

**HEALTH HAZARDS AMONG COAL MINERS:AN ENVIRONMENTAL
EPIDEMIOLOGICAL STUDY IN CHERAT COAL MINES NOWSHERA**

KHYBER PAKHTUNKHWA

PHD THESIS



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Session 2008-09

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Thesis submitted to Department of Environmental
Sciences University of Peshawar in partial fulfillment of
the requirements for the degree of Doctor of Philosophy

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*This research work
Is dedicated to all those
coal miners who lost their
lives during coal mining*

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All glory be to **ALLAH**; The Most Merciful, Gracious and Compassionate; The Real Bless Of The Universe, Who gave me the ability to contribute a drop of awareness and cognition from the existing ocean of knowledge and wisdom. In offer my countless salutations upon the **Holy Prophet Hazrat Muhammad (PBUH)**, the real source of justice and guardian for mankind.

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MUHAMMAD ISHTIAQ

LIST OF ABBREVIATIONS

Abbreviation	Stands For
AAAAI	American Academy of Allergy Asthma and Immunology
AAS	Atomic Absorption Spectroscopy
Al	Aluminum
Arc-GIS	Arc-geographic information system
Ca	Calcium
CCWP	Complicated Coal Worker Pneumoconiosis
Cd	Cadmium
CDC	Centers for Disease Control and Prevention
CNS	Central Nervous System
Co	Cobalt
COPD	Chronic Obstructive Pulmonary Disease
Cr	Chromium
CRL	Central Resource Laboratory
Cu	Copper
CVS	Cardio Vascular System
CWP	Coal Worker Pneumoconiosis
CXR	Chest-X-Ray
DIK	Dak Ismael Khel
ECG	Echo Cardio Graph
EDX	Energy Dispersive Using X-Ray
EIA	Environmental Impact Assessment
EPA	Environmental Potential Agency
ETT	Exercise Tolerance Test
F	Fluorine
F	Frequency
FC	Fixed Carbon
FCMHS	Federal Coal Mine Health and Safety
Fe	Iron
FEV(1)	Forced Expiratory Volume at 1 second
FVC	Forced Vital Capacity
GERD	Gastro-Esophageal-Reflex-Disease
GIT	Gastro Intestinal Tract
HCl	Hydro Chloric Acid
HF	Hydrofluoric Acid
HMs	Heavy Metals
HNO ₃	Nitric Acid
HSC	Health and Safety Commission

IARC	International Agency for Research on Cancer
IEA	International Environmental Agreements
IFA	Independent Factor Analysis
ILO	International Labor Organization
IOM	Institute of <i>Occupational</i> Medicine
JK	Jabba Khushk
JT	Jabba Tar
K	Potassium
KPK	Khyber Pukhtunkhwa
LRT	Lower Respiratory Tract
Mg	Magnesium
MPEL	Maximum Permissible Exposure Limits
MSHA	Mine Safety and Health Administration
N	Nitrogen
N	Number of Samples
Na	Sodium
Ni	Nickel
NIH	National Institute of Health
NIOSH	National Institute for Occupational Safety and Health
NOHSC	National Occupational Health and Safety Commission of Australia
NWFP	North West Frontier Province
OELs	Occupational Exposure Limits
OSHA	Occupational Safety & Health Administration
P	Phosphorus
P/A View	Posterior / Interior View
Pb	Lead
PCCAP	Physicians' Continued Competence Assessment Program
PEFR	Peak Expiratory Flow Rate
PELs	Permissible Exposure Limits
PFTs	Pulmonary Function Tests
PMF	Progressive Massive Fibrosis
PMs	Particulate Matters
Ppb	Parts Per Billion
PPEs	Personal Protective Equipments
ppm	Parts Per Million
PSR	Physicians for Social Responsibility
S	Sulfur
SCWP	Simple Coal Worker Pneumoconiosis
SD	Standard Deviation
SEM	Scanning Electron Microscope

SKT	Shakot
SOB	Shortness of Breath
SPSS	Statistical Package for the Social Sciences
SUPARCO	Space and Upper Atmosphere Research Commission
URT	Upper Respiratory Tract
USGS	United States Geological Survey
USA	United States of America
VM	Volatile Matter
VM	Volatile Matter
WHO	World Health Organization
XRD	X-Ray Diffraction
Zn	Zinc

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KHYBER PUKHTUNKHWA PAKISTAN**

ABSTRACT

Coal and coal mining industry has great significance to the development of any country; but the unsustainable and unplanned coal mining causes various environmental and health hazards. Thus despite being the most vibrant economic source, the ill planned practices during mining and the absence of health and safety regulations has become the potential source of environmental and occupational health hazards around the Globe specifically in Asian countries and Pakistan is among one of them. In this environmental epidemiological study, real-life patterns of disease and exposures were analyze to examine the associations between occupational environment coal dust exposure determinants and health outcomes of disease at a population level; so this research work has been carried out to identify and highlight the adverse environmental and occupational health impacts among coal miners occur as a result of potential exposure to respirable hazardous dust released during coal mining located in District Nowshera, Cherat including Shakot, Jaba Tar, Jaba Khushk and Dak Ismail Khel, Khyber Pukhtunkhwa, Pakistan. A detailed study was conducted to assess the geo chemical composition of coal raw samples; air quality within the occupational and para-occupational environment and to identify the prevalence of various health hazards particularly pneumoconiosis and silicosis among coal miners working in Cherat coal mines.

Twenty (20) number of representative raw coal samples were collected from various coal mines including Shakot, Jaba Tar, Jaba Khushk and Dak Ismail Khel and were investigated qualitatively for major mineralogical contents by XRD analysis and showed quartz, calcite and

kaolinite; as major dominant minerals. These coal samples were quantitatively assessed for heavy metals including chromium, Zinc, Lead, Copper, Cobalt, Nickel and Cadmium using atomic absorption spectrophotometer (AA Model 700). The results display the presence of significant quantity of different heavy metals in coal samples: Chromium (2.7-74.1ppm), Zinc (6.3-26.1ppm), Lead (17.2-42.1 ppm), Copper (5.4-40.0ppm), Cobalt (1.5-20.3ppm), Nickel (0.7-18.4ppm), Cadmium (1.1-5.1 ppm) (mean conc). The mean concentrations of all raw coal samples were compared with PELs of Cr (< 1 ppm), Cd (< 1 ppm), Pb (< 1 ppm) & Cu (< 1 ppm) as defined by Federal EPA of USA.

Twenty four (24) number of particulate matter (PM₁₀ µ) samples were collected within the vicinity from Shakot, Jaba Tar, Jaba Khushk and Dak Ismail Khel coal mines, using High Volume Air Sampler Series 302 of Sierra Anderson USA. The results revealed high levels of PM₁₀ concentrations of coal mine air dust, having mean of 441.1 mg/m³ (235.57-837.59 mg/m³), which were comparatively higher than the PELs as mentioned by the U.S. standards for PM₁₀ of 150 µg/m³, Occupational Safety and Health Administration (OSHA), World Health Organization (WHO), International Labor Organization (ILO), and American Conference of Governmental Industrial Hygienists (ACGIH). The mean coal mine air dust concentration was identified as 2 to 6 times ≥ as compared with the International Permissible Exposure Limits.

The respirable particulate samples of PM₁₀ µ were subjected to X-Ray Diffractometer, Scanning Electron Microscopy, Energy Dispersive Spectrometry to confirm the quantitative and qualitative contents of various toxic minerals as were investigated as major minerals in the rock coal samples. The XRD analysis of the selected four coal mine air dust samples from the study areas revealed and confirmed crystalline silica/quartz, calcite and kaolinite and thus strongly correlates with the CXR, LFTs findings and XRD of the coal samples.

The analytical results of PM₁₀ samples were subjected to AAS700, Perkin Elmer, USA, to reveal the presence of several heavy metals including chromium, Zinc, Lead, Copper, Cobalt, Nickel and Cadmium as were already identified in the coal samples. The concentrations of Zn, & Ni in all air samples were within the permissible limits while concentrations of Pb, Cr, Co & Cd; were above the Permissible Exposure Limits (PELs), of American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Value (TLV) & National Institute for Occupational Safety and Health (NIOSH) of chromium (1.0), Zinc (5.0), Lead (0.075), Copper (1.0), Cobalt (0.1), Nickel (1.0) and Cadmium (0.005) mg/m³. Moreover the concentrations of Cu were normal in JK, JT & SKT while higher only in DIK air samples (show).

To establish the relationship of environmental and various health hazards i.e. pneumoconiosis and silicosis among the coal miners, a detailed medical examinations of n=400 of coal miners was carried-out to perform various analytical tests including pulmonary function tests and Chest X-rays P/A views. The pulmonary function tests showed restrictive pattern of respiratory diseases in n=210 (52.50%), obstructive pattern in n=63 (15.75%) and only n=127 (31.75%) showed normal pulmonary function tests; and were labeled as having no respiratory health problem/s. The chest x-rays (P/A View) showed that micro & macro-nodular opacities; consistent with pneumoconiosis and silicosis (restrictive lung diseases) were observed in n=188 (47%), hyper inflated lung fields (obstructive diseases) in n=72 (18%) and normal chest x-ray in n=140 (35%) of coal miners. This might be the factor responsible for high prevalence of pneumoconiosis and silicosis, as was confirmed by Chest X-Rays and Pulmonary Function Tests of among the coal miners.

In addition to that half of coal miners were having signs & symptoms of different other systemic health problems; like respiratory system, Central Nervous System, Cardio-vascular

System, Gastro-Intestinal Tract, urinary system, ear nose throat, eye, skin/foot, musculo-skeleton system and miscellaneous health problems e.g. hepatitis, fever etc.

The overall analytical data indicate that the untrained and uneducated coal miners are highly exposed to toxic substances specially quartz/silica, calcite and kaolinite minerals; and other heavy metals including chromium, Zinc, Lead, Copper, Cobalt, Nickel and Cadmium and thus are at high risks to occupational diseases specially pneumoconiosis and silicosis among the coal miners.

CHAPTER # 1

INTRODUCTION

Environmental epidemiology is concerned with the external factors which greatly affect the incidence and prevalence of health conditions and thus helps to identify relationships between environmental exposures and incidence of disease in populations or cohort groups so on that ground this cross sectional study was designed to assess the geochemistry of coal, environmental quality and health hazards among the cherat coal miners, of Nowshera Pakistan.

1.1. Coal and Coal Mining

Coal mining plays an important role in the development and economic stability of any country. Most of the world's energies are obtained from fossil fuels and among them coal is one of the abundant source around the Globe. Coal is the major source of energy being consumed in domestic and commercial sectors including Power plants, railway, cement, fertilizer industries, homes, hotels and brick kilns. There are around 185 billion tons of indigenous coal reserves in Pakistan, out of which Khyber Pukhtunkhwa Province contributes about 90 million tons from Hangu/Orakzai and Cherat/Nowshera (Alam, 2010). Despite being the most vibrant economic source, the improper practices during the coal mining and processing including drilling, blasting, loading, unloading and transportation has become the major cause of environmental and occupational health hazards in the workplace atmosphere (Baur, 2011). The toxic emission/ dust released during these operations not only deteriorate the environment but also pose the miners to various health risk (Mandal K et al., 2011). The toxic emissions including methane, silica and other substances containing particulate matter (dust), is the common phenomenon during various mining operations i.e. drilling, blasting, loading, unloading, and transportation. As a result of

high level exposure to these toxic substances, the epidemics of lung diseases occur among the miners.

1.2. Occupational Health and Safety

The occupational health and safety administration, international agency for research on cancer and world health organization have set enforceable permissible exposure limits (PELs) in order to control and prevent the occupational workers from the hazardous and adverse health effects related to substandard exposure limits (PELs). The occupational safety and health administration (OSHA); PELs are based and regulated on an 8-hour Time Weighted Average (TWA) exposure to the amount and concentration of substances in occupational environments. The permissible exposure limits standards are set by WHO, ILO, International Agency for Research on Cancer (IARC) for silica are 0.05mg/m³ per 8 Hours and if exceeded this limit then will result in silicosis, silico-tuberculosis, pneumoconiosis, and lung cancer etc. In Pakistan, coal mining standards are not in accordance to the various PELs. Advance stage of fibrosis in coal miners occurs due to respirable form of silica and thus needs proper effective dust prevention measures in coal mining environment as studied by Halldin et al., (2015); and Miller et al., (2015).

1.3. Environmental Impacts of Coal Mining

1.3.1. Coal Mine Air Dust

The coal dust not only deteriorates the environmental air quality but also poses the miners to various health hazards (Mandal et al., 2011). Coal dust in coal mines is the major culprit followed by harsh environment and most difficult job which causes health problems in coal

miners. The presence of excessive amounts of particulate matter especially fine dusts dispersed in coal mines environment is associated with multiple health hazards to workers exposed. The workers have to work in highly hazardous conditions without having proper personal protective equipment to save themselves against occupational injuries and diseases. Due to poor air circulation especially at the working faces, substantial amounts of dusts are generated and remain suspended in mine workings. Therefore it is necessary to assess the health problems associated with coal dust. Dust production during surface coal mining results in toxic emission of respirable particles and thus contaminate the working environment in coal mines (Lashgari et al., 2015)

1.3.2. Permissible Exposure Limits

The permissible exposure limits standards are set by WHO, ILO, IARC for silica are 0.05mg/m³ per 8 Hours and if exceeded this limit then will result in silicosis, silico-tuberculosis, pneumoconiosis, and lung cancer; but Pakistan has no coal mining standards.

Apart from the high levels of PM₁₀ concentrations, the low levels had also severe adverse effects. A recent study of west Virginia showed that young miners can develop severe form of CWP although their exposure were legal and well within the standard PELs (Wade et al 2010).

The episodically approached level of PM₁₀ concentrations in violation of the OSHA standards; the local surrounding regions had about 2-3 km areas where high levels of PM₁₀ were investigated above the baseline standards. The coal dust particles in any sizes contains varying amounts of lead, mercury, chromium and uranium as trace elements (Sharma and Singh 1991)

The various mining process and the transportation of coal, causing some proportion of coal into dust and thus become airborne. The fraction of coal dust smaller than 500 micron and smaller than 10 microns are important as they directly enters the end respiratory parts of the lungs. These dust particles results in many health hazards but the most importantly is the CWP (Hathaway et al 1991).

The major dominant coal minerals are illite, kaolinite, and quartz. Kaolinite and quartz are the major silicates found in the coal. The presence of these silicates indicates that they are formed during early period of coal formation. Al and Si leave the organic matter and then finally crystallize as kaolinite and quartz. Kaolinite is the most prevalent mineral in most coal matrices and kaolinite and quartz persist throughout the regions of coal mines.

1.4. Health Hazards

Mining is considered as the hazardous profession despite less number of reported accidents and injuries in the twentieth century (Appalachian Center, 2009). Occupational hazards are one of the most difficult and dangerous challenge faced by mankind. In the coal mining industry there are so many exposures and the most common among these are: respiratory infections, lung fibrosis, lung cancer, pneumoconiosis, injuries, hearing loss, musculoskeletal problems, ear, nose, throat, skin and gastrointestinal problems. Heavy physical work, severity of the working conditions, work place injuries and often combined occupational dust exposure, are the major work related factors and causing high incidence and prevalence rates of mortality and morbidity among workers (David, 2009 and Fawell, 2002). Dust particles produced during mining activities acts as a triggering factor during respiration in the dusty environment and causing ill effects on the workers (Borm et al., 2015)

In Pakistan the incidence and prevalence of occupational related accidents and injuries is much high (Khanzode et al., 2012) due to carbon particles, silica and heavy metals. Moreover there is no proper reporting system, thus no data is available regarding occupational health and safety.

1.5. Pneumoconiosis

In the initial stages, the coal workers' pneumoconiosis represents in a mild form and then with continuous exposure to coal mine dust resulting in a severe stage, which causes lung parenchymal fibrosis with alterations in the lungs function tests. This black coal dust deposit in lungs during process of respiration and then finally results in anthracosis (Kumar et al., 2007), which has peculiar representation on Chest-X-Ray postero-anterio view. The coal workers' pneumoconiosis have a slow onset of development; which can easily be prevented by avoidance of coal mine dust; but in final stages all the lung parenchyma get fibrosed due to inhalation and deposition of coal mine dust (CDC, 2009). There is positive association between coal dust exposure years and pneumoconiosis prevalence (Liu et al., 2010). The important contributory factors for incidence of pneumoconiosis include exposure time of a person to dusty conditions, physical characteristics of materials, mineralogical and chemical composition of material from which dust is produced, and size and concentration of dust particles.

Miners engaged in coal mines develop myocardial infarction and there is an increased risk of mortality from Ischemic Heart Diseases, associated with cumulative exposure to coal dust (Landen et al., 2011). The coal mine workers with lost up to 54% binaural high tone hearing are more prone to coal mine accident (Viljoen et al., 2006). Apart from the respiratory health problems, the coal miners also have multiple systemic health problems like ear, nose, throat,

cardiovascular, gastric, central nervous system, urinary, skin, foot, muscular-skeleton and miscellaneous health problems due to hard and intense environment of the coal mines as well to the difficult and manual types of work in the underground coal mines.

As coal mining is one of the most hazardous professions, which poses high risks of occupational injuries and diseases to workers associated to this profession. Among many types of occupational diseases related to mining, diseases of the respiratory system including pneumoconiosis, silicosis and asbestosis have significant adverse effects on the workers health. These diseases are caused due to inhalation of fine respire-able fraction of dust (8.5 micron or less). Occupational diseases like pneumoconiosis caused by fine dust are a major cause of suffering and misery among mine workers. A large number of workers due to harsh working conditions and lack of awareness do not know about the consequences of working in high concentrations of harmful dusty environments. Majority of them also lack access to the most basic health care and continue to work for longer periods in hazardous environments without realizing the consequences.

In developing countries like Pakistan, incidence of respiratory diseases including coal workers pneumoconiosis is a significant problem and many mine workers die of such diseases every year, as there is no planned approach for prevention of these diseases at national level. No authentic data is available about the existing state of occupational respiratory diseases among coal mine workers. A large number of cases of diseases remain undetected due to absence of any systematic approach of conducting regular medical examination of workers. This research work would help in increasing awareness among all concerned about the importance of control processes. The mining industry, which lacks necessary expertise about engineering aspects of improving occupational health and safety, would be main beneficiary of this work. By reducing

the risk of injuries and illness, the productivity can be improved and significant saving in medical expenses and compensation claims can be achieved.

Keeping in view, the high level of coal dust exposure which poses threats to environment and coal mine workers as well, this environmental epidemiological study is of great importance and deals to evaluate, monitor and assess, coal miners health and their environment; to establish a strong statistical relation between coal dust in mine environment and health effects, to identify various risk factors and to suggest recommendations for its control and prevention of pneumoconiosis. Up till now, unfortunately no environmental epidemiological study of such nature has been conducted, and the prevalence of health problems is more in these coal mine workers, so this study has been proposed to help in the reduction and prevention of various occupational health problems in Cherat coal miners, District Nowshera, Khyber Pukhtunkhwa.

This research work was conducted to assess the following objectives:

- To assess air quality of the Cherat coal mines.
- To estimate the prevalence of occupational health problems among coal miners of Cherat.
- To estimate the prevalence of pneumoconiosis among coal miners of Cherat.
- To evaluate the various risk factors associated with occupational health problems among coal miners of Cherat.
- To suggest and recommend remedial measures for control and prevention of occupational health problems in coal mines.

CHAPTER # 2

LITERATURE REVIEW

In environmental epidemiological studies, the impact of environmental determinants which affect the occupational environment and had hazardous impacts on the workers thus all the occupational and para-occupational determinants in coal mining industry will be assessed as an environmental epidemiological study demands.

2.1. Coal

Blander, (2011) revealed that coal is a sedimentary combustible rock, occurs mostly in nature in brown and black colors. Coal seams and coal beds occur in rocks strata in layers or veins. Moreover, the anthracite coal is the harder metamorphic form, because of later elevated temperature and pressure exposure. Major component of coal is carbon, followed by hydrogen, sulfur, oxygen, and nitrogen elements.

Nuwer, (2012) assessed that worldwide coal is considered as one of the largest source of electricity generation; as well as the largest global manmade carbon dioxide releasing source. In 2000, carbon dioxide world gross emission was 8,666 million tons from coal usage. Coal when used for electricity generation releases carbon dioxide in large amount as compared to electric plant which emits around 1000 pounds carbon dioxide. Moreover, USA has changed their view regarding energy production sources and has shifted to electric power generation instead of coal exploration and thus use for electric purposes. So, adverse effects of coal consumption and their impacts on human and environment is greatly reduced. The dependency on coal as an important energy source was reduced and thus reduction in release of carbon dioxide have occurred; and hence since 1992, carbon dioxide release into the environment was less in the start of year 2012,

and were far less as compared to the previous seasons of any recorded carbon dioxide emission during the start of any year.

According to EIA-IEA, (2012) reports; coal is a naturally occurring combustible solid form of natural energy resource and mostly the abundant form available in each country of the world. Since 4,000 years ago, when it was introduced and used for various purposes like burning for heating and cooking; till its use for electricity generation; coal has become an important source of energy besides oil and natural gas. Moreover, USA has discovered natural deposits of coal resources approximately 1.7 trillion tons and recoverable coal reserves which seemed to be sufficient till 2230 as a major natural energy source; and the coal reserves of USA are estimated to be approximately 280 billion tons and which could be explored by different modern scientific technologies. Thus these USA estimating coal reserves were nearly 26 percent of the total world's coal reserves and today the modern science has estimated the world coal to be 510 billion tons that modern science can easily discover in near future.

British Petroleum, (2011) and EIA-IEA, (2012) reported that United States recoverable reserves of coal were twice to the reserves of Middle East oil; and approximately 100 countries of the world have recoverable reserves; among them 12 major countries are Great Britain, Germany, India, UK, China, former USSR, Brazil, Nigeria, South African countries, Poland, Colombia and Australia possessing the largest coal reserves of recoverable types.

