosed by doctor	1.Yes	2.No	Worsening of condition after SCPP 1.Yes,	2. No
A. Respiratory/ Pulmonary	- Bronchitis - Chronic Bronchitis - Pneumonia - Emphysema - Asthma - COPD				
B. Heart troubles	- Arrhythmia - Stroke - Angina - Heart failure				
C. Blood Pressure	- Hypertension - High blood pressure etc.				

14. SMOKING HISTORY

A	Have you ever smoked cigarettes? (NO means less than 1 cigarette a day for a year)	1.Yes	2. No	3. Does not apply
B	Do you currently smoke cigarettes? (As of 1 month ago)			
C	How many cigarettes do you smoke now?	Cigarettes per day ________		

==

ANNEX B

Pictorial view of Ambient air quality monitoring at the study area during field surveys.

Surroundings of Sahiwal Coal Power Project.


Ambient Air Quality Monitoring Instruments for SPM, PM10, PM2.5, NO, NO2, SO2, CO, O3.

Ambient Air Quality Monitoring during Daytime and Nighttime for 24-hour average concentrations.

ANNEX C

Modeling Setup for Air Dispersion Modeling

Power Generation	1,320 MW (2x660)		
Number of Stacks	2		
Stack height (m)	180 (590 ft)		
Stack diameter (m)	7.3 (23 ft)		
Emissions (g/s)	Sulphur Dioxide	Nitrogen Oxides	PM
	286.28	604	71.54
Gas Exit Temp (K)	323.15 (50 ^{o}C)		
Gas Exit Velocity (m/s)	22.3		
Flu Gas Exit Flow Rate (m^3/s)	931.83		
Anemometer Height (m)	9.75 (31.9 ft)		
Ambient Air Temperature (K)	299 (255.5 ^{o}C)		
Terrain	Simple and Flat		
Meteorology	Full Meteorology (All stability classes and wind speeds)		
Distances	Range between 1 m and 50,000 m (3.2 ft and 164,041 ft)		

ANNEX D

Atmospheric Air Dispersion Modelling Results

Sr.#	Distance (m)	NO2 1 hr. avg	NO2 Annual avg.	SO2 1 hr. avg.	SO2 Annual avg.	PM 1 hr. Avg.	PM Annual avg.
1	1	0	0	0	0	0	0
2	100	0	0	0	0	0	0
3	200	4.99E-13	3.99E-14	2.36E-13	1.89E-14	5.91E-14	4.73E-15
4	300	4.01E-09	3.20E-10	1.90E-09	1.52E-10	4.75E-10	3.80E-11
5	400	4.63E-03	0.00037	2.19E-03	0.000176	5.48E-04	4.39E-05
6	500	3.91	0.3128	1.853	0.14824	0.4631	0.037048
7	600	105.6	8.448	50.03	4.0024	12.5	1
8	700	379.7	30.376	180	14.4	44.98	3.5984
9	800	604	48.32	286.3	22.904	71.55	5.724
10	900	933.1	74.648	442.3	35.384	110.5	8.84
11	1000	1120	89.6	530.8	42.464	132.6	10.608
12	1100	1238	99.04	586.6	46.928	146.6	11.728
13	1200	1247	99.76	591.3	47.304	147.8	11.824
14	1300	1206	96.48	571.4	45.712	142.8	11.424
15	1400	1151	92.08	545.5	43.64	136.3	10.904
16	1500	1098	87.84	520.4	41.632	130.1	10.408
17	1600	1049	83.92	497.3	39.784	124.3	9.944
18	1700	1005	80.4	476.1	38.088	119	9.52
19	1800	963.4	77.072	456.6	36.528	114.1	9.128
20	1900	929.6	74.368	440.6	35.248	110.1	8.808
21	2000	899.6	71.968	426.4	34.112	106.6	8.528
22	2100	871.4	69.712	413	33.04	103.2	8.256
23	2200	844.8	67.584	400.4	32.032	100.1	8.008
24	2300	819.7	65.576	388.5	31.08	97.09	7.7672
25	2400	796	63.68	377.3	30.184	94.28	7.5424
26	2500	773.6	61.888	366.7	29.336	91.63	7.3304
27	2600	752.4	60.192	356.6	28.528	89.12	7.1296
28	2700	732.4	58.592	347.1	27.768	86.74	6.9392
29	2800	713.3	57.064	338.1	27.048	84.49	6.7592
30	2900	695.3	55.624	329.5	26.36	82.35	6.588
31	3000	678.1	54.248	321.4	25.712	80.32	6.4256
32	3500	603.7	48.296	286.1	22.888	71.5	5.72
33	4000	575.4	46.032	272.7	21.816	68.15	5.452
34	4500	566.3	45.304	268.4	21.472	67.08	5.3664
35	5000	540.5	43.24	256.2	20.496	64.02	5.1216
36	5500	508.7	40.696	241.1	19.288	60.25	4.82
37	6000	476.6	38.128	225.9	18.072	56.45	4.516