Mathur et al., (2003), and Peckham, (2005) concluded that coal is gold and coal mining and production is important for the growth and development of a country and thus is used for so many purposes like boiling, cooking, and in industries for heating purposes. Therefore, coal is used as an alternative to oil and wood and thus prevents wastage of other resources. Moreover,

the coal production has a direct effect on economy and besides its own importance; it provides employment, resulting in the exploration of other natural resources which help in the progress of the country.

2.1.1 Coal Geo-Chemistry

2.1.1.1 Heavy Metals

Swaine, (1990) concluded in a study that coal is a heterogeneous solid fuel forming from the plant material and contains most of the elements of the periodic table combined with most of the earth crust minerals. Moreover, coal also has different amount of trace elements in their composition and is mostly associated with organic fractions like beryllium, gallium, boron, phosphorous, antimony, titanium, vanadium and germanium; while those associated with inorganic constituent include, cadmium, chromium, manganese, molybdenum, zinc, zirconium, cobalt, selenium ,arsenic, nickel and lead. Thomas, (2002) conducted a study and found that certain trace and minor elements when present in large quantity like cadmium, arsenic, chromium, lead and mercury, if present in high amounts, causing many environmental problems and issues and thus prevents the utilization of coal on a large scale. Besides them, zinc, vanadium, titanium and boron have adverse effects on the metallurgical industry. In a study of Calendar, (2004) it was concluded that heavy metals like Ni, Zn, Cr, Pb, Cu, Co and Cd having densities above 5 g/cm³ are also present in the coal in different concentrations.

Riemann and Caritat, (1998) studied that Lead has either a whitish or bluish color metal, having atomic number 82. It is soft, ductile but is a bad and poor electricity conductor. Due to corrosion resistance and low melting point lead is used for manufacturing different metals since centuries. It has density of 11.342g/cm³, atomic weight of 207.2 and is used widely as a radiation

shield. $+2$ and $+4$ are the two oxidation states of lead. The $+4$ state of lead is uncommon in the ecosystem of earth and acts as a strong oxidizing agent. Lead comprises of four isotopes which are stable and some have half life of 15 million years Lead is located in 7-A group of periodic table and has chalcophilic affinity.

The trace elements in coal samples in all regions of the world vary in their composition. The concentration of heavy metals in coal can be many times more than their standard PELs. Naturally occurring coals is sediment, organic in nature, contain remnants of composed plant and is used widely for burning purposes. The presence of various trace elements like lead, arsenic, cadmium, chromium, and mercury; often halts the coal from being used for any requisite burning activity. The presence of toxic elements like Ar, Cd, Pb, and Cr in the coal might be hazardous detrimental to bio-life as they accumulate inside the bodies via bio-magnification, bio-concentration and bio-accumulation. Most of these metals are toxic and when accidentally gain entry into the body, results in de-saturation of proteins as of enzymes (Adaikpoh et al 2005).

The formation of coal starts from the peat in the coal mires. In mires, swampy environment, the peat formation takes place and finally coal is formed from the peat via intricate process. Approximately 80-92 elements are present in the coal in the form of trace elements. Some elements are present in concentrated form while others act as a hazardous agent if the concentration is more than the standard recommended limits. Up till now about 118 different minerals are identified in coal (Schweinfurth, 2009).

The major minerals present in coal are; illite clay, pyrite, quartz, and calcite; constituents of oxygen, aluminum, silicon, iron, sulfur, and calcium etc. Minerals in coal samples exist in crystals alone or clusters of crystals mixed with organic matter. The coal quality is identified by

coal rank. The well known coal ranks are lignite (brown coal), sub-bituminous, bituminous and anthracite. Fixed carbon, moisture analysis, volatile matter and caloric values are used in the coal ranking (Schweinfurth, 2009).

Callender, (2004) studied that Zinc has 30 atomic number; and is also whitish or blue color metal, 7.133 g/cm^3 density and is located in 2-B group of the periodic table. Along with lead, zinc is a heavy metal having chalcophilic affinity. It has atomic weight 65.39, melting point 419.58°C , and boiling point 907°C and is divalent in all forms. It has five stable isotopes ($^{64}\text{Zn} = 49\%$).

In studies conducted by Leckie and Davis, (1979); Li, (2000) and Webelements, (2002) found that Copper has 29 atomic number with 63.546 atomic weight, having two stable isotopes and density 8.94 g/cm^3 , is a brassy yellow color in metallic compounds form and in green and yellow color in carbonates forms. Moreover, It has melting point 1084.87°C and is malleable element. It belongs to transition metals of group IB of the periodic table and its lithosphere concentration is approximately $39\mu\text{g/g}$ and is one of the abundant heavy metal

Nriagu, (1980) studied that Nickel has 28 atomic number, 58.71 atomic weight and 8.9 g/cm^3 density; having five stable isotopes is the most abundant element and has a whitish silvery color with 1453°C melting point. Moreover, it is a hard, good thermal conductive, of moderate strength and a poor ductile element and like steel it can be easily fabricated by various industrial procedures. It is located in 8-A group of periodic table elements, and is a transition metal.

Faust and Aly, (1981) studied that Chromium has 24 atomic number, 51.996 atomic weight, having density 7.14 g/cm^3 and is having 4 (four) isotopes which are stable and is located with transition metals and is in 6-B group of periodic table. Moreover, the color of the crystalline

chromium steel-grey and is a hard luster metal having 1863°C melting point. In the lithosphere, zinc and chromium are the abundant heavy metals. In chromite mineral form, it naturally occurs. Chromium, in its small quantities replaces many minerals.

Krishnamurthy and Wilkins, (1994) in a study reported that the highest quality of chromite is used in metallurgical industry while in melting furnaces for bricks manufacturing the low grade Chromium is used. Moreover, the Chromium alloy and metal industries are the major Chromium atmospheric emissions while the municipal incineration and coal combustion are the smaller Chromium emissions. Furthermore, the electroplating and the metal finishing industries are the major sources of aquatic environment Chromium emissions. Cr^{III} is an essential trace element while Cr^{VI} is a potent carcinogen.

In Callender, (2004) and Nriagu, (1980) studies, the Cadmium has 48 atomic number, 112.40 atomic weight, having eight stable isotopes, and having density 8.65 g/cm³. It is a soft ductile, whitish or silvery color light blue metal. Moreover, Cadmium in its mineral state and other earth metals is associated with Zinc and having 321°C melting point, belongs to IIB group of periodic table elements and has two states of oxidations in its aqueous solution form. Furthermore, cadmium having lithosphere concentration of 0.1 ppm, along with Chromium and Zinc is a strong chalcophilic. Cobalt is a silvery white metal and is resistant to corrosion and alkalis but soluble in acids. Cobalt occurs as a sulphide in rocks and ore bodies and commonly associated with sulphides of silver, Nickel, Lead, Copper and Iron. It is placed in group VIII of periodic table. It has a boiling point 2928°C and melting point 1495°C.

Siddiqui et al., (2011) studied that the concentration of Copper in Sind coal mines was 6 to 51 ppm range with 22 ppm mean value. Nickel ranges from 8 to 41 ppm with mean of 23 ppm.

Cd range concentration was from 0.1 to 0.4 ppm with mean of 0.34 ppm. Cr ranges from 8 to 22 ppm with range of 12 ppm. The mean value of zinc was 40 ppm with range of 12 to 75 ppm. The Lead range was 7 to 39 ppm with mean value of 23 ppm. Cobalt ranges from 0.05 to 0.55 ppm with mean value of 0.25 ppm. When the Cd concentration in the human body exceeds the normal value then results in Ouchouch condition. The individual HMs concentration variability in the different coal samples might be due to either natural or anthropogenic causes during the coal formation phases (Jauro et al., 2008).

2.1.1.2 Silica and Coal Dust

In a study conducted by Cowie et al; 2010, it was concluded that silicosis is mainly caused by coal dust inhalation having silica as one of the major coal dust constituent. Moreover in a study conducted by Maciejewska, (2007); it was found that crystalline silica is always related with occupational environment and in majority of cases, is the main culprit and has fatal human effects.

According to CDC report (2009), it was revealed that over exposure to respirable dusts containing crystalline form of silica is much hazardous to human respiratory system as compared to non-silica dust. Moreover, accumulative exposure of about 10 years is normally required to develop silicosis nodules of size visible on x-ray film and in case of silicosis; rounded nodules are normally visible on chest radiographs in upper zones of lungs. In a report released by OSHA, (2010), it was observed and confirmed that acute silicosis results due to over exposure to very high concentration of silica dust and it may take shorter duration 6 months to 2 years for progression of silicosis to death.

According to the findings of Begin et al; (1989), it was concluded that initially small nodules of silicosis are visible on chest radiograph of an effected workers and with further exposure to excessive amount of respirable content of silica dust, these nodules get enlarged and result in the formation of fibrotic mass that may lead to respiratory failure, pulmonary hypertension of secondary heart failure.

It has been found that once the disease is in the progressive stage, it may progress further even without further exposure to harmful silica dust. Among various physical factors, particle size has significant effect in causation of the disease. According to a study; it was concluded that different particles sizes showed varying trends in biological effects of dusts containing silica. It is now believed that silicosis predisposes to lung cancer and as such IFA has classified silica as a cancer causing agent. The damage caused to lungs is usually irreversible and permanent damage of the effected part may take place (Attfield et al; 2014).

According to the study conducted by Negash, (2002), it was stated that accumulation of dusts in lungs and reaction of lungs tissues to it causing pneumoconiosis. Moreover, it is further classified on pathological basis into non-collagenous pneumoconiosis caused by non-fibrogenic dusts and collagenous pneumoconiosis caused by fibrogenic dusts like silica and asbestos. In CCWP, the large masses were mainly in upper lung parenchymal tissue and are more than 1cm in diameter and causing impairment in lung functions, which is obvious on the PFTs. Moreover, in coal mining, it may be due to coal dust associated with silica while in silicosis its dominant due to silica dust and the nodules having more than 1cm diameter coalesce to form large nodules and are a diagnostic feature of CCWP/ PMF.

Jones et al, (2010), concluded that SEM was done to assess morphology and size of coal mine air dust and XRD to find different mineral groups in coal mine air dust samples. According to studies conducted by Roggli and Shelburne, (1988) and Jones et al, (2002); studied that shape and various mineral groups investigated in coal mine air dust samples showed the presence from somewhat spherical, rounded particles of silica/quartz minerals; by SEM technique, to complex irregular collection of several mineral particle sizes and shapes of coal mine air dust. Besides quartz was also present in coal dust. Moreover, during various coal formation stages and coal mining activities, causing coal tailing excavation, and thus results in production of these various mineral groups. Furthermore, silica/quartz showed high levels and 3.8 – 22 % of crystalline particles in coal mine air dust. The most dangerous and fatal fact was that SiO_2 was present in all types of dust generated during industrial operations and get entry into human body through respiratory tract. Ghose and Majee (1998); conducted a study to estimate dust generation levels in an Indian surface coalmines; has indicated that operations including crushing, loading, unloading points, conveyor belts are major sources.

Maseki,(2013) studied that the presence of silica in crystalline form further aggravates the problem and this point has been highlighted and thus indicates the adverse effects of crystalline silica on human respiratory system. Engelbrecht and Derbyshire, (2010) studied that the particles investigated in the study were mostly of large size and comprised of large size mineral dust particles. Thus these mineral particles mixed with the local soil dust and many studies have confirmed the presence of these coarse particles, during the dusty events of coal mining. According to the results and analysis conducted by Lin, (2001); the mineral dust was the major component of these large coarse mixed particles in coal mine air dust. Huertas et al, (2012) studied and concluded that based on the elemental composition and morphology analyzed by

SEM and EDX; the coal mine air dust particles were classified into: aluminosilicates, quartz/silica, biological particles, Fe oxide, Ca rich particles and industrial particles group of minerals; which showed irregular and smooth particles typically clay minerals and including quartz, calcite, and potassium feldspar.

In a study conducted by Bujak et al (2008) showed major composition of SiO₂, followed by organic dust minerals, which were beyond the standards for coal mine air dusts, and thus prone the workers to fibrosis of lungs parenchyma. Li et al, (2010) concluded in a study that SiO₂ particles (silica) are characterized by high content of Si and O, with silica particles has tubular structure. The origin of pure silica either may be natural or anthropogenic source. Moreover, the silica/quartz has the major constituency as compared to other minerals; thus these silica particles were related to soil dust contaminations. Furthermore, in coal mines, the blasting, digging, transportation and other mining activities results in production of silica dust particles.

In a study conducted by Lee et al (1996), the SEM and EDX analysis of coal dusts revealed that all coal dust samples consist of Al and Si-O (silicates) as major common constituents and exhibits elements that are characteristic of themselves. Rawat et al, (1982) studied that the X-Ray diffraction studies showed that aluminum; kaolinite and quartz minerals were present in coal dust. In a study conducted by Lee et al (1996), the diffraction pattern for coal dust samples had a) high kaolinite contents; b) small amount of muscovite/ potassium aluminum silicate hydroxide, c) pyrite FeS₂, d) Muscovite, and e) calcite; and all coal dusts contain a small amount of quartz (crystalline SiO₂). Song et al, (2008) conducted a study and investigated that Quartz, kaolinite, pyrite, and calcite were investigated as were studied by XRD measurements of Cprek et al (2007).

2.2. Environment of Coal Mines

Graber et al., (2014), Baker and Nieuwenhuijsen, (2008) concluded that various environmental epidemiological studies indicated that exposure to coal dust contribute to injuries, illnesses, disabilities, and deaths; and needs appropriate health care actions to avoid, prepare for, and effectively manage the health risks associated with harmful coal dust exposures. Moreover, Mandal et al., (2011) studied that coal dust not only deteriorates the environmental air quality but also poses the miners to various health hazards. Furthermore, Pachauri et al., (2013) study concluded that particulate matter mass is the major criteria for air quality assessment.

Pope et al., (2009) in a study revealed that high levels of PMs were related to adverse effects on the human health. Moreover, these high PMs levels causing reduction in life expectancy and is associated with potential negative effects on human health. Zanobetti and Schwartz, (2009) and Aneja et al., (2012) concluded in their studies that more and consistent PM₁₀ exposure is strongly related to mortality and morbidity related to cardiovascular and respiratory system.

U.S. EPA, (2010) reported that USA department (EPA) has formulated PMs PELs standards of 150 $\mu\text{g}/\text{m}^3$ for ambient air quality monitoring and assessment. Moreover, USA has drafted a new range of PM₁₀ of 65-85 $\mu\text{g}/\text{m}^3$ for 24 hours period in order to address the growing trend of occupational health problems among the miners. Hendryx et al., (2008) studied that continuous exposure to PMs is considered as one of the fatal and hazardous condition and poses great amount of risk to miners.

Aneja et al., (2012) studied that the PMs of opencast coal mines in Appalachia, USA was 197.5 $\mu\text{g}/\text{m}^3$; in another study conducted by Dubey and Pal, (2012) at Dhanbadthe was 194

$\mu\text{g}/\text{m}^3$; and in Turkish study of Tecer et al., (2008) at Zonguldak was ($1848 \mu\text{g}/\text{m}^3$). Ghose and Majee (2007) in a study conducted in India and found the concentration as $780 \mu\text{g}/\text{m}^3$, while in Onder and Yigit, (2009) study at Turkey was $1848 \mu\text{g}/\text{m}^3$. According to Huang et al., (2008) study; coal is labeled as a complex material of heterogeneous characteristics; and thus due to coal fundamental properties; is responsible for adverse health problems.

Jones et al., (2010) concluded that SEM was done to assess morphology and size of coal mine air dust and XRD to find different crystals and mineral groups in coal mine air dust samples. According to the studies conducted by Hower et al., (1999); Sokol et al., (2002); Gieré et al., (2003) and Jones et al., (2002) studied that shape and various mineral groups investigated in coal mine air dust samples showed the presence from somewhat spherical, rounded particles of silica/quartz and Fe minerals; by SEM technique, to complex irregular collection of several mineral particle sizes and shapes of coal mine air dust.

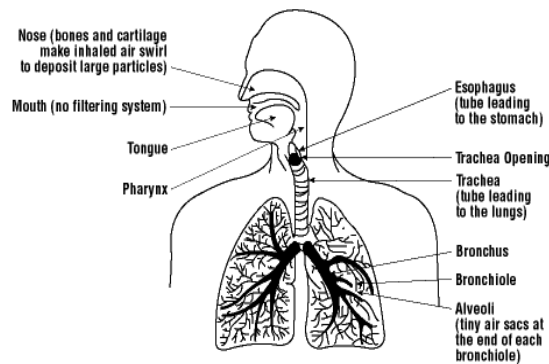
Ghose and Majee, (1998) conducted a study to estimate dust generation levels in an Indian surface coalmines; has indicated that operations including crushing, loading, unloading points, conveyor belts are major sources. Smokiest et al., (2004), Mukherjee et al., (2005) and Harrison et al., (2005) studied that the presence of silica in crystalline form further aggravates the problem and this point has been highlighted and thus indicates the adverse effects of crystalline silica on human respiratory system.

2.2.1. Particulate Matters in Mine Dust

These particulate matters have different concentration in different sites of coal mines. These particulate matters can easily enter the human body through respiratory route and causing adverse ill effects on the body. The respiratory system of the human body can be classified as

URT and LRT. The URT has parts from nose to larynx i.e. nose, nostrils, nasal passages, mouth, back of the mouth, and finally larynx. The LRT starts from larynx till the alveoli and terminal respiratory bronchioles and have larynx, trachea, bronchus, bronchi, bronchioles, air sacs and alveoli as shown in Figure 1.

Figure 1. The Human Respiratory System Pathway



2.2.2. Particulates Deposition in the Respiratory System

Klassen et al., (1991) studied that during occupational workplace, the respiratory system is the major route through which coal dusts and particulate matter enters into the human body. If there are particulate matters present in air, the workers will inhale them. There are four ways through the PM will be deposited in the lungs; interception, impaction, sedimentation, and diffusion. **Interception:** The PM gets deposited when it moves close to the surface of airway and touches and lodges to it. For all fiber types of PM, this interception is a vital phenomenon. The PM intercepted is determined by the length of fiber like diameter of the PM fiber less than $1\mu\text{m}$, and length $200\mu\text{m}$ be intercepted in bronchial part of the respiratory system of human body. **Impaction:** When PMs are suspended in air, they travel in air, along with velocity of air, which depends on the mass of the particulate matter. When the air bends, the PM instead of bending,

stick to the original path of air travel movement and thus stick to the surface of impact. This impact as discussed earlier depends on the mass of PM, and air velocity. So PM having diameter more than 10 μm are retained in the nose and throat of the respiratory system because of their impaction in the URT and therefore it is impossible to gain entry into the LRT parts of the lungs.

Sedimentation: PM as having less weight or suspended in the air. These particular matters have to overcome air resistance and gravitational force, to travel along with the air velocity. So ultimately these lighter PM having diameter less than 1 μm gain entry into lower respiratory tract i.e. bronchi and bronchioles and enters the gaseous exchange sight and alters the oxygenation of deoxygenated blood. These PM settles on the lung surface. When the diameter is less than 0.5 μm , the sedimentation is significant. **Diffusion:** When the diameter of PM is smaller than 0.5 μm then the PM exhibits motion similar to the gas molecules which are present in air. Such PM having 0.5 μm diameter get deposited on the lung wall. For PM to be deposited, the diffusion is a significant mechanism. In diffusion the PM diffuse and deposit on alveoli and small air ways.

2.2.3. Heavy Metals in Coal Mine Air Dust

Aneja et al., (2012) studied that heavy metals were present in coal mine air dust i.e. chromium, zinc, lead, copper, cobalt, nickel and cadmium. Moreover, the concentration of lead and copper showed varied ranges with varied mean values of ppm in coal mine air dust samples. Interestingly all of the investigated metals in coal mine air dust were confirmed and studied to be present in coal samples. Polyák et al., (1994) revealed in a study that toxic heavy metals like Cu, Cd, Cr, Co, Ni, and Pb, were present in coal mine air dust samples. Moreover, Cd was found in convertible forms in all coal samples. In study conducted by Zhu et al., (2010) the coal dust samples investigated by Atomic Absorption Spectroscopy (AAS) had Lead concentrations of $9.1 \pm 38.3 \text{ ng/m}^3$. Moreover, in a study conducted by Rawat et al., (1982), investigated that zinc, copper, cadmium, and nickel were also determined directly by atomic absorption spectrophotometry and this shows that coal miners were prone to various occupational health problems associated with HMs and toxic elements in coal mine air dust particles.

2.3. Health Impacts of Coal Mining

In studies conducted by Baur, (2011); Kang and Kim, (2010); Vearrier and Greenberg, (2011) and Graber et al., (2011), confirmed that coal miners were prone to respiratory health problems during coal mining and had high prevalence of pulmonary hazards like dry cough, productive cough, dyspnoea/shortness of breath, pneumoconiosis, lung cancer and chest pain as studied by Graber et al., (2011). Acute and chronic lung diseases among various occupations are common among those miners who are exposed to dust particles containing different chemicals (Ahuja et al., 2015). Vearrier and Greenberg, (2011) reported that coal miners also diagnosed as having hypertension and palpitations and thus they need to be further investigated for major

acute and chronic health problems. Fedotov, (2005) study has estimated that 30-50% of workers in industries and high-risk sectors in the developing countries and thus they may contract respiratory ailments predominantly pneumoconiosis and silicosis. In many studies, Saiyed et al., (2004), Giuffrida et al., (2001), Wang et al., (1999), Zinman et al., (2002), and Ross and Murray, (2004); have concluded and expressed that the situations of occupational respiratory diseases in the developing countries is on rise and causes many occupational health problems among coal miners.

In Kumar et al., (2009) study, it was reported that pneumoconiosis or coal worker's pneumoconiosis (CWP) is actually caused after the reaction of the lung tissue parenchyma to the foreign coal dust accumulation in the lungs. A study was conducted by Li et al., (2012) which revealed that there is high prevalence of pneumoconiosis, and in pneumoconiosis there is reduced bone mineral density and thus the coal miner's complaints of body aches and musculoskeleton problems.

Onder M. and Onder A, (2009) studied that the chest x-rays of coal miners showed; micro nodular opacities (1 - 5 mm); and Santo, (2011) and Kang and Kim, (2010) also reported bilateral or unilateral calcifications along with macro nodular opacities (>1 cm) and hyper inflated lung fields on CXRs. Moreover, according to Baur X, (2011) study; the hyper inflated lung fields can be labeled as COPD or asthma; which had 5-25% COPD prevalence. Laney and Petsonk, (2012) in a study also revealed that in SCWP, there were micro-nodular opacities as these findings were confirmed on CXR. Graber et al., (2011) and Wang et al., (2007) concluded that on the basis of CXR P/A view findings, the following diseases can be labeled; SCWP, CCWP, Silicosis, Tuberculosis, Sarcoidosis, Interstitial, Lungs Diseases, Lung Cancer, Metastatic Lung Diseases, Bronchial Asthma and COPD i.e. Chronic Bronchitis, Emphysema.

A study was conducted by Goldyn et al., (2008) in which there were findings in lungs parenchymal tissue and had diffuse lung diseases, which showed high prevalence of restrictive diseases on CXR findings and on PFTs. In another study, conducted by Dos S Antao et al., (2005) showed 35.4% of rapidly progressive CWP among coal miners.

A study was conducted by Santo, (2011) in which there were hyper-inflated lung fields and labeled as COPD, emphysema or asthma. In a study conducted by Naidoo et al., (2004) concluded that the prevalence of pneumoconiosis calculated is 2-4%; and in other study conducted by Cimrin et al., (2005) the pneumoconiosis prevalence was found as 13.5%. In Cimrin et al., (2005) study, the prevalence of CCWP was 7.5%; whereas in a study conducted by Leikin et al., (2009) estimated that 2% of coal miners developed CCWP. A study was conducted by Laney et al., (2012) which had higher prevalence of CWP in 3 states i.e. Kentucky, Virginia, and West Virginia; but advanced CWP and PMF was more prevalent among them.

Blackley et al., (2014), Wang et al., (2013), Graber et al., (2011) and Kang and Kim, (2010) in their studies concluded that the coal miners pulmonary function tests showed restrictive pattern and thus coal miners have restrictive type of respiratory diseases i.e. SCWP, CCWP, Silicosis, Tuberculosis, Sarcoidosis, Interstitial, Lungs Diseases, Lung Cancer, Metastatic Lung Diseases. Moreover, the restrictive pattern of the PFTs is also labeled by Wang et al., (2007). Studies were conducted by Santo, (2011) and Baur, (2011) which showed that coal miners also showed obstructive pattern of respiratory diseases.

Kumar et al., (2007), studied that coal workers' pneumoconiosis (CWP) or black lung disease is strongly related to coal dust, when the exposure exceeds the maximum duration. Initially the coal worker pneumoconiosis present with mild disease, have no sign and symptoms

but eventually progress to a severe form of CCWP or PMF. This more severe and serious form of CCWP/ PMF is developed after repeated or prolonged exposure to the dusty environment in which coal particles having carbon as the major constituents, along with silica. Thus it is actually the simple coal worker pneumoconiosis, which progresses to complicated coal worker pneumoconiosis.

In a study conducted by Stansbury et al., (2013) and Pattichis et al., (2002) it was concluded that complicated pneumoconiosis is an advanced stage of simple pneumoconiosis which is associated with massive fibrosis. The severity of the disease is judged with the help of chest radiographs and according to ILO classification, opacities are classified in different categories based on their size and shape. Laney et al., (2011) study, it was revealed that profusion of opacities ranges from 0 to 3.0 represents normal conditions while the most abnormal condition is denoted by 3. According to Seixas et al., (1992), CDC and NIOSH, (2011) reports, it was concluded that coal workers' pneumoconiosis (CWP) is due to coal dust exposure and is one of the work related occupational disease. Moreover, SCWP and CCWP are histologically the major types of pneumoconiosis, on the basis of small irregular massive large fibrotic lesions in the lung tissues.

Laney et al., (2011) study, the coal workers pneumoconiosis/ black lung disease, is one of the major work related occupational health disease, mostly associated with coal dust exposure. Coal worker pneumoconiosis is common among coal miners or those having long history of exposure to coal dust along with tobacco smoking. Slowly and gradually this coal dust accumulates in lung's parenchyma and causing severe inflammatory reactions and the body is unable to remove coal dust and thus causing coal worker pneumoconiosis.

Viljoen et al., (2006) reported that coal miners were exposed to different kinds of noises due to the various operations in the coal mines; and for assessment of hearing impairment, miners showed a high prevalence. In a study conducted by Vearrier and Greenberg, (2011) it was reported that due to coal dust exposure, silica, improper coal mine ventilation and exhaust systems in coal mines, the nose/throat problems were more among coal miners and thus nasal block, common cold/flu, sore throat and rhinitis/rhinnorhea. Moreover due to harsh, humid and improper lightening system in coal mines, the coal miners presented with eye problems i.e. dimness of vision, eye discharge, watering and redness.

In a study conducted by Wood et al., (1999) also reported that due to unhygienic occupational environment of coal mines; the coal miners had nail, foot problems, as well skin allergies/problems. In studies conducted by Vearrier and Greenberg, (2011) and Hendryx, (2009) due to exposure of coal miners to coal mine air dust, soil dust and coal contact; and thus heavy metals and toxic elements exposure causes bio-accumulation and bio-concentration in human body; and causing Dysuria/Burning Micturation, Pyuria/Pus and few also complaint of other renal problems like kidney stones etc.

Hendryx, (2009) conducted a study on coal miners, and finally confirmed and found health problems in respiratory, heart and kidneys. Vearrier and Greenberg, (2011) studied that as coal miners were used to heavy manual work during coal mining; like loading and uploading, therefore Musculo-Skeleton health Problems showed high prevalence. Moreover, in studies conducted by Bhattacharjee et al., (2007), Gallagher et al., (2009), Gallagher S et al., (2009) and Widanarko et al., (2012); that musculo-skeleton system problems like body-aches, knee joint pain, upper limbs/shoulder pain.

A study was conducted by Vearrier and Greenberg, (2011) in which occupational health problems in different systems of the body were assessed i.e. Cardio-vascular effects, Pulmonary effects, Neurological effects, Ophthalmological effects, Renal effects and Musculoskeletal effects. According to Appalachian Center, (2009) reported that mining is considered as the hazardous profession despite less number of reported accidents and injuries in the twentieth century and all underground coal mining activities is known to be rescue occupations worldwide. In a study conducted by CDES, (1981); it was revealed that although workers have enough level of knowledge regarding injuries and risks but they ignore the importance of occupational health and safety measures.

In studies conducted by Mathur et al., (2003) and Feller, (2010) it was found that the impacts of health problems in coal miners is not only on coal miners but it also effects the progress of the industry/company/organization and thus they also faces economic crises due to less production. In a study conducted by Viljoen et al., (2006) it was concluded that the surface mining does not cause as much hearing loss due to noise but the underground coal mine workers shows an increased prevalence rate of hearing loss which is induced by loud noise. Moreover, the coal mine workers with lost up to 54% binaural high tone hearing are more prone to coal mine accident. According to the study conducted by Awan, (2004) mining due to its harsh work environment not only possesses high risk of injuries to workers but also is associated with many health hazards in the form of occupational diseases. Moreover, the important types of occupational mining diseases notified by the Government of KPK are Pneumoconiosis including silicosis and asbestosis, Carcinoma of the lungs, Nystagmus, Dermatitis, Heat stroke, Carbon monoxide poisoning, Loss of hearing acuity and Tuberculosis.

According to studies of Cram, (2004), Naidoo et al., (2005), Harrison et al., (2005), WHO, (2000), NIOSH, (2003) and Discoll et al., (2005) among fatal occupational diseases, the respiratory/lung diseases affect health of many workers every year globally. In a study conducted by Donghue, (2004) different occupations have specific inherited hazards; the most important categories as indicated by include physical, chemical, biological and psycho-social hazards. Moreover, underground coal mining comparison to other work related hazards is labeled as to have an increased prevalence of occupational injuries/accidents and health problems. Furthermore, in a study conducted by Awan, (2004) revealed that mining due to its specific work environment presents many difficult working conditions to workers.

According to Sasa et al., (2011) study, underground coal mining is one of the dangerous professions throughout the world, causing deaths and injuries among coal miners. Besides health problems and serious injuries the coal mining results in negative effects in the coal mining community as well as huge economic loss. In a study conducted by Li and Song, (2009) it was concluded that in majority of the instances of occupational injuries and deaths, there is negligence on part of the management and administration. In a study conducted by Khanzode et al., (2010) it was revealed that there were so many models which were proposed to assess the severity of injuries. Zhang et al., (2011) study, it was concluded that accident causation theory and by application of modern safety measures; the development, structure and concept of hazards are analyzed and studied. Moreover, on the basis of classification of occupational hazards, one can effectively explore and analyzes the prevention and control models.

2.4. Pneumoconiosis

Dust particles entry into the human respiratory system results in lung fibrosis and is diagnosed through radiological imaging along with consistent symptoms among miners (Álvarez et al., 2015). Castranova et al, (2000) study revealed that mainly there are three effects of coal dust on lungs tissue. First is the Anthracosis, which is relatively a harmless carbon dust deposition on lung tissue, then SCWP and finally CCWP/ PMF; and thus progressive coal worker's pneumoconiosis occurs in 10% of coal miners and requires years of coal dust exposure along with other dust related hazards like asbestosis, talcosis and berylliosis. Moreover, coal worker pneumoconiosis is one of the fibro-silicotic pneumoconiosis diseases. Silica is considered to be highly fibrogenic as compared to the coal dust.

In a study conducted by Vanhee et al., (1995) it was concluded that coal dust when enters the human body, results in inflammation and eventually causing fibrosis and setup the progression and make up of coal worker pneumoconiosis.

2.4.1. Appearance of Coal Workers' Pneumoconiosis

In a study conducted by Kumar et al., (2009) it was stated that in simple coal worker pneumoconiosis, 1-2 mm diameter of nodular macrophage aggregations was seen in lungs surrounded by a network of collagen. These aggregations were seen around respiratory bronchioles mostly around initial coal dust accumulation site. Cowie et al., (2010) study, the SCWP may progress to CCWP, if there is continuous coal dust exposure, resulting in coalesce of small nodular lesions into massive wide spread large fibrotic nodules.

According to Halldin et al., (2014) and PCCAP, (1979) it was confirmed that the differences between coal worker pneumoconiosis and silicosis are not so clear on CXR, and one has to ask questions regarding nature and duration of job in coal mining. In a study conducted by Castranova et al., (2000) it was concluded that in SCWP there is also mediastinal and hilar lymph node enlargement in 30% patients. Cowie et al., (2010) study, it was revealed that in CCWP, there are diffused and massively light areas in middle and upper lung zones and having large rounded diffuse nodules and could be liable as CCWP, Silico-Tuberculosis and metastatic lung cancer.

2.4.2. Presenting Features of Coal Workers' Pneumoconiosis (CWP)

In a study conducted by Mo et al., (2014) and Cowie et al., (2010) it was confirmed that patient, with CWP often having shortness of breath, chest tightness, wheezing and cough. Moreover, on general physical examination there will be no findings specific for pneumoconiosis and thus those coal miners who developed COPD will have prolong expiration accompanied by wheezing, which may be heard in workers exposed to coal dust. According to a study conducted by Samet, (2007) it was concluded that the complications of CWP are respiratory failure, COPD, chronic bronchitis, Cor-Pulmonale and Tuberculosis.

2.4.3. Diagnostic Criteria of Pneumoconiosis

Driscoll et al, (2005) study concluded that occupational respiratory disease effect quite large number of workers globally, and according to an estimate, during year 2000 about 386,000 deaths occurred due to non-malignant respiratory diseases and among these COPD caused 318,000 deaths while pneumoconiosis was the cause of death in 30,000 cases.

According to the studies conducted by Rappaport, (2006) and PSR, (2009) it was concluded that CWP also termed as black lung disease, is one of the major work related occupational health disease, mostly associated with coal dust exposure. Moreover, the CWP is common among coal miners or those having long history of exposure to coal dust along with tobacco smoking. Slowly and gradually this coal dust accumulates in lung's parenchyma and causing severe inflammatory reactions and the body is unable to remove coal dust and thus causing CWP.

According to a report of CDC, (2009) it was stated that in initial stages of CWP, the miners complain of no symptoms but in advanced stages resulting in severe and debilitating signs and symptoms and thus have high prevalence of morbidity and mortality. In a study conducted by Liu et al., (2010) it was revealed that there is positive association between coal dust exposure years and pneumoconiosis prevalence; moreover, according to Landen et al., (2011) the miners engaged in coal mines develop myocardial infarction and there is high risk of death/mortality with continuous exposure to coal mine dust from acute coronary transient diseases.

Mason et al., (2010) concluded that PFTs are the useful measures which estimate the amount of air taken in and release from the lungs during the respiratory process, and how significant is the process of oxygenation from outer environment into the human body blood. Spirometry is normally performed to assess lung functions i.e. amount and speed of air inhaled and exhaled; and is done for the measurement of respiratory problems like COPD, asthma, emphysema, lung fibrosis and cystic fibrosis. Moreover, spirometry; LFTs and Spirogram are the synonyms/alternatives used for pulmonary function tests (PFTs), and the normal values of PFTs are based on sex, ethnicity, height and age of individuals. Spirometry values are abnormal when

they are less than 80% of the predicted values for that age and height. Spirometry is used for screening and early diagnosis for respiratory health conditions among workers exposed to hazardous occupational environments (Redlich et al., 2015).

In a study conducted by Reynolds, (2011) concluded that FVC test changes slightly and depends on the type of equipment used. Initially a long deep breath is taken by the patient and then exhale forcefully into the Spirometry sensor, readings are taken at 1 sec, 5 sec etc. In upper air way obstruction this expiration is followed by rapid inspiration. Mostly before taken reading in order to get familiar with instrument, several episodes of inspiration and expiration are carried out. After that forceful and hard expiration (exhalation) is asked. During Spirometry in order to prevent air escape from nose, a soft nose clip is advised and to avoid the spread of micro-organisms a mouth piece filter will be used.

CHAPTER # 3

MATERIALS AND METHODS

An environmental epidemiological study needs to be evaluated on all aspect of the impact of occupational and para-occupational determinants which strongly affect the occupational environment and coal mine workers thus geochemistry of coal, environmental quality of coal mines and hazards assessment were done to correlate findings of health hazards and their relationship and correlation with coal geochemistry and environmental quality.

Nowshera is one of the largest cities, located about 30-35 Km East of Peshawar on Grand Trunk Road (Nowshera, Gazetteer of the NWFP), at 34°0'55N, 71°58'29E as shown in Figure 2. In the West, Nowshera is bordered by District Peshawar, in the Northeast by District Swabi, in Northwest by Districts of Charsadda and Mardan, in the East by District Attock., thus the center of Khyber Pukhtunkhwa is occupied by the District Nowshera.

Study Design and Sampling Technique

A cross-Sectional study was conducted in Shakot, Jaba Tar, Jaba Khushk and Dak Ismail Khel in which 400 male coal miners who worked for more than 1year were proportionately selected from Cherat, Nowshera, Khyber Pukhtunkhwa. These 400 coal miners were proportionately selected from the study area i.e. Shahkot, Jabba Tar, Jabba Khushk and Dak Ismail Khel coal mines of Cherat Nowshera. 180 coal miners from Shahkot, 120 from Jabba Tar, 60 from Jabba Khushk and 40 from Dak Ismail Khel.

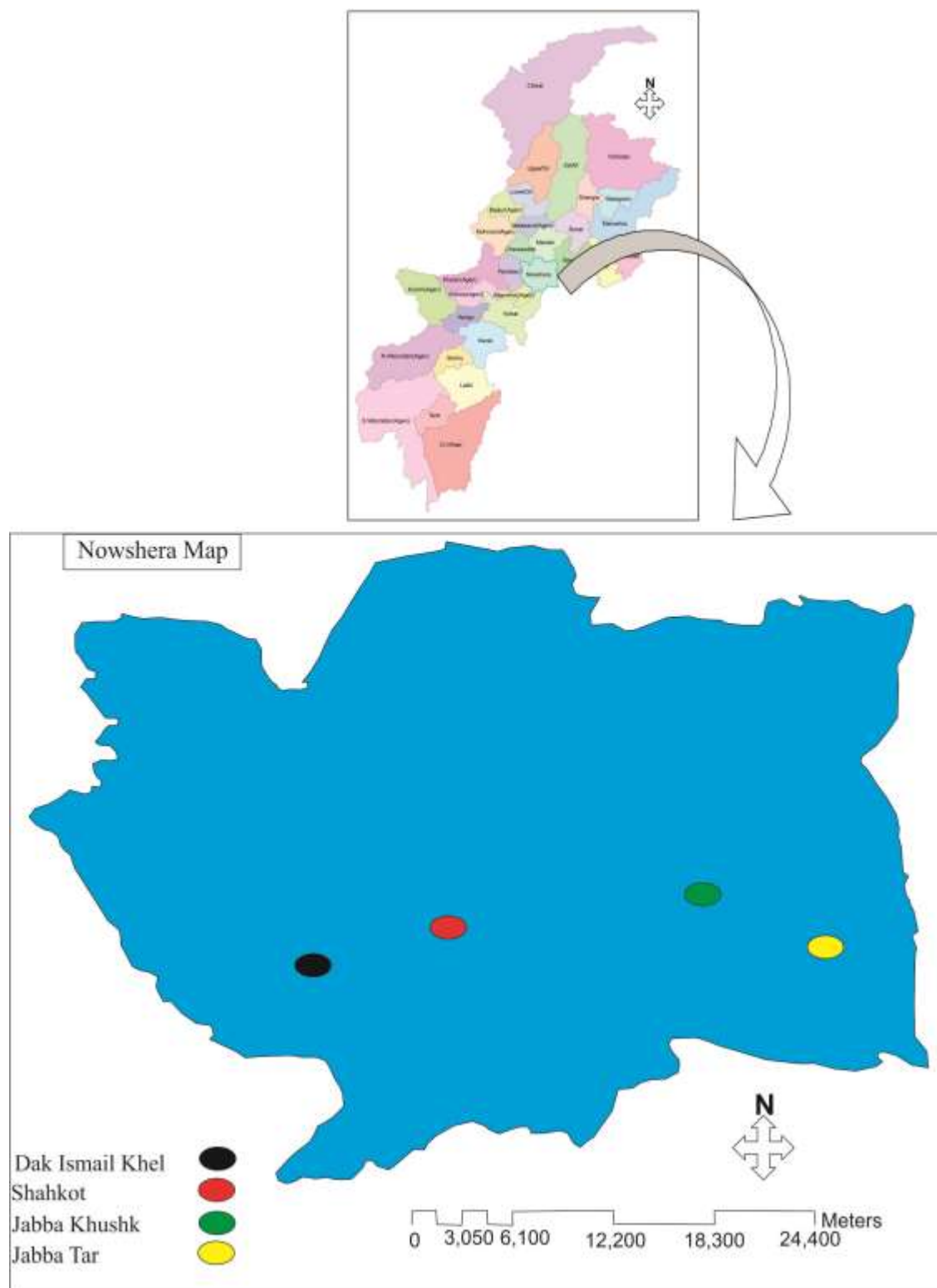


Figure 2: Map Showing Khyber Pukhtunkhwa Province, Along With District Nowshera Showing Four Study Areas of Cherat.

Data Collecting Tools

3.1. Coal Samples Collection

Coal samples of weight approximately (3-4 kg) were hammered and then collected from the coal mines in the Shakot, Jabba tar, Jabba Khushk and Dak Ismail Khel of Cherat, District Nowshera as shown in Figure 3. All the coal samples were collected in different sample bags; these samples were properly numbered in the field and brought to the Geochemistry Laboratory of the National Center of Excellence in Geology, Peshawar University for heavy metal analysis.

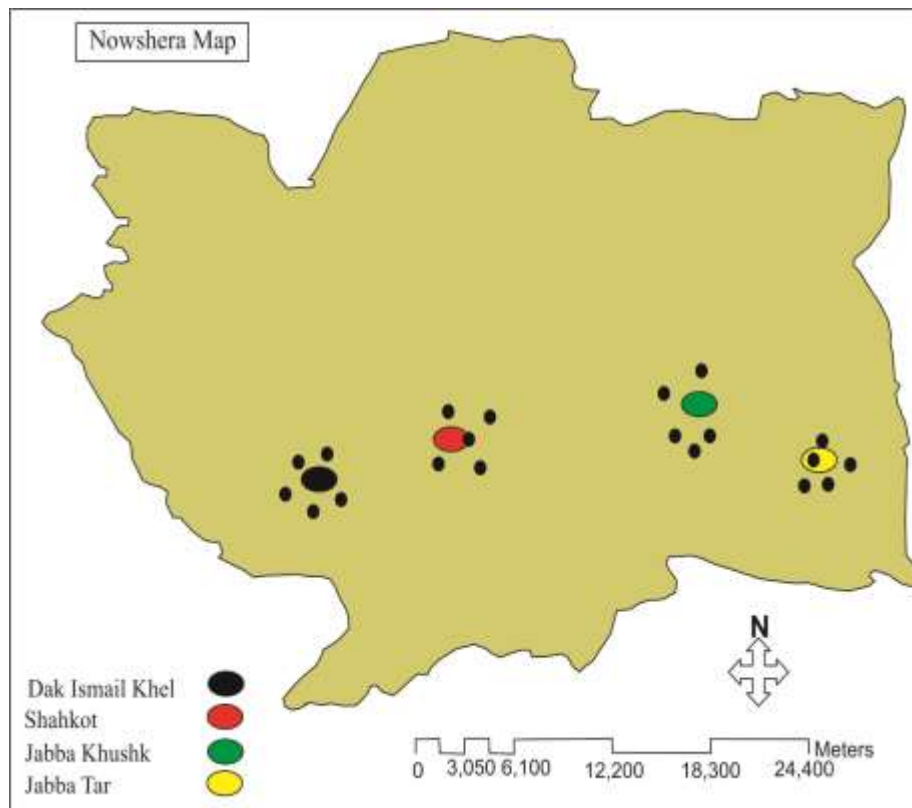


Figure 3: District Nowshera Map Showing Coal Samples (n=20) Collected from the Four Study Areas of Cherat

3.1.1. Laboratory Methods for Coal Sample

3.1.1.1. Crushing and Pulverizing of Coal Samples

Representative coal samples collected during field were air-dried and crushed by the jaw-crusher. The crushed coal samples were then pulverized in a tungsten carbide ball mill to – 75 micron (200 mesh size) with a quartz flush between the samples. A portion of individual sample was collected after proper quartering and coning. During this whole process greater care was practiced to avoid contamination. The powdered samples were stored in the airtight glass bottles. These bottles, after removing the lids, were kept in the oven at 110 °C for two hours in order to remove the moisture.