38	6500	461.3	36.904	218.6	17.488	54.64	4.3712
39	7000	442.3	35.384	209.6	16.768	52.38	4.1904
40	7500	422.1	33.768	200.1	16.008	50	4
41	8000	402.3	32.184	190.7	15.256	47.65	3.812
42	8500	395.6	31.648	187.5	15	46.86	3.7488
43	9000	396.2	31.696	187.8	15.024	46.93	3.7544
44	9500	393.7	31.496	186.6	14.928	46.63	3.7304
45	10000	388.8	31.104	184.3	14.744	46.05	3.684
46	15000	308.7	24.696	146.3	11.704	36.57	2.9256
47	20000	256.3	20.504	121.5	9.72	30.35	2.428
48	25000	212.8	17.024	100.8	8.064	25.2	2.016
49	30000	181.7	14.536	86.14	6.8912	21.53	1.7224
50	40000	141.7	11.336	67.14	5.3712	16.78	1.3424
51	50000	116.8	9.344	55.37	4.4296	13.84	1.1072

1 hours average values have been converted into average annuals by a multiplication factor of "0.8" as specified by USEPA Screening Procedures for Estimating the Air Quality Impact of Stationary Sources, Revised," EPA-454/R-92-019, page 4-16

ANNEX E

Ambient Air Quality Monitoring Results at Station 1 (Chak 75/5R)

Time	CO mg/m³	SO2 µg/m³	O3 µg/m³	NO µg/m³	NO2 µg/m³	PM2.5 µg/m³	PM10 µg/m³	SPM (µg/m3)
15:30	1.386	25.805	10.946	21.629	36.183	49.244	131.415	
16:30	1.031	25.158	18.141	24.157	35.86	49.3	137.672	
17:30	0.945	25.893	6.866	25.442	36.23	54.253	150.511	
18:30	0.941	26.816	2.431	24.77	33.938	33.066	120.993	
19:30	0.99	25.694	2.011	20.163	35.606	40.297	160.373	
20:30	0.738	26.874	0.441	24.024	35.413	31.13	139.878	
21:30	0.603	25.529	0.498	24.958	35.483	39.764	156.682	
22:30	0.598	25.482	0.494	24.899	35.447	31.277	155.622	
23:30	0.607	23.012	0.201	21.809	33.592	36.242	99.993	
0:30	0.845	22.965	0.29	16.965	33.156	31.995	149.474	
1:30	0.798	25.05	0.702	19.046	33.244	40.339	120.763	
2:30	0.794	24.361	0.565	19.791	34.895	37.585	131.965	
3:30	0.846	25.541	0.163	16.324	34.83	39.681	139.828	
4:30	0.58	22.845	0.138	16.194	33.097	37.261	109.226	
5:30	0.672	23.148	0.328	18.578	34.291	32.727	113.751	
6:30	0.839	22.831	1.46	19.417	34.944	40.719	148.751	
7:30	0.899	23.808	1.381	20.392	35.594	32.556	172.619	
8:30	0.762	22.866	1.469	20.522	35.682	40.902	133.859	
9:30	1.011	24.103	0.626	19.258	34.839	34.132	99.6	
10:30	0.763	22.865	0.753	19.45	35.681	40.897	133.841	
11:30	0.96	22.317	0.713	20.817	34.601	34.833	103.157	
12:30	0.783	22.507	2.46	20.161	35.441	38.976	153.206	
13:30	1.182	24.951	4.284	18.54	35.076	36.04	109.269	
14:30	1.246	26.232	12.539	20.407	35.83	34.829	150.38	
MIN	0.58	22.317	0.138	16.194	33.097	31.13	99.6	
MAX	1.386	26.874	18.141	25.442	36.23	54.253	172.619	
AVG.	**0.876**	**24.455**	**3.3915**	**20.744**	**34.933**	**38.593**	**134.425**	**777**