3.1.1.2. Preparation of Stock Solution-A for Coal Samples

For the decomposition of the coal samples, a method of Jeffery and Hutcheson, (1986) was adopted as follows. Correct 1.0 g of coal sample in powdered form was taken and put in Teflon beaker. Then 10 ml of hydrofluoric acid (HF) was added, and then on steam hood at low temperature till it becomes dry. Then 20 ml of 2 normal HCL was added to the residue and heated a little bit. The solution was cooled and filtered through a fine filter paper. After that de-ionized distilled water was added to make it 50 ml, after then stored in a polythene bottle and solution was taken to the lab for atomic absorption of heavy metals by atomic absorption spectrophotometer (AA Model 700).

Figure 4. Collection of Coal Samples (n=20) from Study Areas of Cherat, Nowshera



3.1.2. Determination of Heavy Elements in Coal Samples

Heavy metals were determined on Flame mode of atomic absorption spectrometer Model 700 with calibrated working standard of 2.5ppm, 5.0ppm and 10.0ppm made from stock standard solution of 1000ppm; having different parameters for determination of heavy metals as shown in Table 1.

Table 1. Standardization of Atomic Absorption Spectroscopy (Model 700) for coal samples

Heavy Metals	Lamp height nm	Lamp Energy	Lampe Current mA	Mode	Fuel Flow liter/min	Air Flow liter/min	Burner Height nm	Slit Width nm
Cu	324.8, 325.8	40	30	Absorption	1	5	10	0.2
Ni	232	30	24	Absorption	1	5	10	0.2
Mn	279.5	38	20	Absorption	1	5	10	0.2
Co	240.7	22	30	Absorption	1	5	10	0.2
Pb	217, 283.3	355	10	Absorption	1	5	10	0.7
Cd	228.8	26	4	Absorption	1	5	10	0.7
Cr	357.9	67	25	Absorption	1	5	10	0.7

3.1.3. XRD analysis of coal rock samples

Eight (08) representative rock coal samples each collected from the four study areas were analyzed quantitatively for major minerals in order to correlate our health problems data

especially pneumoconiosis and silicosis with heavy metals present in coal samples, in coal mine air dust samples and to correlate minerals of coal with the minerals of coal mine air dust.

3.2. Air Samples Collection and Preparation

Based on environmental epidemiological study to identify the occupational and para-occupational environment with in the vicinity of coal mines, about 24 air samples of PM_{10} were collected by High Volume Sampler series 302 of Sierra Anderson USA; for a duration range of 8 hours per sample using filter papers weighted before and after samples collection from Shahkot, Jabba Tar, Jabba Khushk and Dak Ismail Khel study areas of Cherat coal mines, Nowshera; as were shown in Figures 5 and 6. For collection of high volume air samples, SUPARCO help and collaboration was taken; they cooperated and helped accordingly in the completion of research thesis.

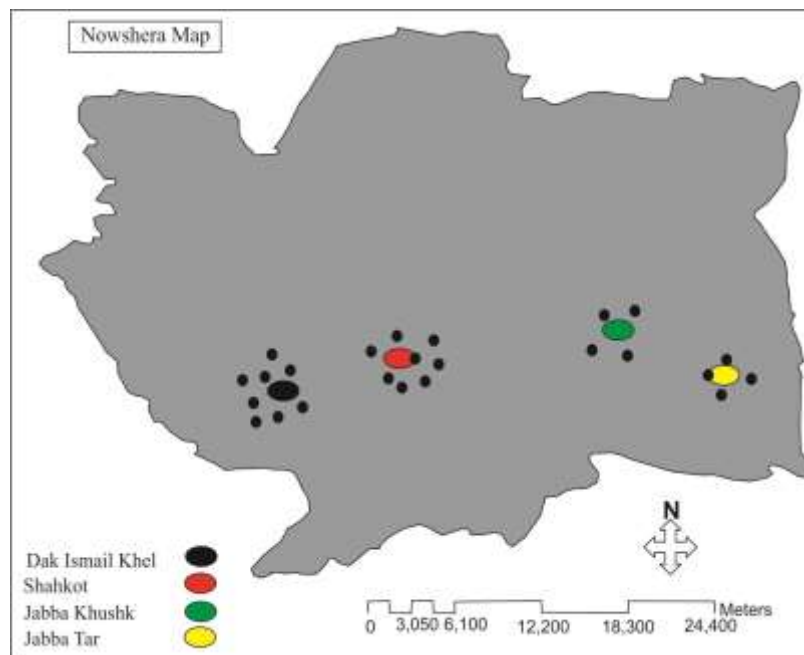


Figure 5: District Nowshera Map Showing PM_{10} Air Samples (n=24) Collection

3.2.1. Preparation of Air Samples for Scanning Electron Microscopy (SEM)

The collected wattman fiber filter papers were aseptically transferred from the study area to the Central Resource Laboratory; Peshawar University, for SEM. A conductive adhesive special tape was placed on the surface of the stub. Then approximately 1 cm diameter from piece of filter paper was cut and placed on the stub. Then with the help of a sterilized glass the sample piece was pressed and then stub was placed in gold coating machine for gold coating on the surface. Then the stub was placed in the stub holder of SEM and EDX machine. The detectable features of the surface of the sample, such as the shape, size and arrangement of the particles by which the object is composed and their relative atomic and weight percentages in areas measured in micrometers in diameter can be determined by utilizing the Scanning electron microscopes.



Figure 6. Collection of Air Samples from Research Study Areas

The configuration of the Scanning Electron Microscope installed in CRL is: JEOL, Japan, model JSM 5910, Energy 30 KV, having maximum magnification 300,000 X and with maximum resolving power of 2.3 nm.

3.2.2. Preparation of Air Samples for X-Ray Diffractometry (XRD)

The collected wattman fiber filter papers were aseptically transferred from the study area to the CRL Laboratory Peshawar University for XRD. A slide having 2 x 1 cm hole in the center (blank slide) was taken and then the same size of piece of collected filter paper was placed in the blank slide hole. Then the plasticin was applied from the lower side to fix the piece of filter paper on the blank slide, and then the slide was ready for XRD analysis. In XRD, some have wavelengths which are equal to crystalline solids spacing; and thus different intensities can be created when strikes a crystal. The scientific instrument utilized is named as XRD. The XRD instrument detects the intensities and angles of the light emitted; and thus finally the XRD system records intensity of the emitted/ diffracted beam with respect to their movements on the circle of the goniometer. Thus the crystal analysis were recorded for all the angles and their respective intensities and be presented accordingly. The XRD used in the CRL is of Model JDX-3532, and is made by JEOL Japan; using 24-55 KV voltage, current 2.5-80 mA, X-rays K-alpha radiations were used at 2θ at -3 to 160° of temperature.

3.2.3. Collection and Preparation of air samples for AAS

The wattman fiber filter papers were collected during field visits data collection from the study areas of Cherat, Nowshera; and transferred them to Biological Laboratory; Department of Environmental Sciences, Peshawar University. Aqua Regia was prepared and then the filter papers were rolled and placed in a Teflon beaker and 20ml of Aqua Regia was added to each of

the Teflon beaker. Then Teflon beaker was placed in fume hood for heating to dissolve the filter paper. After that 80 ml of 2 Normal HCl solutions was prepared and 20 ml each was added to the Teflon beaker containing the dissolved filter paper. After a little bit heating, the solution was filtered after cooling and then de-ionized water was added to the filtrate up to mark 50 ml in the flask. Then the solution was ready for analysis and transferred to CRL laboratory Peshawar University.

Atomic absorption spectrometry (AAS) is performed for the elemental concentrations, when the samples are in liquid form and also used for any substance if the sample is digested into liquid solution by standard methods of solutions preparations. In this method the calculated mass of sample is dissolved in standard solutions and then finally the solid material elemental features can be investigated. Atomic absorption is the most reliable laboratory technique utilize for the investigation of elemental concentrations in ppm or ppb of a sample in gram. The instrument used was A.A. Analyst 700, Perkin Elmer, USA; having lamps for 26 elements but only the desired elements which were assessed in the coal samples were assessed that are cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and zinc and (Zn) lamps with Flame furnace technique.

3.3. Health hazards

3.3.1. Medical Examinations of Coal Miners

Medical examination was conducted in Cherat different coal mines for interviewing coal miners. The screening examinations of all 400 coal miners were conducted for various health problems like respiratory system, Central Nervous System, Cardio Vascular System, Gastro Intestinal Tract, urinary system, ear nose throat, eye, skin and foot (Wood et al., 1999) musculo-skeleton system (Widanarko et al., 2012) and miscellaneous health problems (Mandal et al.,

2011; Vearrier and Greenberg, 2011) as shown in Figures 7, 8 and 9. Laboratory investigations and preliminary data were collected regarding their job and environment in which they are working. Chest X-Ray (P/A view) was advised to correlate and screen the miners for various health problems (Naidoo et al., 2004).

After pilot study, a detailed Pre-Tested structured questionnaire was formulated to collect the demographic data for important variables like age, (Kuempel et al., 2009) marital status (Yu et al., 2008) duration of coal mining job, coal mine air dust years of duration, job satisfaction (Kang and Kim, 2010) coal mine working conditions, health protection measures, anthropometric assessment, smoking history (Kunar et al., 2008) number of cigarettes per day, any other addiction, previous coal mine injury/accident (Torma-Krajewski et al., 2009) and previous medical and surgical illnesses (Hendryx, 2009; CDC., 2009).

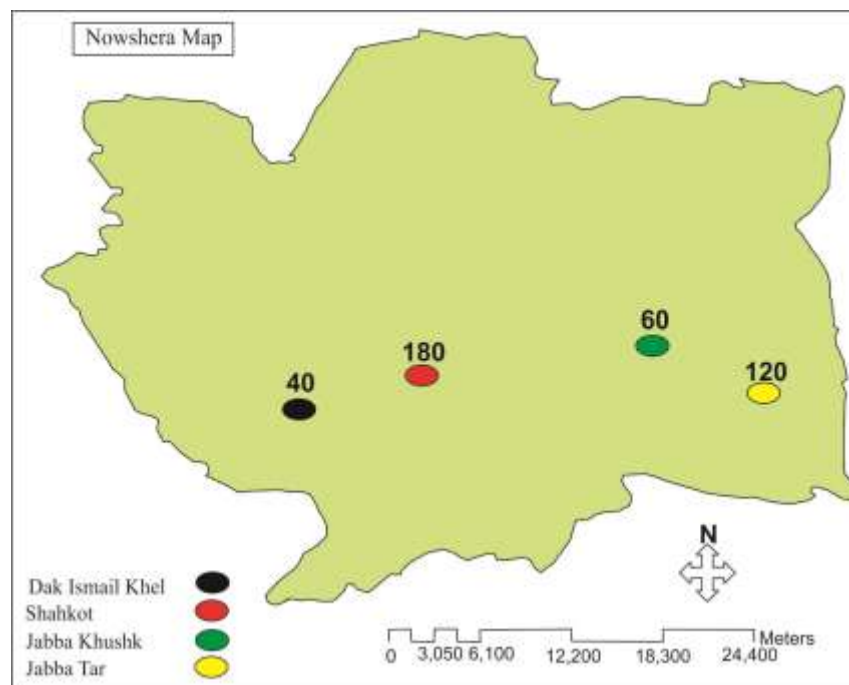


Figure 7: District Nowshera Map Showing Coal Miners (n=400) Selected from the Four Study Areas of Cherat



Figure 8. Coal Miners Of Cherat Nowshera KPK Pakistan



Figure 9. Medical Examination of Cherat Coal Miners, Nowshera, KPK

3.3.2. Chest X-Ray (P/A View)

Chest X-Ray P/A was conducted to correlate and screen the coal miners for various health problems. For the assessment of respiratory health problems and pneumoconiosis among 400 coal miners, coal miners were first examined medically and then referred for Chest X-rays (P/A View) to the nearby CXR-lab facility i.e. Pabbi Station Nowshera. These 400 coal miners were proportionately selected from the study area i.e. Shahkot, Jabba Tar, Jabba Khushk and Dak Ismail Khel coal mines of Cherat Nowshera. 180 coal miners from Shahkot, 120 from Jabba Tar, 60 from Jabba Khushk and 40 from Dak Ismail Khel Before referral of coal miners for Chest X-rays (P/A View), a detailed structured proforma was filled for each coal miner's data i.e. Name, Age, Sex, height, weight, Duration of job, Smoking history, Past/Present Medical/Surgical illness, Respiratory Health problems/Pneumoconiosis (Shortness of Breath, Cough, Productive Cough, Chest Pain), Forced Expiratory Volume at 1 Second (FEV1), Forced Vital Capacity (FVC) and Peak Expiratory Flow Rate (PEFR).

The chest X-rays (P/A View) facilities were freely provided in order to get high compliance from the coal miners. Through these CXR the coal miners were screened for respiratory health problems and pneumoconiosis. After that the chest x-rays were collected from the lab facility and then observed / evaluated for presence of any findings of respiratory health problems and pneumoconiosis. After the chest X-rays (P/A View) the chest X-rays were labeled as having; micro-nodular opacities, macro-nodular opacities, calcifications, hyper-inflated lungs field and normal CXR findings. Those coal miners who presented with signs and symptoms of Respiratory Health problems/Pneumoconiosis i.e. Shortness of Breath, Cough, Productive Cough and Chest Pain; were provided free face masks. Free face masks were also distributed among coal miners during visiting coal mines and collection of research data.

3.3.3. Pulmonary Function Tests (PFTs)

For the assessment of respiratory health problems and pneumoconiosis among 400 coal miners, PFTs were conducted. Before PFTs, a detailed structured proforma was filled for each coal miner's data along with history of any respiratory and other health problem/s i.e. Name, Age, Sex, height, weight, Duration of job, Smoking history, Respiratory Health problems/Pneumoconiosis (Shortness of Breath, Cough, Productive Cough, Chest Pain), FEV1, FVC and PEFR. After Spirometry FEV1, FVC and PEFR of each coal miner's were calculated, which is the observed value of that coal miner; and then compared with the predicted values of FEV1, FVC and PEFR of coal miners as shown in Table 2 After that the coal miners were labeled as having restrictive pattern, obstructive pattern or normal PFTs pattern.

Table 2. Normal peak expiratory flow rate (PEFR) values on EU scale

Height (cm)	PEFR (L/min)*
120	215
125	240
130	260
135	275
140	300
145	325
150	350
155	375
160	400
165	425
170	450
175	475
180	500

* Mean; 2 SD = ± 100

3.4. Statistical Data Analysis

The Statistical Package for the Social Sciences (SPSS version-16) was used for statistical data analysis. Standard deviations and mean were analyzed for continuous variables, whereas percentages were analyzed for categorical variable data. Arc-geographic information system (Arc-GIS) was used for making map of the study area.

CHAPTER # 4

RESULTS

An environmental epidemiological study needs to be evaluated on all aspect of the impact of occupational and para-occupational determinants which strongly affect the coal mines environment and coal mine workers thus coal geochemistry, environmental quality of coal mines and hazards assessment were done to correlate findings of health hazards with coal geochemistry and environmental quality.

In this environmental epidemiological study, the geochemistry of coal, environmental quality of coal mines and hazards assessment were done and results were presented in forms of tables and figures and thus this research work identified adverse environmental and occupational health impacts due to hazardous impacts of poor environmental quality among coal miners.

4.1. Coal Raw Samples Analysis

4.1.1. Quantitative Coal Raw Samples Analysis For Selected Heavy Metals

The concentration of some selected heavy elements in the coal samples of Shakot, Dak Ismael Khel, Jabba Tar and Jabba Khushk, Cherat district Nowshera KPK Pakistan is shown in Table 3 and Figure 10.

4.1.2. Ultimate analysis of coal samples

The mean and range of percentage moisture, volatile matter, and fixed carbon % contents of the coal samples were investigated in four samples each from the study areas as were shown in Table 4.

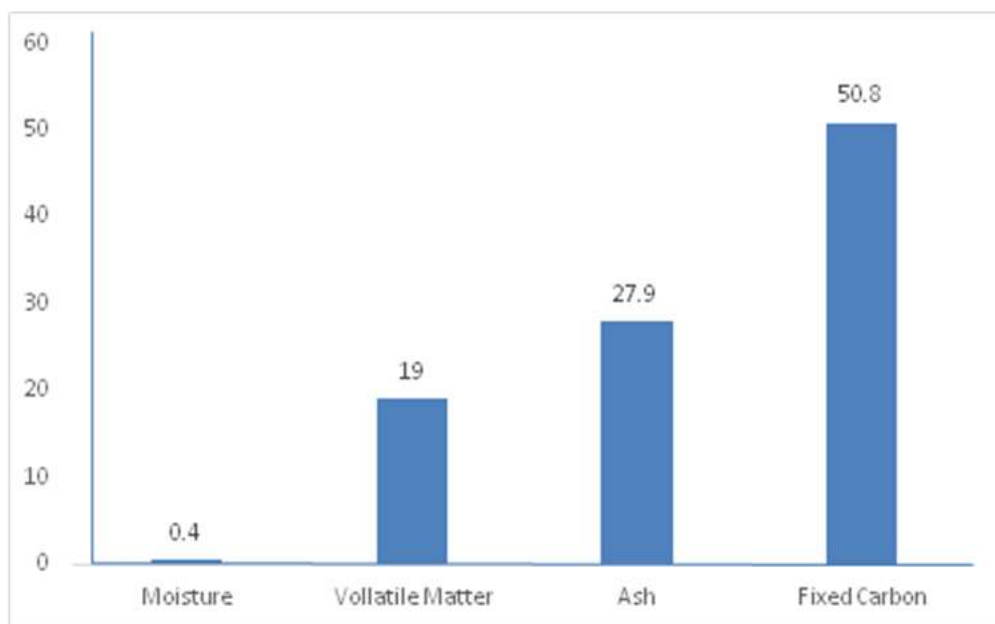


Figure 10. Graph Showing Mean Ultimate Analysis of Coal Samples of Study Area Cherat, Nowshera, KPK Pakistan

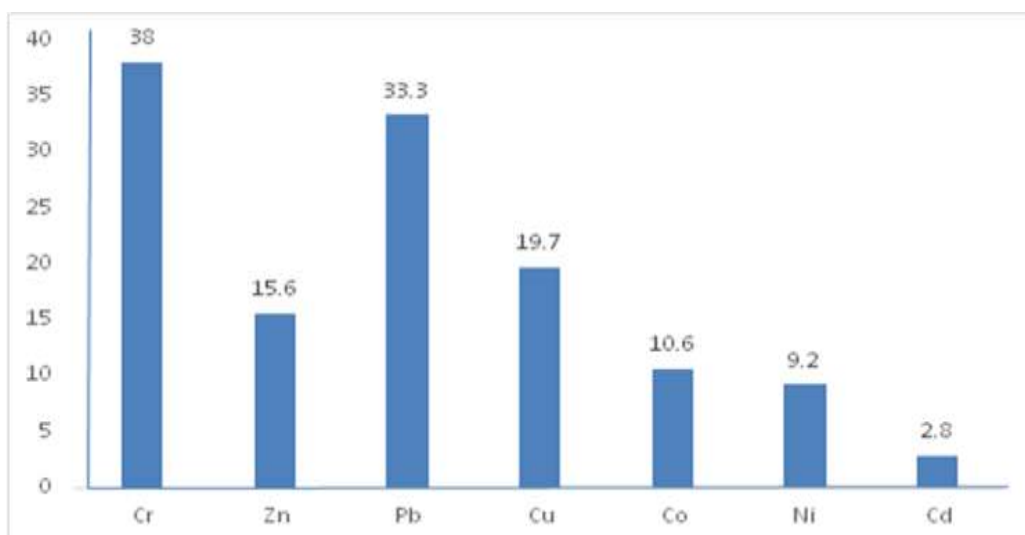


Figure 11: Graph Showing Mean Heavy Metal Concentrations (ppm) in Coal Samples of Study Area Cherat, Nowshera, KPK Pakistan

Table 3. Heavy metal concentrations (ppm) in coal samples collected from study area

Heavy Metals	Federal-EPA Limits (ppm)	USGS/ ASTM PELs (ppm)	Statistics	Shahkot	Dak Ismael Khel	Jabba Tar	Jabba Khushk
Cr	<1	22	Range	2.7 - 4.6	40.3 - 63.1	60 - 74.1	23.5 - 64.6
			Mean	3.55	52.37	67.8	28.42
			Standard Dev	0.83	9.59	6.21	5.45
Zn	ND	11	Range	6.3 - 9.4	12.1 - 22.2	10.8 - 14.7	22.3 - 26.1
			Mean	8.05	17.92	12.57	23.7
			Standard Dev	1.39	4.92	1.73	1.67
Pb	<1	4.8	Range	17.2 - 20.7	33.5 - 37.1	34 - 41.5	34.8 - 42.1
			Mean	19.22	35.25	39.02	39.5
			Standard Dev	1.64	1.55	3.40	3.22
Cu	<1	12	Range	5.4 - 8.7	31.7 – 40	22.1 - 23.7	9.8 - 12.9
			Mean	7.45	36.55	23	11.67
			Standard Dev	1.52	3.73	0.67	1.36
Co	ND	3.9	Range	1.5 - 5.2	11.2 - 17.5	14.7 - 20.3	4.6 - 8.8
			Mean	3.82	14.02	17.8	6.67
			Standard Dev	1.64	2.75	2.40	1.75
Ni	ND	9.4	Range	0.7 - 3.2	11.5 - 18.1	9.7 - 18.4	4.2 - 7.9
			Mean	1.47	15.4	13.97	5.8
			Standard Dev	1.16	3.01	3.84	1.76
Cd	<1	0.058	Range	1.1 - 2.2	2.1 - 4.1	2.8 - 5.1	1.6 - 3.6
			Mean	1.7	3.07	3.85	2.37
			Standard Dev	0.54	0.93	0.99	0.87

Table 4. Ultimate Analysis of Coal Samples Collected from the Cherat Study Area

Ultimate Analysis	Statistics	Shahkot	Dak Khel	Ismael	Jabba Tar	Jabba Khushk
Moisture (wt %)	Range	0.2 - 0.4	0.4 - 0.6		0.3 - 0.8	0.3 - 0.7
	Mean	0.27	0.5		0.52	0.47
	Standard Dev	0.096	0.082		0.222	0.171
Volatile matter (db %)	Range	16.4 - 20.4	17.6 - 22.4		16.7 - 19.8	16.4 - 20.6
	Mean	18.8	20.1		18.57	18.45
	Standard Dev	1.728	1.963		1.382	1.936
Ash (db %)	Range	23.8 - 28.4	25.2 - 28.4		29.6 - 31.8	25.4 - 29.5
	Mean	26.55	26.95		30.5	27.4
	Standard Dev	2.009	1.340		0.931	1.846
Fixed Carbon (%)	Range	48.8 - 53.2	47.1 - 52.2		45.6 - 51.2	50.8 - 57.9
	Mean	50.3	49.9		49	53.95
	Standard Dev	2.030	2.412		2.394	3.058

4.1.3. Qualitative XRD analysis of coal samples

Four rock coal samples each collected from the four study areas were investigated by XRD to assess the major mineralogical aspect of coal as were shown in Figures 12, 13, 14 and 15.

4.2. Coal Miner's Environment

4.2.1. Coal Mines Air Dust Samples

Twenty four (24) PM₁₀ air samples were collected from the coal mines of cherat, on the wattman fiber filter paper; i.e. Shakot, Dak Ismael Khel, Jabba Tar and Jabba Khushk as shown in Tables 5 and 6; Figure 16.

4.2.2. Scanning Electron Microscopy of Air Samples

The results of Scanning Electron Microscopy of Air Samples Collected through PM₁₀ were shown in Figures 17 to 22.

4.2.3. Concentrations of Coal Mine Air Dust

The concentration of coal mines air dust in micro-gram per cubic millimeter in all 24 samples collected from the study areas with the help of Wattman fiber filter papers collected through PM₁₀, as were shown in Table 5.

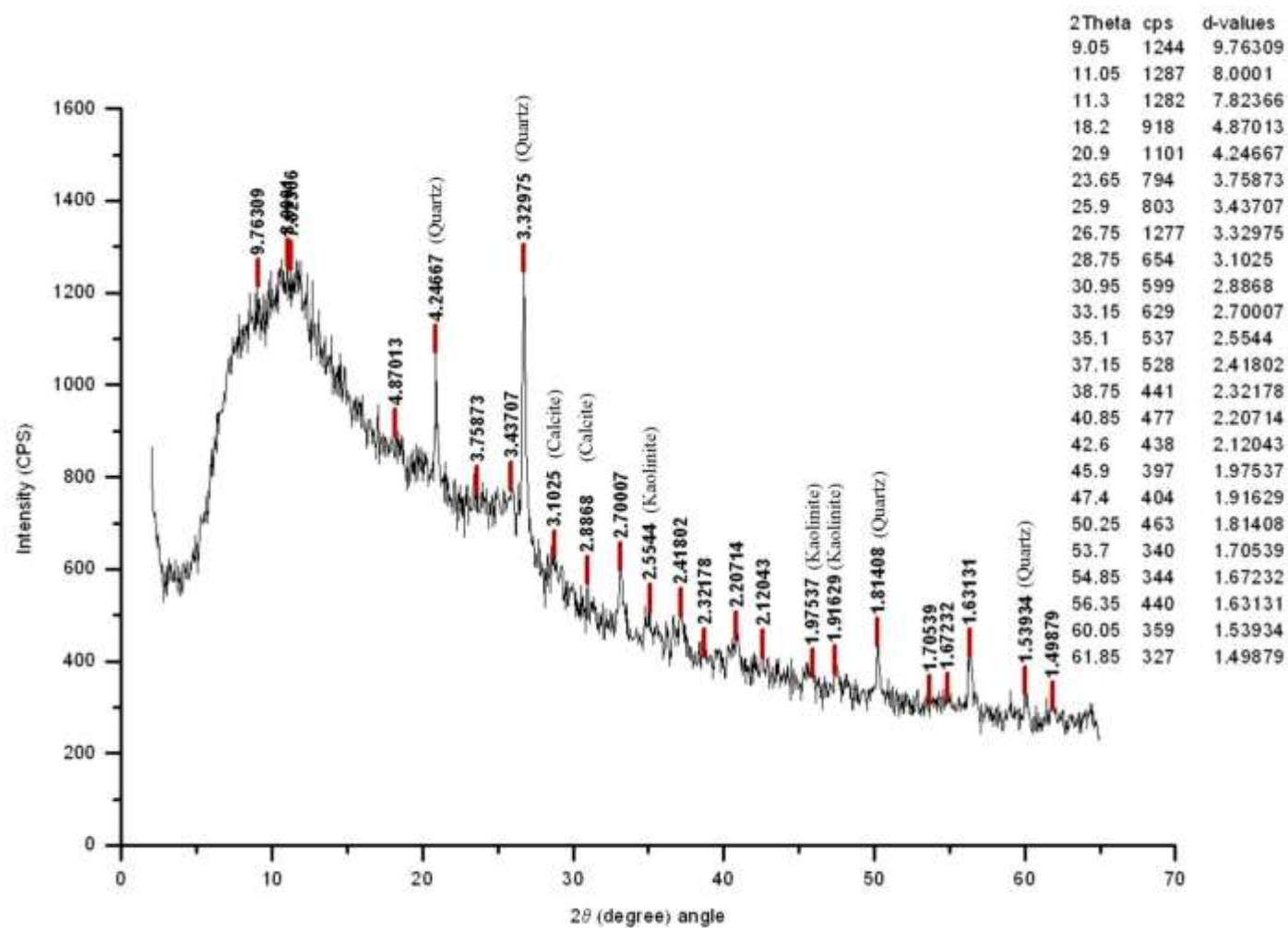


Figure 12. XRD of Coal Sample of the Study Area Shakot (SKT-005) Cherat, Nowshera

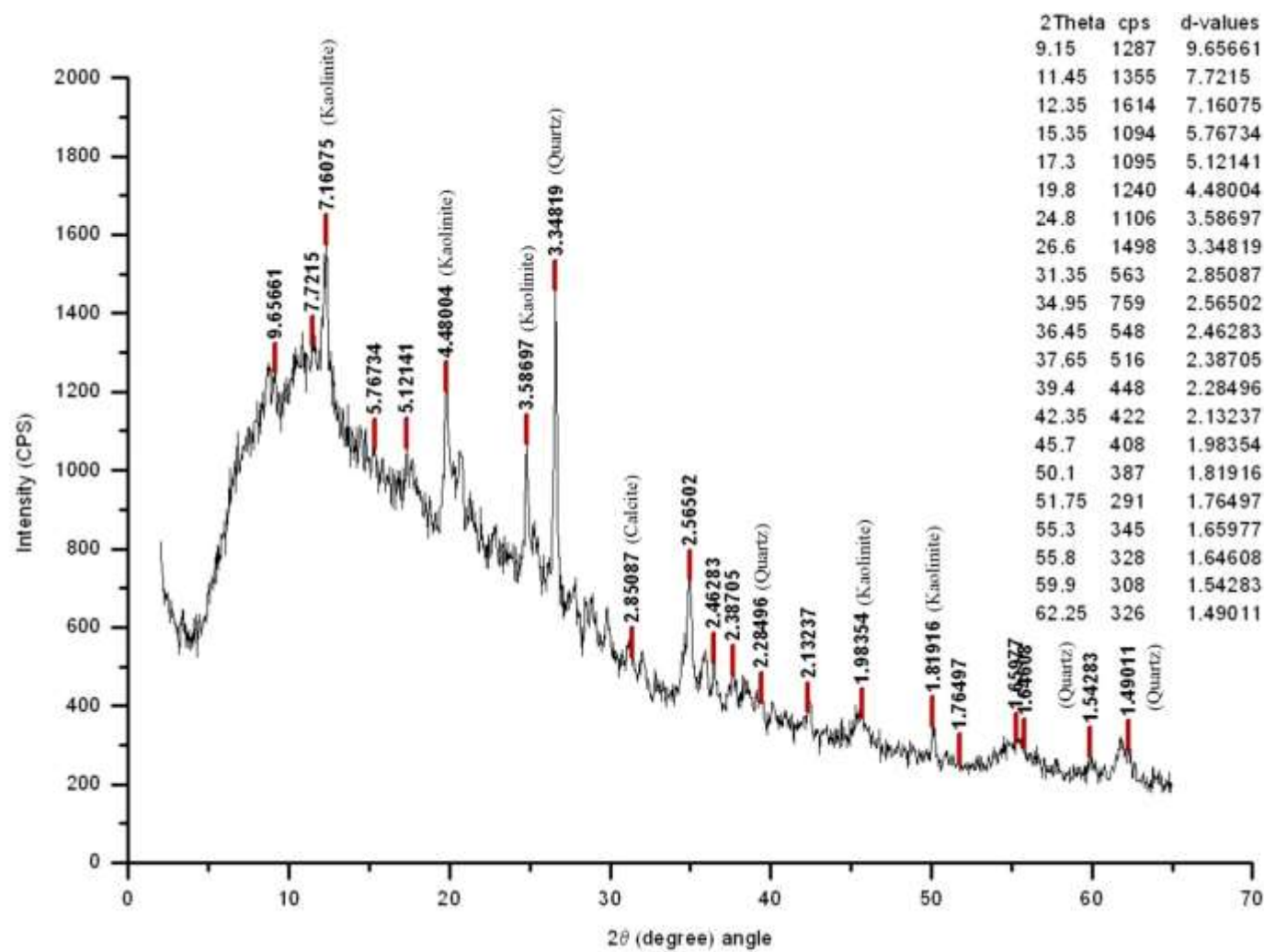


Figure 13. XRD of Coal Sample of the Study Area Dak Ismael Khel (DIK-010) Cherat, Nowshera

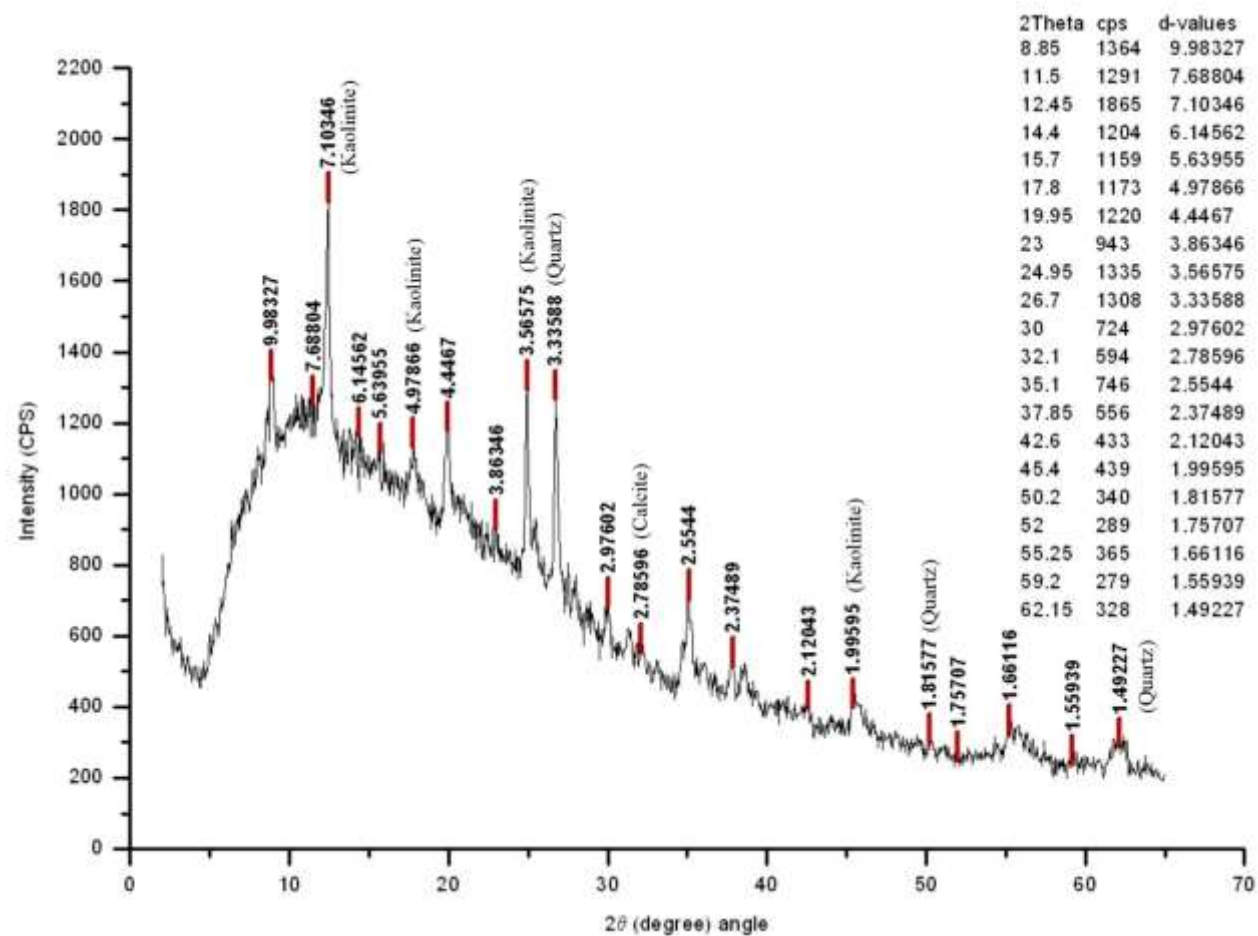


Figure 14. XRD of Coal Sample of the Study Area Jabba Tar (JT-014) Cherat, Nowshera

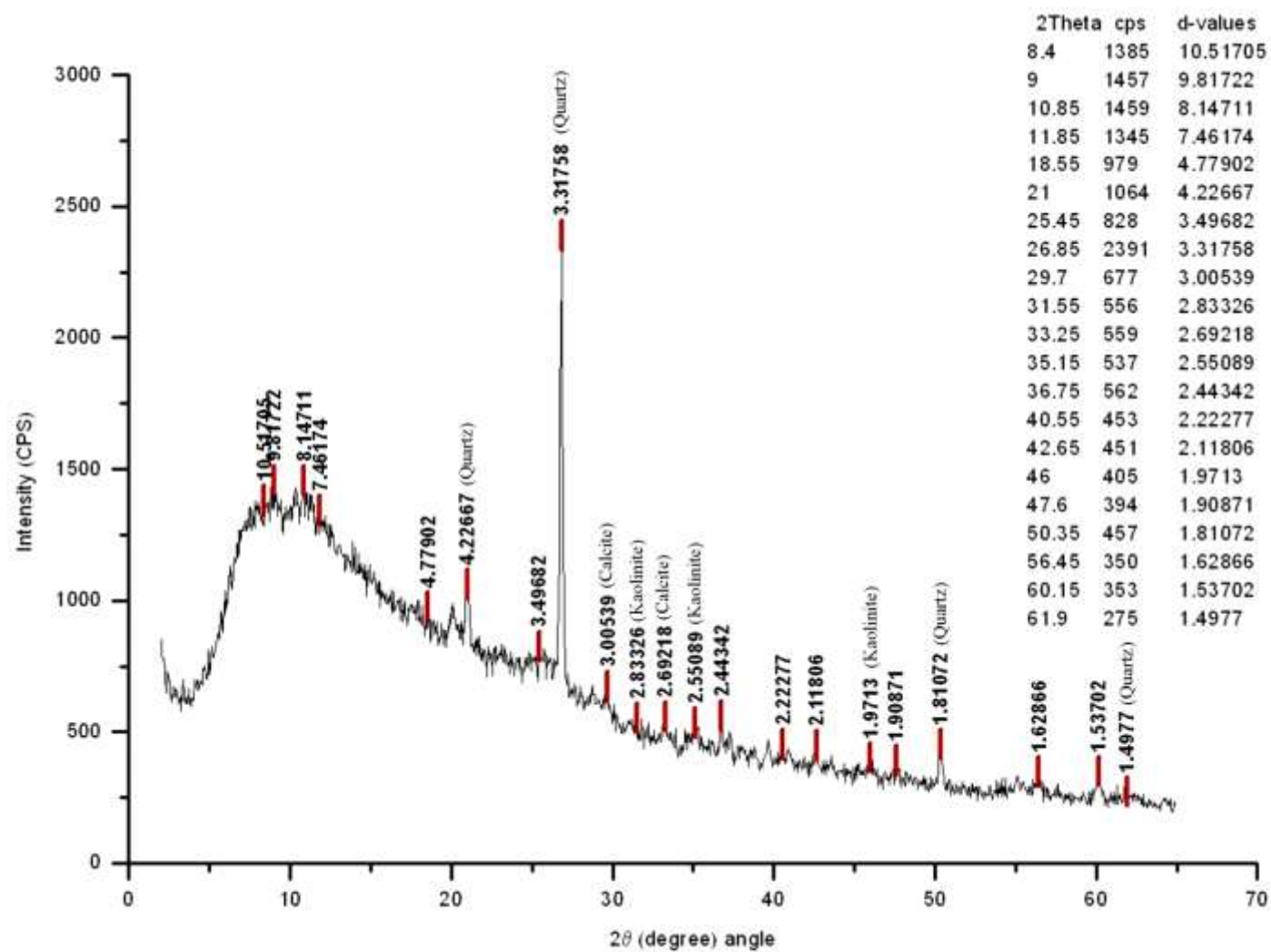


Figure 15. XRD of Coal Sample of the Study Area Jabba Khushk (JK-016) Cherat, Nowshera

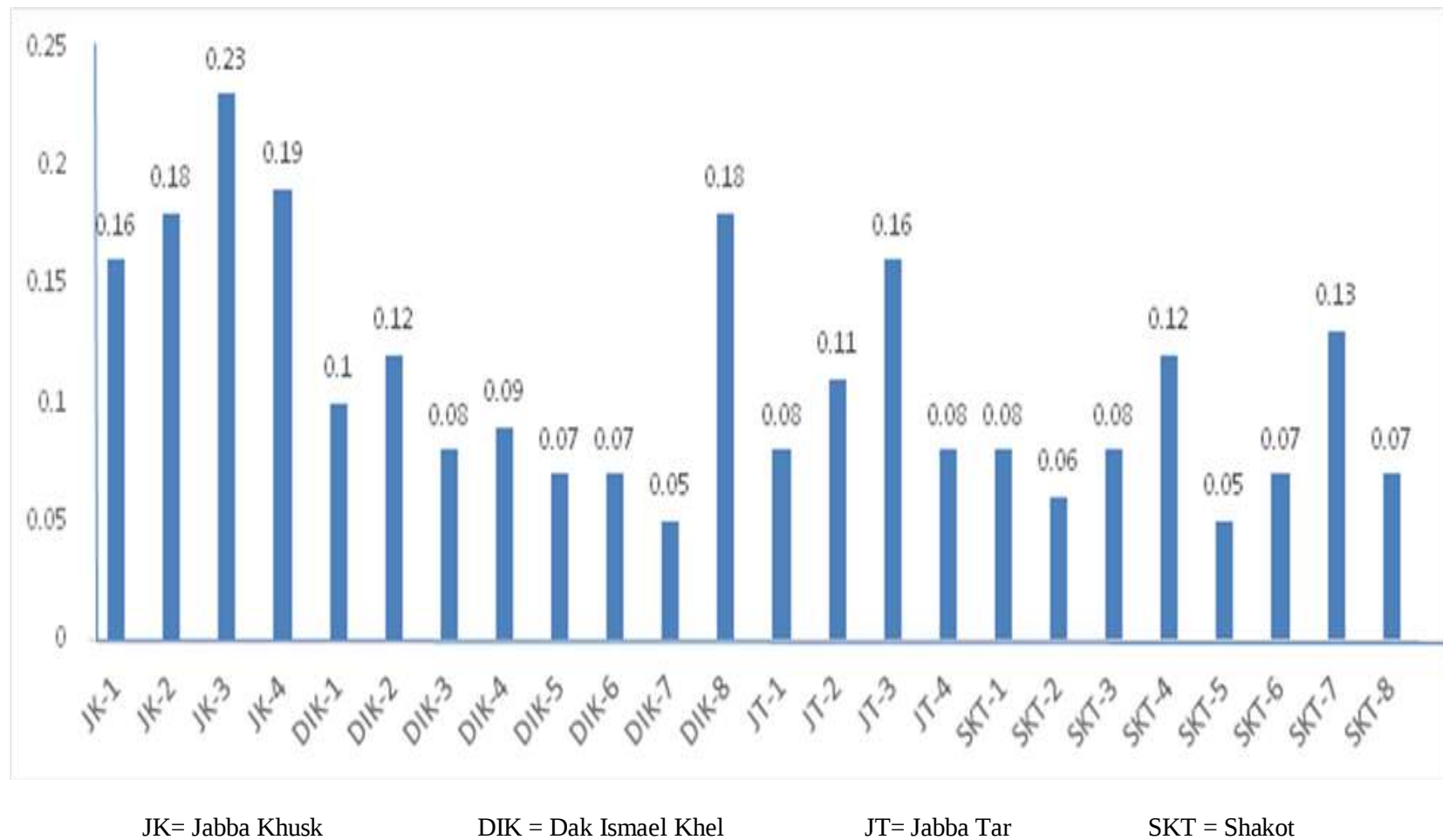


Figure 16. Showing the Difference in Weight (gm) of Coal Mine Air Dust Samples

Table 5. Concentration in $\mu\text{g}/\text{m}^3$ (n=24) of coal mine dust collected by PM_{10}