ANNEX F

Ambient Air Quality Monitoring Results at Station 2 (Chak 76/5R)

Time	CO mg/m³	SO2 µg/m³	O3 µg/m³	NO µg/m³	NO2 µg/m³	PM2.5 µg/m³	PM10 µg/m³	SPM µg/m³
15:30	2.356	37.098	14.78	25.22	42.66	51.322	130.346	
16:30	2.43	38.321	19.88	27.54	41.21	52.2	134.823	
17:30	1.25	36.986	9.87	28.34	42.32	56.336	151.972	
18:30	1.98	37.123	6.932	26.22	40.01	38.09	124.813	
19:30	1.798	34.879	3.981	26.59	41.45	42.34	154.786	
20:30	1.111	36.768	2.12	21.88	42.01	32.5	141.09	
21:30	1.52	36.3	0.998	26.91	41.66	41.32	134.212	
22:30	0.99	32.987	0.789	25.32	40.92	34.08	97.988	
23:30	0.889	30.324	0.632	23.99	39.88	32.66	121.08	
0:30	0.87	32.567	0.541	24.21	37.09	38.92	139.98	
1:30	0.944	29.561	0.391	19.2	36.81	33.76	132.076	
2:30	0.765	30.364	0.298	20.09	38.22	41.52	122.657	
3:30	0.921	29.797	0.89	18.33	35.9	38.81	132.824	
4:30	0.878	31.798	0.342	19.52	34.61	40.28	100.838	
5:30	0.529	32.123	0.167	18.3	36.02	35.2	106.732	
6:30	0.677	34.988	0.329	20.98	33.93	31.78	110.676	
7:30	0.987	37.234	0.989	21.11	36.7	41.88	149.439	
8:30	0.968	38.334	1.897	19.09	38.2	42.79	126.497	
9:30	0.764	37.789	1.567	23.1	32.99	35.492	115.98	
10:30	0.698	35.33	1.328	24.79	37.03	39.89	121.776	
11:30	1.023	37.167	1.235	21.97	39.9	36.776	111.656	
12:30	1.045	36.225	2.65	22.33	41.87	37.82	149.763	
13:30	1.879	37.233	6.87	24.56	43.01	40.75	118.065	
14:30	2.321	38.987	14.23	22.97	42.77	39.98	152.98	
MIN	0.529	29.561	0.167	18.3	32.99	31.78	97.988	
MAX	2.43	38.987	19.88	28.34	43.01	56.336	154.786	
AVG.	**1.252**	**35.012**	**4.375**	**23.023**	**39.049**	**39.854**	**129.301**	**659**

ANNEX G

Ambient Air Quality Monitoring Results at Station 3 (Chak 77/5R)