Sample No	Area	GPS Location	Time in Mins	Before wt (gm)	After wt (gm)	Concentration ($\mu\text{g}/\text{m}^3$) = m/v
1	JK-1	NA	480	2.86	3.02	837.59
2	JK-2	NA	480	2.86	3.04	706.71
3	JK-3	NA	480	2.85	3.08	677.27
4	JK-4	NA	480	2.86	3.05	745.98
5	DIK-1	N 33 50 46.7 E 071 49 23.3	480	2.87	2.97	294.46
6	DIK-2	N 33 50 47.9 E 071 49 24.9	480	2.86	2.98	471.14
7	DIK-3	N 33 50 48.3 E 071 49 26.1	480	2.85	2.93	471.14
8	DIK-4	N 33 50 45.9 E 071 49 26.3	480	2.88	2.97	265.02
9	DIK-5	N 33 50 45.7 E 071 49 25.9	480	2.86	2.93	253.69
10	DIK-6	NA	480	2.84	2.91	235.57
11	DIK-7	NA	480	2.85	2.9	294.46
12	DIK-8	NA	480	2.85	3.03	706.71
13	JT-1	NA	480	2.87	2.95	471.14
14	JT-2	NA	480	2.87	2.98	647.82
15	JT-3	NA	480	2.85	3.01	628.19
16	JT-4	NA	480	2.86	2.94	471.14
17	SKT-1	N 33 51 41.7 E 071 53 24.3	480	2.87	2.95	358.97
18	SKT-2	N 33 52 02.7 E 071 53 34.9	480	2.82	2.88	282.69
19	SKT-3	N 33 51 43.1 E 071 53 23.4	480	2.86	2.94	314.10
20	SKT-4	N 33 51 44.4 E 071 53 22.1	480	2.87	2.99	565.37
21	SKT-5	N 33 52 01.8 E 071 53 33.7	480	2.86	2.91	235.57
22	SKT-6	NA	480	2.86	2.93	329.80
23	SKT-7	NA	480	2.85	2.98	556.80
24	SKT-8	NA	480	2.86	2.93	366.44

t^a = Time Elapsed in Minutes,

m^c = Mass in microgram,

JK= Jabba Khusk

JT= Jabba Tar

F^b = Flow rate in m^3 / minute (25SCFM) = $25 \times 0.0283 \text{ m}^3$

v^d = Time elapsed in minutes x Flow rate in m^3 / minute

DIK = Dak Ismael Khel

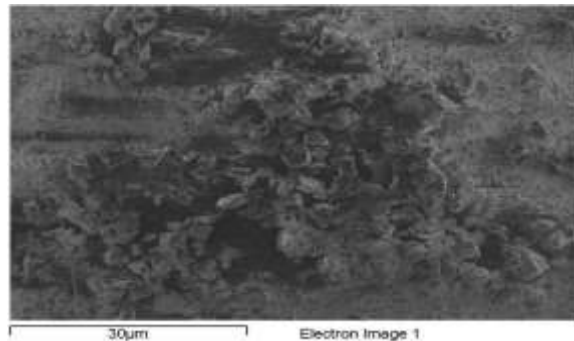
SKT = Shakot

Table 6. The concentration ($\mu\text{g}/\text{m}^3$) and range of particulate matter from different regions of the world near coal mine

Location/Site/Reference	Country	mean	Range ($\mu\text{g}/\text{m}^3$)
		PM ₁₀ ($\mu\text{g}/\text{m}^3$)	
Appalachia (Aneja, 2012)	USA	197.5	144.8 - 250.2
Turkey (Onder and Yigit, 2009)	Turkey	1848	1300 – 3080
Zonguldak (Tecer et al., 2008)	Turkey	51.06	39.66 - 63.59
Dhanbad (Dubey and Pal, 2012)	India	194	N/A
Cherat, Nowshera (Present study)	Pakistan (Present study)	441.1	235.57 - 837.56

PM₁₀ = Particulate Matter

NIOSH = National Institute for Occupational Safety and Health



Spectrum processing :

No peaks omitted

Processing option : All elements analyzed (Normalised)

Number of iterations = 5

Standard :

C CaCO₃ 1-Jun-1999 12:00 AM

O SiO₂ 1-Jun-1999 12:00 AM

F MgF₂ 1-Jun-1999 12:00 AM

Na Albite 1-Jun-1999 12:00 AM

Mg MgO 1-Jun-1999 12:00 AM

Al Al₂O₃ 1-Jun-1999 12:00 AM

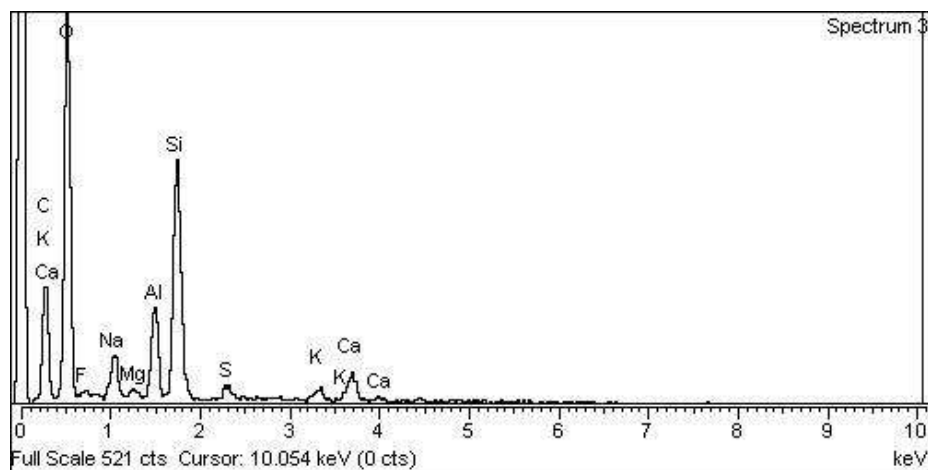
Si SiO₂ 1-Jun-1999 12:00 AM

S FeS₂ 1-Jun-1999 12:00 AM

K MAD-10 Feldspar 1-Jun-1999 12:00 AM

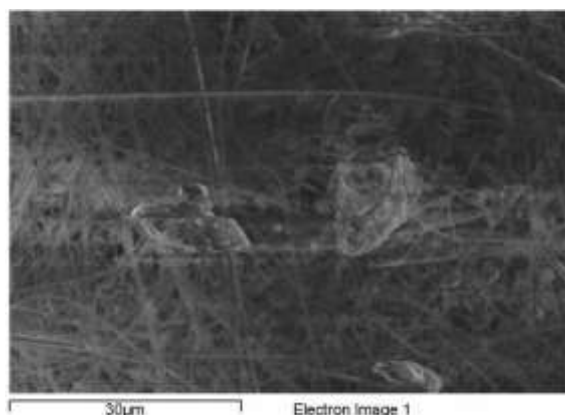
Ca Wollastonite 1-Jun-1999 12:00 AM

Element	Weight%	Atomic%
C	30.40	40.02
O	49.19	48.61
F	0.34	0.28
Na	2.24	1.54
Mg	0.22	0.14
Al	3.56	2.09
Si	10.01	5.64
S	0.78	0.38
K	0.95	0.38
Ca	2.31	0.91
Totals	100.00	



PM₁₀ Mass Concentration ~ 706.71 µgm/m³ (SEM, Wattman fiber filter paper)

Figure 17. Scanning Electron Microscopy of Jabba Khushk (JK-002)



Spectrum processing :

Peak possibly omitted : 2.290 keV

Processing option : All elements analyzed (Normalised)

Number of iterations = 5

Standard :

C CaCO₃ 1-Jun-1999 12:00 AM

O SiO₂ 1-Jun-1999 12:00 AM

Na Albite 1-Jun-1999 12:00 AM

Mg MgO 1-Jun-1999 12:00 AM

Al Al₂O₃ 1-Jun-1999 12:00 AM

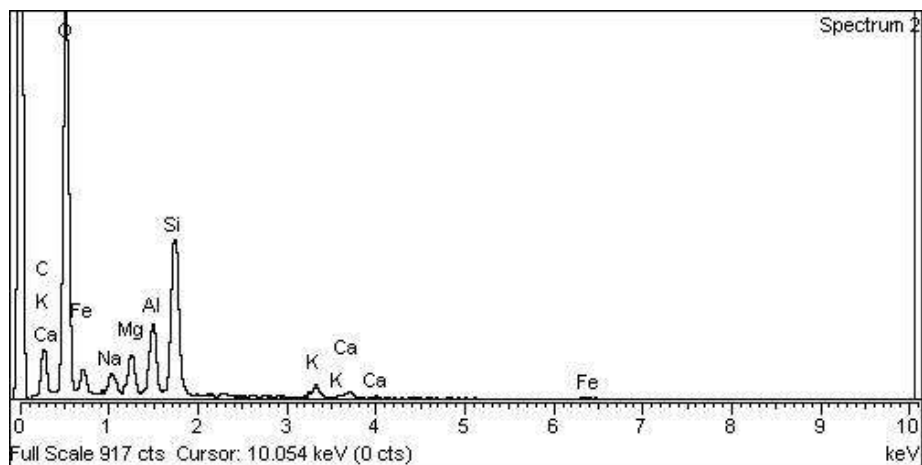
Si SiO₂ 1-Jun-1999 12:00 AM

K MAD-10 Feldspar 1-Jun-1999 12:00 AM

Ca Wollastonite 1-Jun-1999 12:00 AM

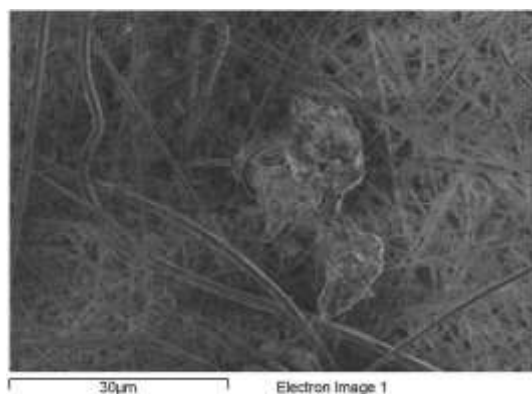
Fe Fe 1-Jun-1999 12:00 AM

Element	Weight%	Atomic%
C	19.60	26.93
O	58.39	60.22
Na	1.56	1.12
Mg	2.50	1.70
Al	4.08	2.50
Si	10.93	6.42
K	1.20	0.51
Ca	0.88	0.36
Fe	0.85	0.25
Totals	100.00	



PM₁₀ Mass Concentration ~ 471.14 μg/m³ (SEM, Wattman fiber filter paper)

Figure 18. Scanning Electron Microscopy of Dak Ismael Khel (DIK-002)



Spectrum processing :
No peaks omitted

Processing option : All elements analyzed (Normalised)

Number of iterations = 5

Standard :

C CaCO₃ 1-Jun-1999 12:00 AM

O SiO₂ 1-Jun-1999 12:00 AM

F MgF₂ 1-Jun-1999 12:00 AM

Na Albite 1-Jun-1999 12:00 AM

Mg MgO 1-Jun-1999 12:00 AM

Al Al₂O₃ 1-Jun-1999 12:00 AM

Si SiO₂ 1-Jun-1999 12:00 AM

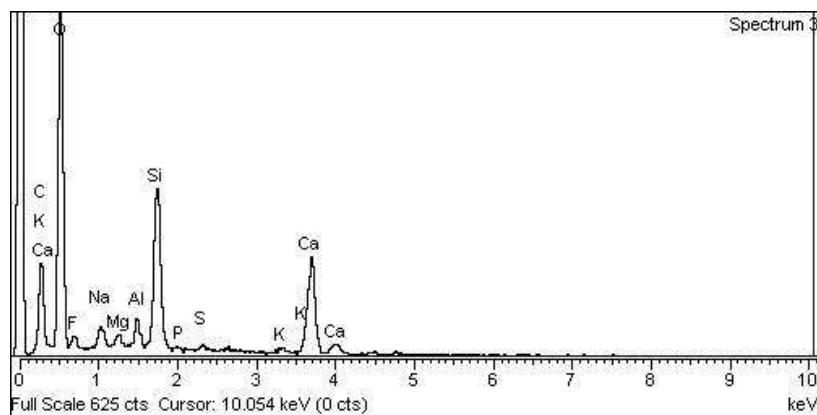
P GaP 1-Jun-1999 12:00 AM

S FeS₂ 1-Jun-1999 12:00 AM

K MAD-10 Feldspar 1-Jun-1999 12:00 AM

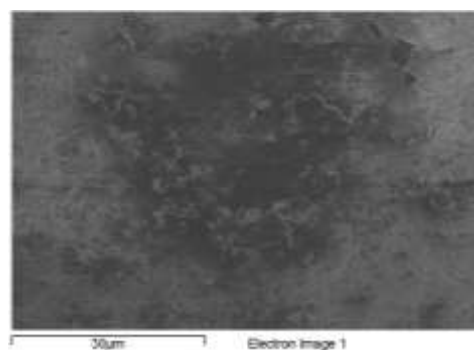
Ca Wollastonite 1-Jun-1999 12:00 AM

Element	Weight%	Atomic%
C	22.93	31.71
O	51.55	53.53
F	4.02	3.51
Na	1.37	0.99
Mg	0.59	0.40
Al	1.24	0.76
Si	8.15	4.82
P	0.18	0.09
S	0.26	0.13
K	0.49	0.21
Ca	9.23	3.83
Totals	100.00	



PM₁₀ Mass Concentration ~ 471.14 µg/m³ (SEM, Wattman fiber filter paper)

Figure 19. Scanning Electron Microscopy of Dak Ismael Khel (DIK-003)



Spectrum processing :
No peaks omitted

Processing option : All elements analyzed (Normalised)

Number of iterations = 5

Standard :

C CaCO₃ 1-Jun-1999 12:00 AM

O SiO₂ 1-Jun-1999 12:00 AM

F MgF₂ 1-Jun-1999 12:00 AM

Na Albite 1-Jun-1999 12:00 AM

Mg MgO 1-Jun-1999 12:00 AM

Al Al₂O₃ 1-Jun-1999 12:00 AM

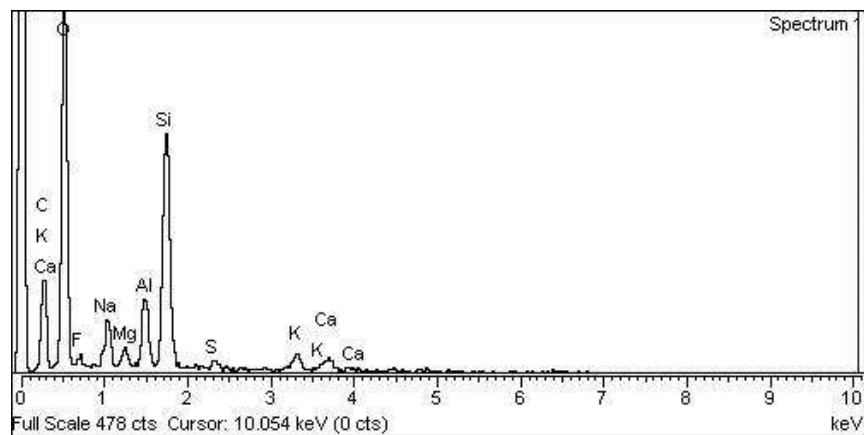
Si SiO₂ 1-Jun-1999 12:00 AM

S FeS₂ 1-Jun-1999 12:00 AM

K MAD-10 Feldspar 1-Jun-1999 12:00 AM

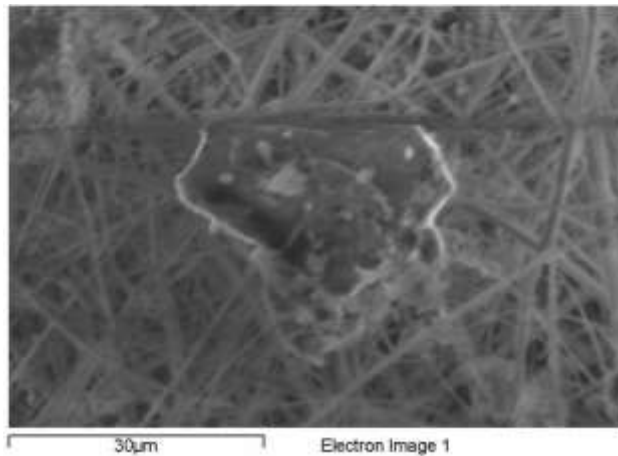
Ca Wollastonite 1-Jun-1999 12:00 AM

Element	Weight%	Atomic%
C	27.97	37.23
O	49.34	49.30
F	1.87	1.57
Na	2.65	1.85
Mg	0.83	0.55
Al	2.89	1.71
Si	11.60	6.60
S	0.40	0.20
K	1.27	0.52
Ca	1.18	0.47
Totals	100.00	



PM₁₀ Mass Concentration ~ 647.82 µg/m³ (SEM, Wattman fiber filter paper)

Figure 20. Scanning Electron Microscopy of Jabba Tar (JT-002)



Element	Weight%	Atomic%
C	14.39	20.47
O	59.38	63.41
Na	2.27	1.69
Mg	3.00	2.11
Al	4.77	3.02
Si	13.67	8.32
K	1.64	0.72
Fe	0.87	0.27
Totals	100.00	

Spectrum processing :
No peaks omitted

Processing option : All elements analyzed (Normalised)

Number of iterations = 5

Standard :

C CaCO₃ 1-Jun-1999 12:00 AM

O SiO₂ 1-Jun-1999 12:00 AM

Na Albite 1-Jun-1999 12:00 AM

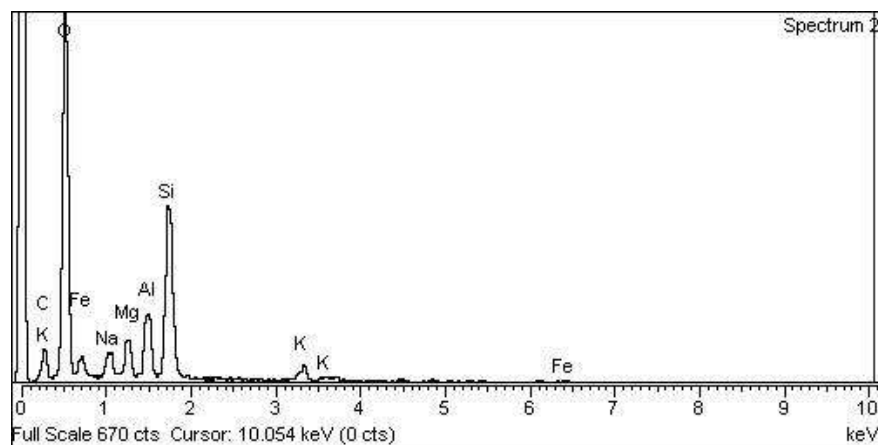
Mg MgO 1-Jun-1999 12:00 AM

Al Al₂O₃ 1-Jun-1999 12:00 AM

Si SiO₂ 1-Jun-1999 12:00 AM

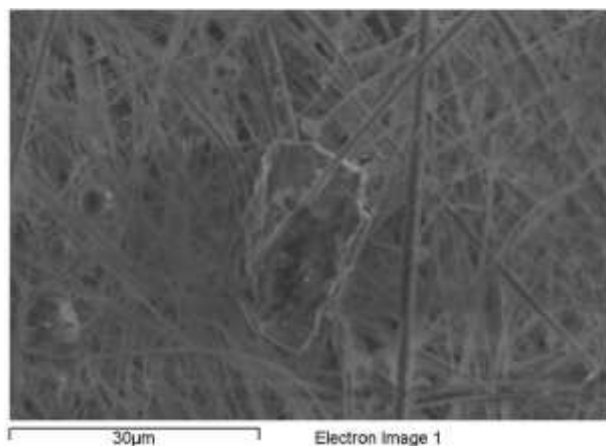
K MAD-10 Feldspar 1-Jun-1999 12:00 AM

Fe Fe 1-Jun-1999 12:00 AM



PM₁₀ Mass Concentration ~ 282.69 μgm/m³ (SEM, Wattman fiber filter paper)

Figure 21. Scanning Electron Microscopy of Shahkot (SKT-002)



Element	Weight%	Atomic%
C	12.38	17.75
O	59.04	63.56
Na	1.14	0.86
Mg	10.30	7.30
Al	0.73	0.47
Si	16.41	10.06
Totals	100.00	

Spectrum processing :

No peaks omitted

Processing option : All elements analyzed (Normalised)

Number of iterations = 5

Standard :

C CaCO₃ 1-Jun-1999 12:00 AM

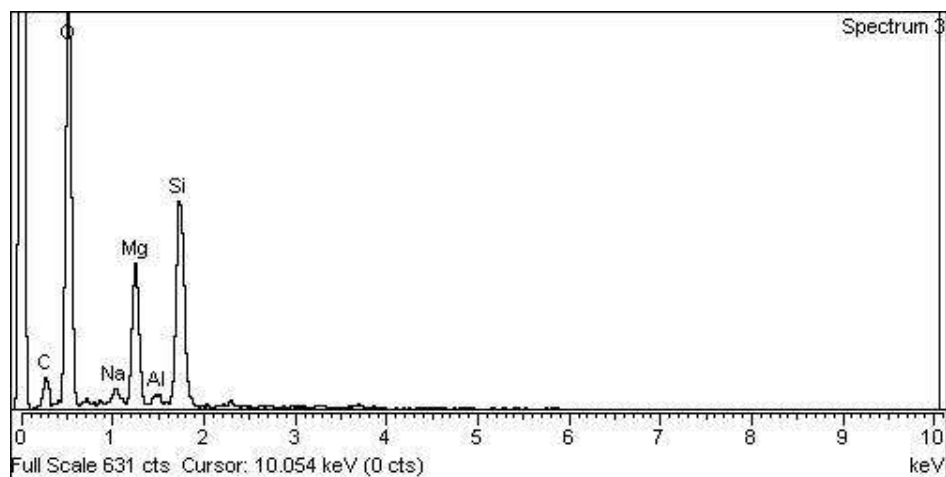
O SiO₂ 1-Jun-1999 12:00 AM

Na Albite 1-Jun-1999 12:00 AM

Mg MgO 1-Jun-1999 12:00 AM

Al Al₂O₃ 1-Jun-1999 12:00 AM

Si SiO₂ 1-Jun-1999 12:00 AM



PM₁₀ Mass Concentration ~ 314.10 µgm/m³ (SEM, Wattman fiber filter paper)

Figure 22. Scanning Electron Microscopy of Shahkot (SKT-003)

4.2.4. XRD analysis of the coal mine air dust samples for qualitative mineralogical assessment

The results of XRD Analysis the coal mine air dust samples for mineralogical assessment Collected through PM₁₀ were shown in figures 23 to 26.