Time	CO mg/m3	SO2 µg/m³	O3 µg/m³	NO µg/m³	NO2 µg/m³	PM2.5 µg/m³	PM10 µg/m³	SPM µg/m³
15:30	3.21	48.1	19.78	36.88	52.66	55.021	165.653	
16:30	3.312	47.11	25.9	35.08	54.13	54.8	154.981	
17:30	2.2	45.9	7.99	36.31	53.91	58.336	162.678	
18:30	2.98	46.77	4.98	34.09	47.98	49.32	155.329	
19:30	1.45	42.997	4.23	29.81	46.32	46.46	162.443	
20:30	2.76	39.22	1.12	25.56	45.82	38.78	154.654	
21:30	0.996	38.65	0.789	28.55	46.11	43.06	148.908	
22:30	0.798	36.145	0.981	30.01	43.29	37.21	127.383	
23:30	0.921	34.05	0.432	25.39	40.69	31.32	132.584	
0:30	0.998	34.229	0.998	26.89	42.71	39.89	135.562	
1:30	1.032	31.99	0.597	22.66	41.02	35.43	127.435	
2:30	1.567	32.02	0.765	21.98	42.94	40.66	131.672	
3:30	0.765	32.877	0.197	23.44	38.73	41.08	102.059	
4:30	0.897	33.76	0.398	21.67	37.88	42.98	98.446	
5:30	0.765	37.289	0.932	21.8	39.92	38.926	116.332	
6:30	0.785	44.556	1.789	22.07	41.21	34.886	132.632	
7:30	0.897	43.009	2.098	23.16	43.63	43.078	143.787	
8:30	0.734	42.98	2.897	34.98	45.77	44.919	145.765	
9:30	0.935	47.776	2.67	36.76	49.8	40.68	143.887	
10:30	0.689	42.998	1.998	37.98	50.99	42.84	159.665	
11:30	1.054	47.665	2.76	35.89	52.64	46.65	156.495	
12:30	1.034	46.254	6.98	36.83	51.58	50.87	157.984	
13:30	1.128	45.98	8.91	36.98	50.32	49.94	162.769	
14:30	1.876	44.889	15.1	37.88	52.56	50.78	160.552	
MIN	0.689	31.99	0.197	21.67	37.88	31.32	98.446	
MAX	3.312	48.1	25.9	37.98	54.13	58.336	165.653	
AVG.	**1.453**	**41.134**	**4.804**	**30.111**	**46.359**	**44.079**	**144.284**	**765**

ANNEX H

Coal Analysis for 2x660 MW Coal Fired Power Plant near Sahiwal

Sr. #	Description	Unit	Design Coal	Worst Coal
1	Total Moisture	% AR	24.82	21
2	Proximate analysis (air dry basis)			
	Moisture	% Air Dried (ad)	14.22	11
	Ash	% ad	5.29	20
	Volatile Matter	% ad	37.5	37
	Fixed carbon	% ad	42.24	32
3	Gross Calorific Value (as received)	kcal/kg	5,027	3,900
4	Net as Received	kcal/kg	4,674	3,644.50
5	HGl		46	45
6	Ultimate Analysis %	% AR		
	Carbon		54.54	43.15
	Hydrogen		4.1	2.41
	Nitrogen		1.16	1.56
	Sulphur		0.66	0.3
	Oxygen		9.43	11.56
	Ash		5.29	20
7	Ash Fusion Temperature			
	IDT	Ḩ	1,160	1,170
	Spherical	Ḩ	1,190	
	Hemispherical	Ḩ	1,220	1,232
	Flow	Ḩ	1,320	1,260
8	Ash analysis %			
	SiO2	%db	47.1	52.94
	Al2O3	%db	25.6	22.96
	Fe2O3	%db	13	11.38
	CaO	%db	3.73	3.78
	MgO	%db	2.1	2.69
	TiO2	%db	0.93	1.11
	Na2O	%db	0.34	0.94
	K2O	%db	1.52	0.87
	P2O5	%db	1.37	0.24
	SO3	%db	2.68	2.54

Source: Feasibility Report Provided by SEPCO III (February 2014)