4.2.5. Selected Heavy Metal Concentrations of Coal Mine Air Dust Samples Collected Through PM₁₀ Through Wattman Fiber Filter Paper

The concentrations of selected heavy elements in the coal mine air dust samples of Shakot, Dak Ismael Khel, Jabba Tar and Jabba Khushk, Cherat district Nowshera KPK Pakistan, as were given in Table 7.

Table 7. Heavy metal concentrations (mg/m³) in coal mine air dust samples

Heavy Metals	Statistics	Jabba Khushk	Dak Ismael Khel	Jabba Tar	Shahkot	Mean Concentration	ACGIH /PELs NIOSH (mg/m³)
Cr	Range	1.05 - 1.19	0.90 - 1.19	1.18 - 1.22	1.03 - 1.24		
	Mean	1.12	1.05	1.2	1.14	1.13	1
	S. D ±	0.09	0.21	0.03	0.15		
Zn	Range	1.59 - 1.82	2.44 - 2.62	2.14 - 2.26	2.11 - 2.21		
	Mean	1.7	2.53	2.2	2.16	2.15	5
	S. D ±	0.16	0.12	0.09	0.07		
Pb	Range	11.76 - 15.30	13.65 - 18.30	17.41 - 20.39	14.91 - 16.63		
	Mean	13.53	15.98	18.9	15.77	16.05	0.075
	S. D ±	2.5	3.29	2.1	1.22		
Cu	Range	1.88 - 1.99	3.46 - 3.62	1.92 - 2.23	1.62 - 1.95		
	Mean	1.94	3.54	2.07	1.79	2.34	1
	S. D ±	0.08	0.12	0.22	0.23		
Co	Range	0.24 - 0.29	0.41 - 0.47	0.42 - 0.48	0.28 - 0.39		
	Mean	0.27	0.44	0.45	0.33	0.37	0.1
	S. D ±	0.03	0.04	0.04	0.08		
Ni	Range	0.76 - 0.77	0.61 - 0.68	0.58 - 0.65	0.50 - 0.62		
	Mean	0.76	0.64	0.61	0.56	0.64	1
	S. D ±	0.01	0.05	0.05	0.09		
Cd	Range	0.23 - 0.33	0.24 - 0.35	0.23 - 0.34	0.29 - 0.40		
	Mean	0.28	0.29	0.29	0.35	0.30	0.005
	S. D ±	0.07	0.08	0.08	0.08		

n = Number of Samples

ppm= parts per million

S. D ± = Standard Deviation

ACGIH = American Conference of Governmental Industrial Hygienists

PELs = Permissible Exposure Limits

NIOSH = National Institute for Occupational Safety and Health

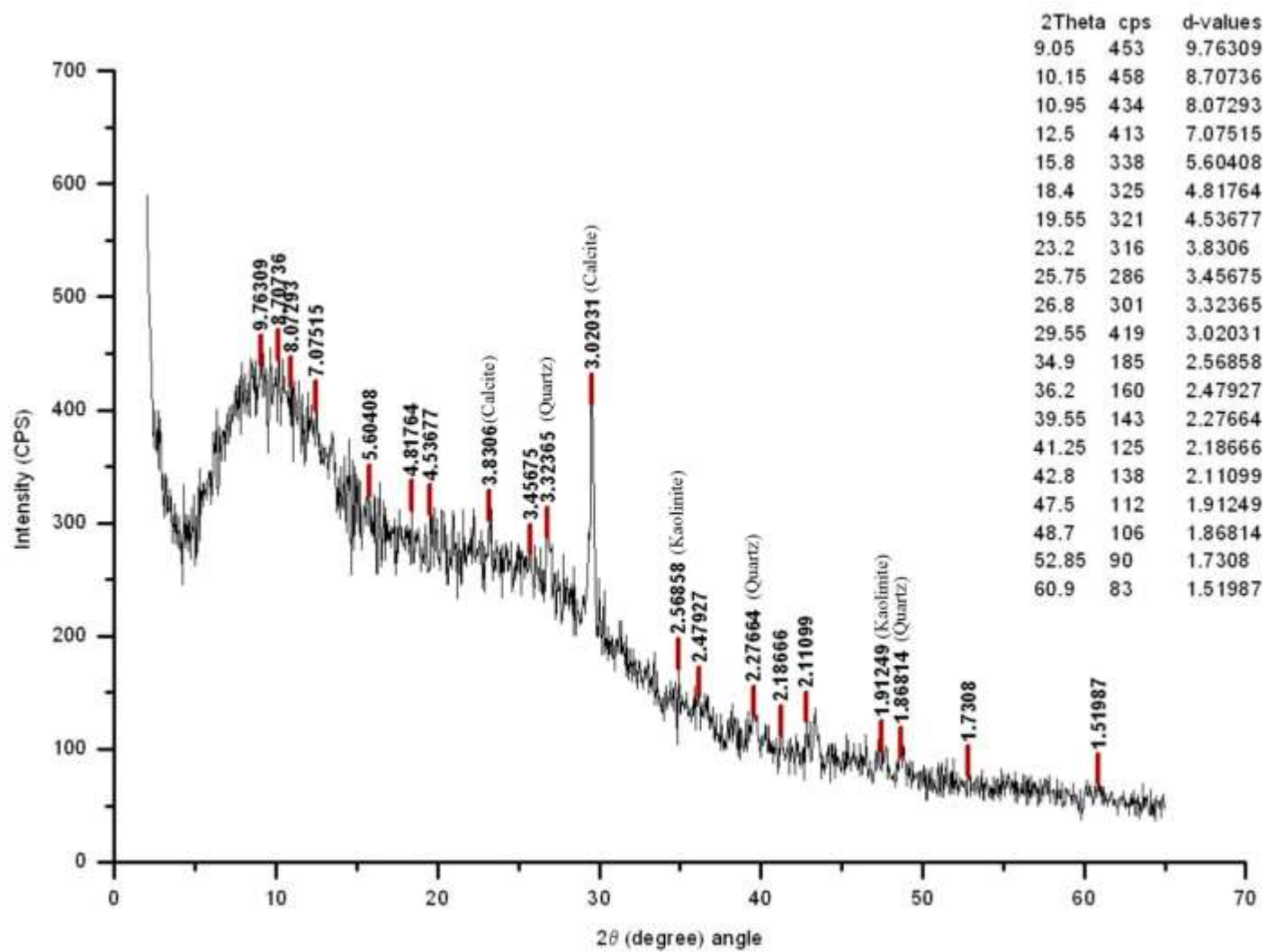


Figure 23. XRD of Coal Mine Air Dust Sample of Shakot (SKT-002)

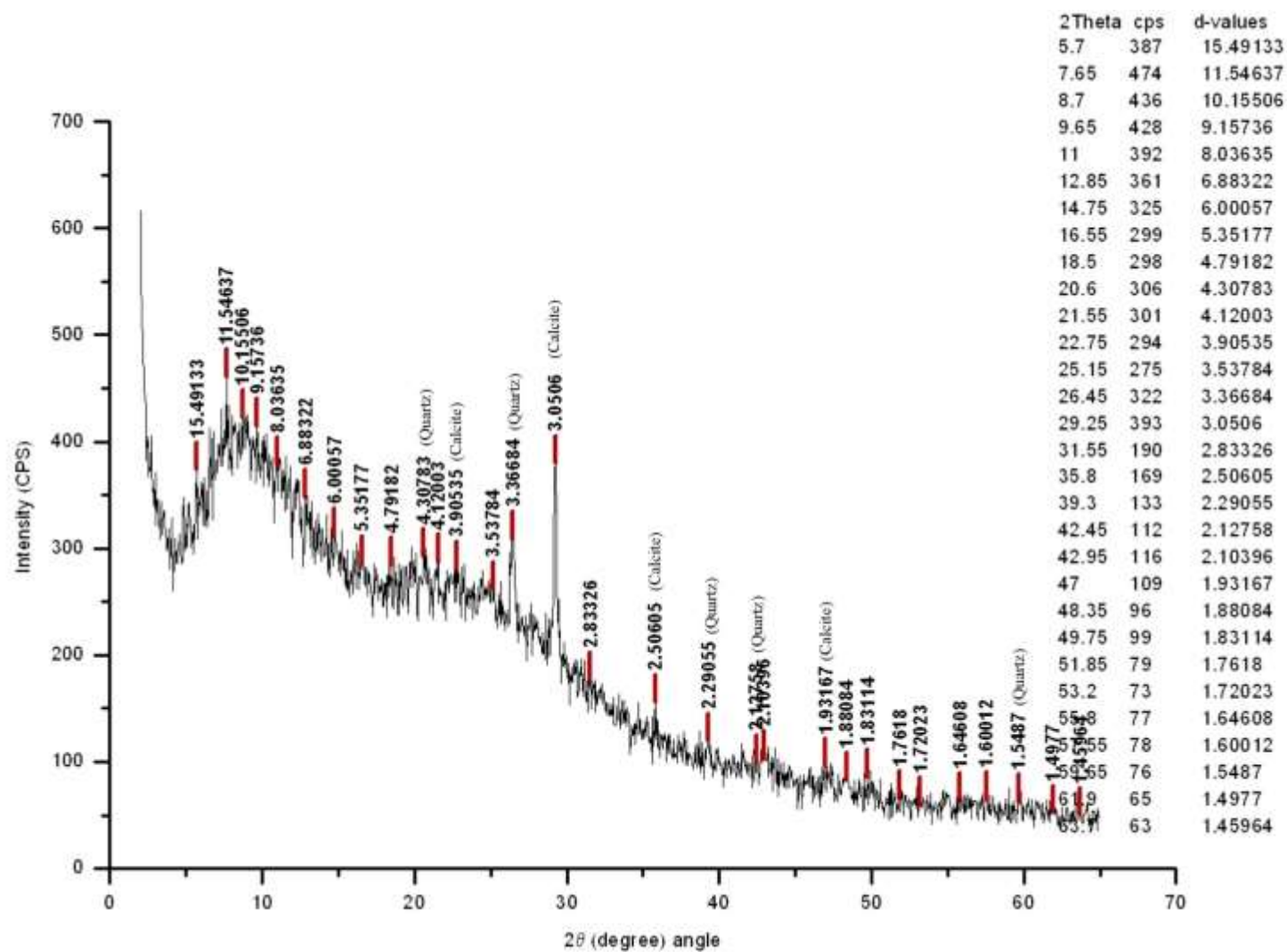


Figure 24. XRD of Coal Mine Air Dust Sample of Dak Ismael Khel (DIK-004)

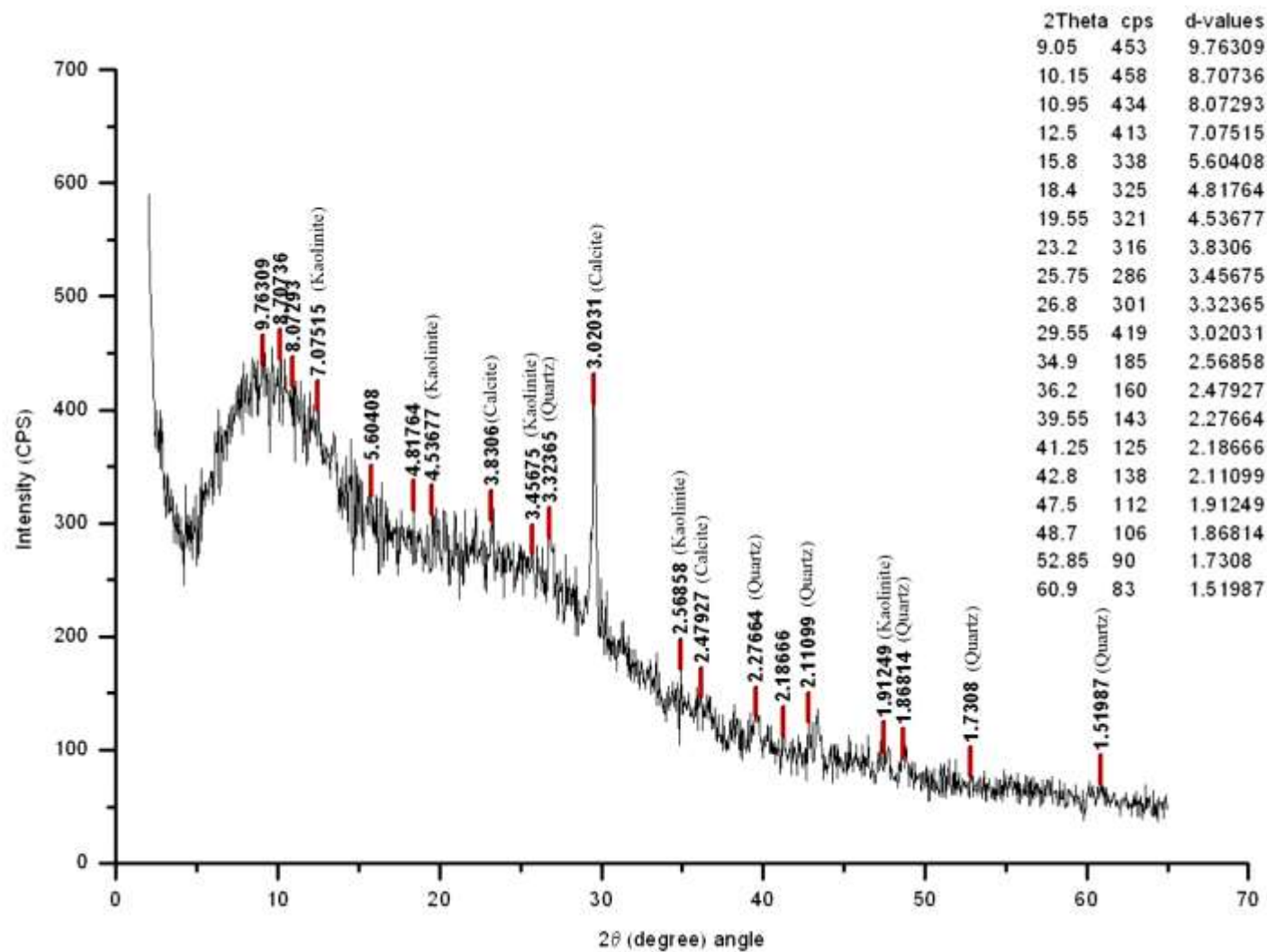


Figure No 25. XRD of Coal Mine Air Dust Sample of the Study Area Jabba Tar (JT-008) Cherat, Nowshera

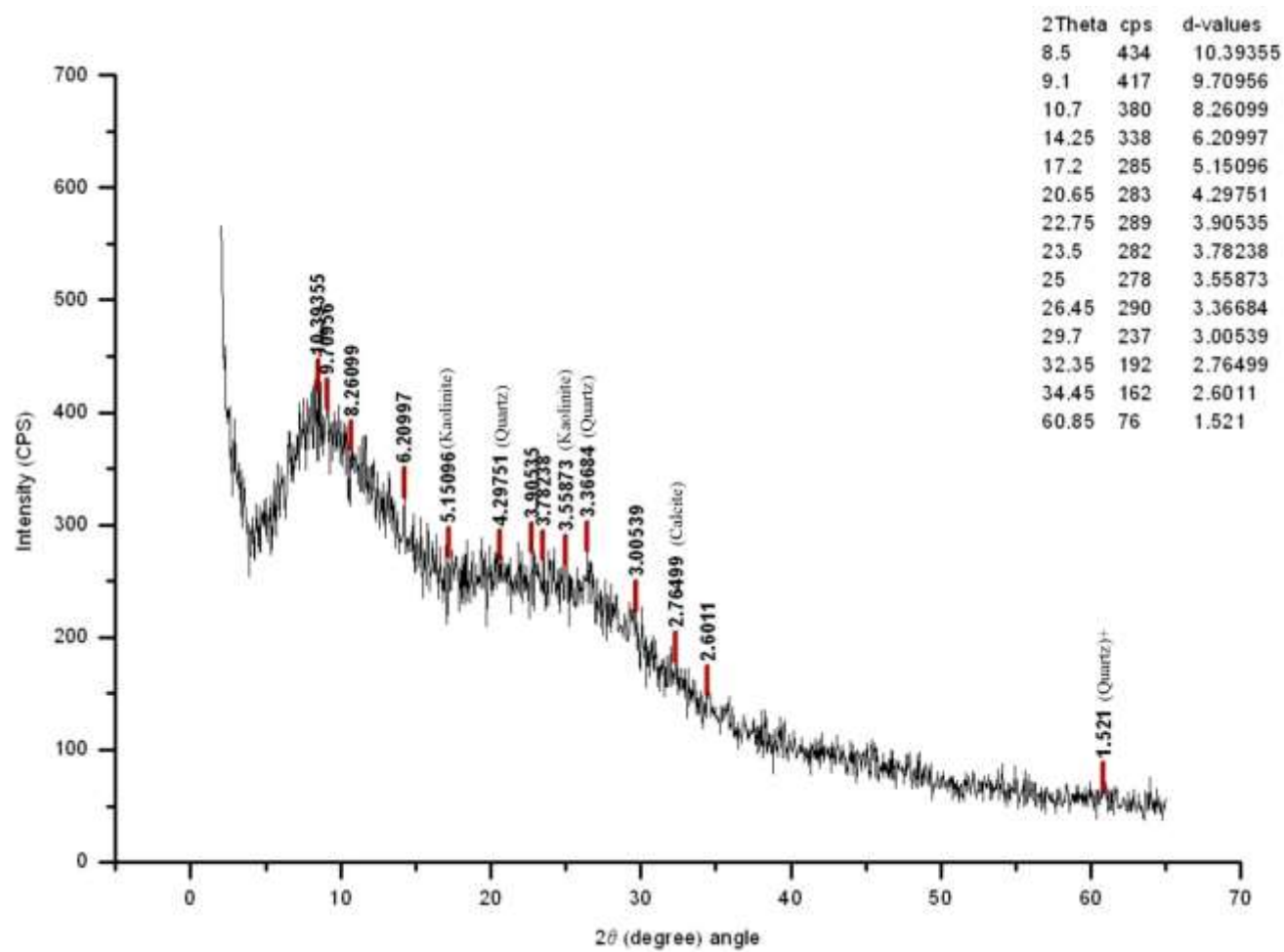


Figure 26. XRD of Coal Mine Air Dust Sample of Jabba Khushk (JK-009)

4.3. Occupational Health Problems Among Cherat Coal Miners

4.3.1. Demographics of Coal Miners Collected Through Structured Questionnaire

The various demographics variables of 400 coal miners were shown in Table 8.

4.3.2. Systemic health problems amongst coal miners

During the medical examinations, the following occupational health problems were observed among the 400 coal miners as shown in Table 9.

4.3.3. Occupational Respiratory Health Problems and Pneumoconiosis by Pulmonary Function Tests

The pulmonary function tests of 400 coal miners during the medical examinations at the study areas of Shahkot, Jabba tar, Jabba Khushk and Dak Ismail Khel showed the prevalence of the following diseases as shown in Table 10.

4.3.4. Occupational Pneumoconiosis Among 400 Coal Miners by P/A View CXR

The P/A View CXR of the 400 coal miners during the medical examinations, showed the prevalence of the following respiratory health problems/Pneumoconiosis among coal miners as shown in Table 11.

On the basis of Restrictive Lung Disease findings of Chest X-rays (P/A View), it can be estimated that 188 (47%) of the coal miners may have pneumoconiosis i.e. SCWP or CCWP as analyzed from Table 11.