ANNEX I

Key Technical Data

Sr. #	Parameter	Value
1	Thermal Cycle Information- Gross Capacity	660 MW at guarantee conditions
2	Thermal Cycle Information- Net Capacity	600 MW (target) at design conditions (26ºC, ambient temperature, dry bulb)
3	Net Plant Heat Rate	2,280 kcal/kWh at design guarantee conditions
4	Main Stream Flow Main Steam Pressure Main Steam Temperature	2,030,000 kg/h 24.2 MPa 566ºC
5	Hot Reheat Flow Hot Reheat Pressure Hot Reheat Temperature	1,669,091 kg/h 4.73 MPa 566ºC
6	Cold Reheat Flow Cold Reheat Pressure Cold Reheat Temperature	1,927,900 kg/h 5.14 MPa 336.7ºC
7	Feed water Pressure	31.4 MPa
8	Coal Burn Rate	299 t/h for the design coal, BMCR load
9	Water Flow to the Plant Circulating Water Flow Circulating Water Temperature Rise in Condenser	458 m^3/h, Two Units 67,150 m^3/h to condenser per unit (closed cooling) 10.5 ºC
10	Wastewater Flow	22 m^3/h approximate for two units
11	Potable Water Supply to Plant	10 m^3/h for two units

Source: Feasibility Report Provided by SEPCO III (February 2014)

ANNEX J

Power Generation by Coal in Various Countries

Sr. #	Country	Power Share Produced by Coal (%)
1	South Africa	93
2	Poland	92
3	China	79
4	Australia	77
5	Kazakhstan	70
6	India	69
7	Morocco	55
8	USA	49
9	Germany	46

Source: Coal Energy for Sustainable Development, World Coal Association

ANNEX K

List of respondents/Participants during Field Work

Sr. #.	Chak No.	Names of the Persons
1	75/5R	Taj Ali
		Jahangir Sipra
		Muhamamd Nasar
		Ahmed Ali
		Mahar Zafar
		Bashir Ahmed
		Allah Ditta
		Saif Ali
		Imntiaz Ahmed
		Muhammad Riaz
		Abdul Nazar
		Muhammad Nazar
		Ahmed Din
		Maraj Din
		Khalil ur Rehman
		Burhan Din
		Bushra Jahan
		Rehman Din
		Imtiaz Ali
		Mazhar Ali
		Muazzam Ali
		Nasrullah
		Ghulam Nabi
		Muhamamd Haji Shahid
		Muhamad Siddiq
		Abdul Razzaq
		Safdar Hussain
		Mohammad Maskin
		Mohammad Saeed
		Mohammad Waheed
		Anwar Hussain
		Mohammad Ijaz
		Bakht Jamal
		M. Ahmed
		Noor Bibi
		Mohammad Yousaf
		Qamar
		Asif Mushtaq
		Muhammad Imtiaz
		Muhammad Jabbar
		Hafiz Muahmmad Junaid
		Chaudhry M. Khalid
		Muhammad Ashraf
		Rana M. Ashar

		Muhammad Nasar Muhammad Khalid Muhammad Muzaffar Muhammad Nasir Abida ilyas
2	76/5R	Azam Ali Habeeb Ali Shair Afzal Yasar Ali Muhammad Aslam Munir Hussain Haji Nazir Ahmed Muhammad Amir Hayat Khan Amir Shahzad Niaz Ali Abdul Ghaffar Rifat Ara Sajid Mehmood Jameela Ahmed Yar Mohammad Sajid Mohammad Zarif Ashiq Hussain Zafar Kamaluddin Mukhtar Ahmed M. Safeer Ahmed Mohammad Hanif Ghulam Nabi Maraj Din Muhammad Naeem Ibrahim Muhammad Latif Noor Muhammad Liaqat Ali Rakha Bashir Ahmed Qasim Ali Latif Muhammad Ibrar
3	77/5R	Muhammad Rafiq Muhammad Sajid Muhammad Nazir Ahmed Niaz Bibi Muhammad Munir Ahmad Muhammad bashir Ahmad Muhammad Sagheer Ahmed Amanullah Khan

	Kasar Mohammed Mohammad Aziz M. Abdul Hameed Muhammad Iqbal Muhammad Aslam Nazeer Ahmed Muhammad Ashraf Fatima Muhammad Rafique Muhammad Yunis Haji Ghafoor Zaitoon bibi Haji Haqnoor