Table 8. Demographics of Coal Miners of Cherat study areas

Demographic Variables	n (400)	%age
Age Distribution of coal Miners		
< 20 years	21	5.3%
20-25 years	146	36.5%
25-30 years	69	17.3%
31-35 years	48	12.0%
36 years and above	116	29.0%
Marital Status of Coal Miners		
Married	237	59.3%
Un Married	163	40.8%
Weight in Kgs		
40-50 Kg	8	2%
51-60 Kg	100	25%
61-70 Kg	188	47%
71 Kg and above	104	26%
Duration of Job in Years		
1-4 years	112	28.0%
5-8 years	112	28.0%
9-14 years	68	17.0%
15 years and above	108	27.0%
Job Satisfaction of Coal Miners		
Satisfied	180	45.0%
Not Satisfied	220	55.0%
Smoking History among Coal Miners		
Smokers	288	72.0%
No smokers	112	28.0%
No of Cigarettes Smokes/ Day		
1-5 cigarettes	108	37.5%
6-10 cigarettes	92	31.9%
11-15 cigarettes	64	22.2%
16 cigarettes and above	24	8.3%
Years of smoking in Years		
1-4 years	148	51.4%
5-8 years	88	30.6%
9 years and above	52	18.1%
Previous Injury / Mine Accidents		
Yes	130	32.5%
No	270	67.5%

Table 9. Health Problems among Coal Miners of Cherat study areas

Health Problems	Presenting Complaints	Frequency	Percentage
Respiratory System Problems	Chest pain	16	7.7%
	Dry cough	106	51.0%
	Cough with sputum/ Blood	44	21.2%
	Dyspnea/ SOB	42	20.2%
Cardio Vascular System Problems	Palpitation	28	70.0%
	Hypertension	12	30.0%
Central Nervous System Problems	Headache	51	37.5%
	Stress/ anxiety	50	36.8%
	Disturbed sleep	35	25.7%
Gastro Intestinal Tract Problems	GORD/ Gastric Discomfort	115	59.9%
	Constipation	8	4.2%
	Maleena	4	2.1%
	Diarrhea	33	17.2%
	Anorexia	32	16.7%
Ear Problems	Impaired hearing	58	50.0%
	Ear block	19	16.4%
	Ear discharge	7	6.0%
	Ear pain	21	18.1%
	Tinnitus	11	9.5%
Nose and throat problems	Nasal block	21	16.9%
	Common cold/ flu	38	30.6%
	Sore-throat	16	12.9%
	Rhinitis/ Rhinnorhea	49	39.5%
Eye Problems	Dimness of vision	53	37.9%
	Eye redness	24	17.1%
	Eye watering	26	18.6%
	Eye discharge	37	26.4%
Foot/ Skin and Nail Problems	Skin allergy	41	25.6%
	Skin Vitilago	2	1.3%
	Foot problems	43	26.9%
	Nail problems	74	46.3%
Urinary system problems	Dysuria/ Burning Micturation	18	56.3%
	Pyuria/ Pus in urine	6	18.8%
	Renal/ Kidney stones	8	25.0%
Musculo-Skeleton Problems	Bodyache	101	41.4%
	Backache	35	14.3%
	Knee joint pain	48	19.7%
	Lower limbs pain	22	9.0%
	Upper limbs pain/ Shoulder Pain	38	15.6%
Miscellaneous Health Problems	Fever	6	16.7%
	Weight	16	44.4%
	Weakness	10	27.8%
	Hepatitis	4	11.1%

Table 10. Pulmonary function tests* findings among coal miners

Lung Disease Pattern	Disease	F	%
Restrictive Diseases	Simple Coal Workers Pneumoconiosis, Complicated Coal Workers Pneumoconiosis, Silicosis, Tuberculosis, Sarcoidosis, Interstitial, Lungs Diseases, Lung Cancer, Metastatic Lung Diseases	210	52.5%
Obstructive Diseases	Bronchial Asthma and Chronic Obstructive Pulmonary Diseases (COPD) i.e. Chronic Bronchitis, Emphysema	63	15.75%
Normal	Nil	127	31.75%
Total		400	

f = Frequency,

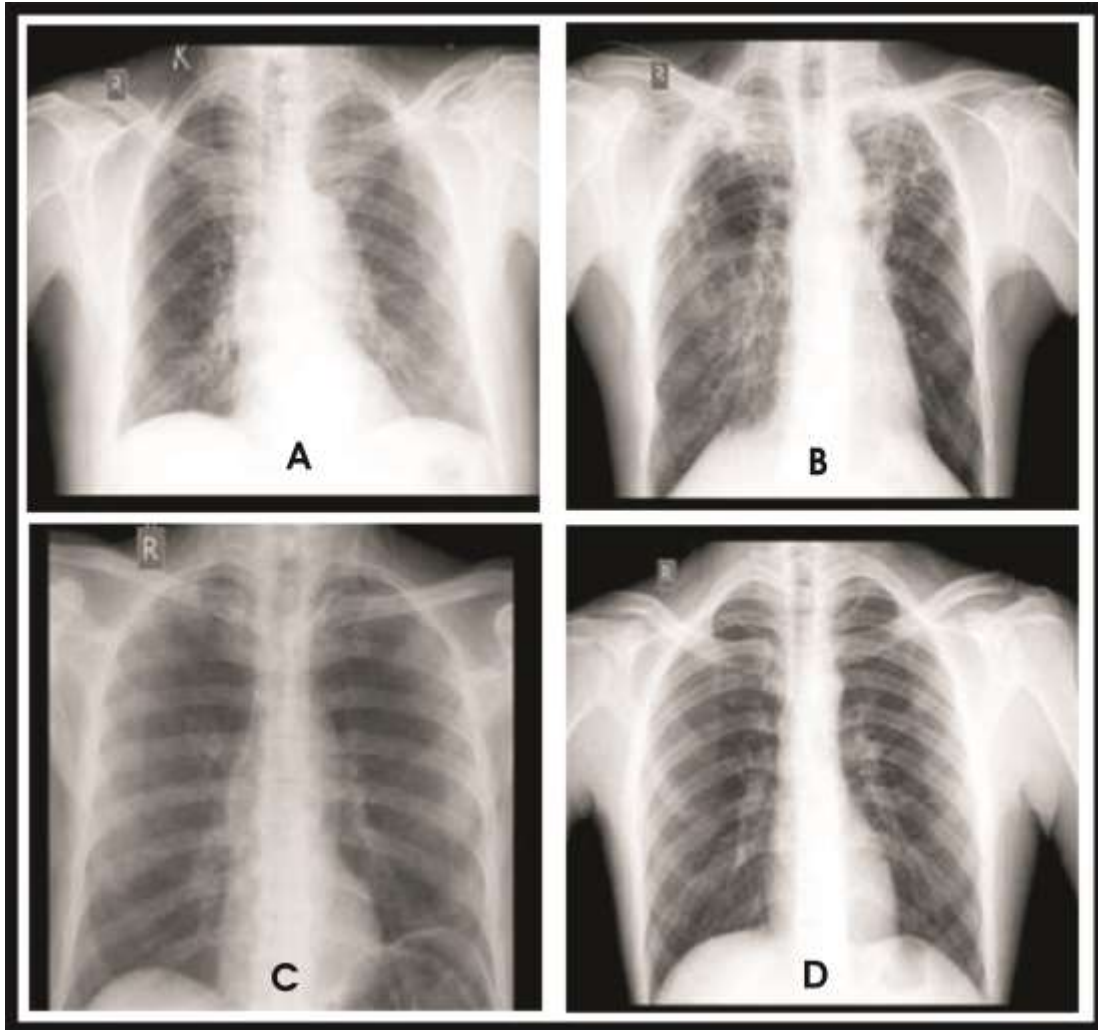
% = Percentage

* After pulmonary function test the FEV1, FEV and PEFr were entered in SPSS for both observed (coal miners) and predicted (standardized with age, sex and height) and showed the restrictive lung disease pattern if FEV1/ FVC x 100 is more than 80, and obstructive lung disease pattern if FEV1/ FVC x 100 is less than 80.

Table 11. Chest X-Rays findings among coal miners (n=400) of Cherat *

Chest X-Rays Findings	Disease	Frequency	Percentage
Normal	NILL	140	35%
Micro Nodular Opacities (1-5mm)	Simple Coal Workers Pneumoconiosis or Tuberculosis	119	29.75%
Bilateral or unilateral Calcifications	Simple Coal Workers Pneumoconiosis Silicosis, Tuberculosis, Sarcoidosis, Interstitial, Lungs Diseases, Lung Cancer (Primary), Metastatic Lung Diseases (Secondary)	54	13.5%
Macro Nodular Opacities (>1 cm)	Complicated Coal Workers Pneumoconiosis, Silicosis, Tuberculosis, Metastatic Lung Cancer	15	3.75%
Hyper Inflated Lungs	Bronchial Asthma OR Chronic Obstructive Pulmonary Diseases i.e. Chronic Bronchitis, Emphysema	72	18%
Total		400	

* All the coal miners were screened for respiratory health problems through CXR P/A view; and then on the basis of CXR findings, the various diseases were labeled as shown in the above table.



**Figure 27: Chest X-Ray Findings. A) Simple Pneumoconiosis B) Advanced Pneumoconiosis
C) Emphysematous D) Asthma/COPD**



Figure 28. Normal CXR:

In chest x-rays there were no diffuse nodules in lung fields, normal chest with no changes on heart shadow, normal spirometry findings, No Signs and Symptoms during medical examination and were labeled as normal chest x- rays

4.4. Frequency Of Musculoskeleton Health Problems Among Cherat Coal Miners

The frequency of different Musculo-Skeleton Disorders, risk factors along with demographic variables among Coal Miners of Nowshera Khyber Pukhtunkhwa Pakistan were shown in Tables 12, 13 and 14.

Table 12. Frequency of different Musculo-Skeleton Disorders Vs Age distribution, Duration of job and Level of Knowledge among Coal Miners

Demographic Variables	Total Population (n=400)	Musculo-Skeleton Disorders (n=244)
Age Distribution		
< 20 years	21 (5.25%)	11 (4.50%)
20-25 years	146 (36.50%)	95 (38.93%)
25-30 years	69 (17.25%)	41 (16.80%)
31-35 years	48 (12.00%)	23 (9.42%)
36 years and above	116 (29.00%)	74 (30.32%)
Duration of Job		
1-4 years	112 (28.00%)	60 (24.59%)
5-8 years	109 (27.25%)	49 (20.08%)
9-14 years	71 (17.75%)	52 (21.31%)
15 years and above	108 (27.00%)	83 (34.01%)
Level of Knowledge		
Good	89 (22.25%)	41 (16.80%)
Poor/ Bad	311 (77.75%)	203 (83.19%)

Table 13. Frequency of different categories of Musculo-Skeleton Problems among coal miners

Health Problem	Category	Frequency
Musculo-Skeleton Problems	Bodyache	101
	Backache	35
	Knee Joint Pain	48
	Lower Limbs Pain	22
	Upper Limbs/ Shoulder Pain	38
	Total	244

Table 14: Frequency of Musculo-Skeleton Disorders Vs Smoking/ Job Satisfaction/ Training/ Personnel Protective Devices

Variables	Response	Total Population (n=400)		Musculo-Skeleton Disorders (n=244)
Smoking History	Yes	289	(72.25%)	165 (67.62%)
	No	111	(27.75%)	79 (32.38%)
Job Satisfaction	Yes	182	(45.50%)	61 (25.00%)
	No	218	(54.50%)	183 (75.00%)
Coal Mine Training	Yes	135	(33.75%)	57 (23.36%)
	No	265	(66.25%)	187 (76.64%)
Usage of Protective Devices	Yes	193	(48.25%)	115 (47.13%)
	No	207	(51.75%)	129 (52.87%)

4.5. Frequency Of Ear Problems Among Cherat Coal Miners Nowshera

Out of all ear problems (n=166); 50% gave history of Impaired Hearing, 16.38% ear block, 6.03% ear discharge, 18.10% ear pain, while 9.48% of coal miners had complaint of tinnitus/or Vertigo as shown in Tables 15, 16 and 17.

The frequency of different categories of Ear Problems, risk factors along with demographic variables among Coal Miners of Nowshera Khyber Pukhtunkhwa Pakistan were shown in Tables 15, 16 and 17.

Table 15. Frequency of different categories of Ear Problems among coal miners

Health Problem	Category	Frequency	Percentage
Ear Problems	Impaired Hearing	58	50.00%
	Ear Block	19	16.38%
	Ear Discharge	7	6.03%
	Ear Pain	21	18.10%
	Tinnitus	11	9.48%
Total		116	

Table 16. Frequency of Different Ear Disorders Vs various variables among Coal Miners

Demographic Variables	Total Population	Ear Disorders (n=116)
Age Distribution		
< 20 years	21 (5.25%)	8 (06.90%)
20-25 years	146 (36.50%)	49 (42.24%)
25-30 years	69 (17.25%)	21 (18.10%)
31-35 years	48 (12.00%)	16 (13.79%)
36 years and above	116 (29.00%)	22 (18.97%)
Duration of Job		
1-4 years	112 (28.00%)	38 (32.76%)
5-8 years	109 (27.25%)	31 (26.72%)
9-14 years	71 (17.75%)	23 (19.83%)
15 years and above	108 (27.00%)	24 (20.69%)
Level of Knowledge		
Good	89 (22.25%)	27 (23.28%)
Poor/ Bad	311 (77.75%)	89 (76.72%)

Table 17. Frequency of Ear Disorders Vs Smoking/ Job Satisfaction/ Training/ Personnel Protective Devices

Variables	Response	Total Population	Ear Disorders (n=116)
Smoking History	Yes	289 (72.25%)	75 (64.66%)
	No	111 (27.75%)	41 (35.34%)
Job Satisfaction	Yes	182 (45.50%)	49 (42.24%)
	No	218 (54.50%)	67 (57.76%)
Coal Mine Training	Yes	135 (33.75%)	43 (37.07%)
	No	265 (66.25%)	73 (62.93%)
Usage of Protective Devices	Yes	193 (48.25%)	38 (32.76%)
	No	207 (51.75%)	78 (67.24%)

4.6. Factors Associated With Occupational Injuries Among Cherat Coal Miners Of District Nowshera Khyber Pukhtunkhwa Pakistan

The frequency of Various Occupational Injuries, risk factors along with demographic variables among Coal Miners of Nowshera Khyber Pukhtunkhwa Pakistan were shown in Tables 18-21.

Table 18. Frequency of Various Occupational Injuries Vs Age Distribution

Age Distribution	Total Population (n=400)	Injuries (n=181)
< 20 years	21 (5.25%)	09 (4.97%)
20-25 years	146 (36.50%)	78 (43.09%)
25-30 years	69 (17.25%)	32 (17.68%)
31-35 years	48 (12.00%)	20 (11.05%)
36 years and above	116 (29.00%)	42 (23.20%)
Total	400	181

Table 19. Frequency of Occupational Injuries Vs Job Duration

Duration of Job	Total Population (n=400)	Injuries (n=181)
1-4 years	112 (28.00%)	72 (39.78%)
5-8 years	109 (27.25%)	43 (23.76%)
9-14 years	71 (17.75%)	25 (13.81%)
15 years and above	108 (27.00%)	41 (22.65%)
Total	400	181

Table 20. Frequency of Occupational Injuries Vs Level of Knowledge Regarding Occupational Safety among Coal Miners

Level of Knowledge	Total Population (n=400)	Injuries (n=181)
Good	89 (22.25%)	27 (14.92%)
Poor/ Bad	311 (77.75%)	154 (85.08%)
Total	400	181

Table 21. Frequency of Occupational Injuries Vs Smoking/ Job Satisfaction/ Training/ Personnel Protective Devices

Variables	Response	Total Population (n=400)	Injuries (n=181)
Smoking History	Yes	289 (72.25%)	142 (78.45%)
	No	111 (27.75%)	39 (21.55%)
Job Satisfaction	Yes	182 (45.50%)	54 (29.83%)
	No	218 (54.50%)	127 (70.17%)
Coal Mine Training	Yes	135 (33.75%)	33 (18.23%)
	No	265 (66.25%)	148 (81.77%)
Usage of Protective Devices	Yes	193 (48.25%)	52 (28.73%)
	No	207 (51.75%)	129 (71.27%)

CHAPTER # 5

DISCUSSIONS

An environmental epidemiological study needs to evaluate all aspects of occupational and para-occupational determinants which strongly affect the occupational environment and thus in this we assessed all the four aspects of occupational environment and found that all the assessed parameters were beyond the international standards of WHO, OSHA and FEPA.

5.1. Geo-Chemistry of Coal Raw Samples Analysis

5.1.1. Geo-Chemistry of Coal Raw Samples Analysis For Selected Heavy Metals

The concentration of Nickel was 0.7 to 3.2ppm in Shahkot; 4.2 to 7.9ppm in Jabba Khushk; 11.5 to 18.1ppm in Dak Ismael Khel and 9.7 to 18.4ppm in Jabba Tar coal samples. It suggests that Dak Ismael Khel and Jabba Tar showed high Nickel concentrations as compared to Shahkot and Jabba Khush coal samples. In this study Nickel ranges from 0.7 to 18.4ppm; with mean value of 9.2ppm while in Siddiqui et al., (2011) study; 8 to 41ppm with mean of 23ppm.

The concentration of cadmium was 1.1 to 2.2ppm in Shahkot; 1.6 to 3.6ppm in Jabba Khushk; 2.1 to 4.1ppm in Dak Ismael Khel and 2.8 to 5.1ppm in Jabba Tar coal samples. Cadmium ranges from 1.1 to 5.1 ppm; with mean value of 2.8ppm, in Siddiqui et al., (2011) study the Cd range concentration was from 0.1 to 0.4 ppm with mean of 0.34ppm. This suggests that the coal samples of Shahkot and Jabba Khushk had less concentrations of cadmium as compared to Dak Ismael Khel and Jabba Tar.

The concentration of chromium was 2.7 to 4.6ppm in Shahkot; 23.5 to 31.4ppm in Jabba Khushk; 40.3 to 63.1ppm in Dak Ismael Khel and 60 to 74.1ppm in Jabba Tar coal samples. In

the study conducted by Siddiqui et al., (2011) Cr ranges from 8 to 22 ppm with the range of 12 ppm, while in this study Chromium concentration ranged from 2.7 to 74.1 ppm, with mean of 38ppm. This suggests that besides Shahkot, the coal samples of Dak Ismael Khel, Jabba Tar and Jabba Khushk were relatively more enriched in Chromium as shown in Table 3. The concentration of zinc was 6.3 to 9.4ppm in Shahkot; 22.3 to 26.1ppm in Jabba Khushk; 12.1 to 22.2ppm in Dak Ismael Khel and 10.8 to 14.7 ppm in Jabba Tar coal samples. The mean value of Zinc was 40 ppm with the range of 12 to 75 ppm in a study conducted by Siddiqui et al., (2011); while in this study, range was 6.3 to 26.1 with 15.6ppm mean value. It suggests that Shahkot had less concentrations of zinc while Dak Ismael Khel, Jabba Tar and Jabba Khushk had relatively more zinc.

The concentration of lead was variable in all coal samples. Lead ranged from 17.2 to 42.1ppm; with the mean value of 33.3ppm in this study while in study conducted by Siddiqui et al., (2011), the range was 7 to 39 ppm with the mean value of 23 ppm. The concentration of Pb was 17.2 to 20.7 ppm in Shahkot; 34.8 to 42.1 ppm in Jabba Khushk; 33.5 to 37.1 ppm in Dak Ismael Khel and 34 to 41.5 ppm in Jabba Tar coal samples as shown in Table 3. This suggests that the coal samples of Shahkot had less concentrations of Pb as compared to Dak Ismael Khel, Jabba Tar and Jabba Khushk. Plumbism is a pathological condition which is caused by the bio-magnifications and bio-concentration of lead in human body (Jauro et al., 2008).

In this study the concentration of Cobalt assessed, ranged from 1.5 to 20.3 ppm; with the mean value of 10.6 while in Siddiqui et al., (2011) study the range was form 0.05 to 0.55 ppm with the mean value of 0.25ppm. The concentration of cobalt was 1.5 to 5.2ppm in Shahkot; 4.6 to 8.8ppm in Jabba Khushk; 11.2 to 17.5 ppm in Dak Ismael Khel and 14.7 to 20.3 ppm in Jabba

Tar coal samples. This suggests that the coal samples of Shahkot and Jabba Khushk had less concentrations of cobalt as compared to Dak Ismael Khel and Jabba Tar.

Moreover, the heavy metals concentrations of lead (Pb), zinc (Zn), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu) and nickel (Ni); in Shahkot coal samples were comparatively less as compared to the coal samples of Jabba Tar, Jabba Khushk and Dak Ismael Khel. When the Cd concentration in the human body exceeds the normal value, this results in Ouchouch condition (Jauro et al. 2008). Besides Shahkot, the Jabba Tar coal samples also had less Heavy metal concentrations as compared to Dak Ismael Khel and Jabba Tar coal samples (Table 3).

According to USGS and ASTM coal samples heavy metals analysis, the concentrations of all samples of the study areas for heavy metals were above the PELs except for Shakot having values within standard limits except for lead (19.22 ppm) and cadmium (1.7 ppm) which were above PELs. Moreover the concentrations of all heavy metals of Dak Ismael Khel and JabbaTar coal samples were higher; only Nickel in Jabba Khush had values within PELs while all the others were higher; while in Shakot all were higher except for lead and cadmium (USGS; ASTM). There was a significant variation in the concentrations of chromium (2.7-74.1ppm), Zinc (6.3-26.1ppm), Lead (17.2-42.1 ppm), Copper (5.4-40.0ppm), Cobalt (1.5-20.3ppm), Nickel (0.7-18.4ppm), Cadmium (1.1-5.1 ppm). The individual HMs concentration variability in the different coal samples might be due to either natural or anthropogenic causes during the coal formation phases (Jauro et al., 2008).

5.1.2. Ultimate analysis of coal samples

Moisture in the coal samples ranged from 0.2 (Shakot) to 0.8 wt % (Jabba Tar), mean moisture was 0.4 wt %; Volatile matter in coal samples ranged from 16.4 (Shakot) to 22.4 db % (Dak Ismael Khel); mean volatile matter was 19.0 db%; ash content in coal samples ranged from 23.8 (Shakot) to 31.8 db% (Jabba Tar); mean ash was 27.9 db%; value of ash (db%) was close to overall mean and range; and fixed carbon in coal samples ranged from 45.6 (Jabba Tar) to 57.9 % (Jabba Khushk); mean fixed carbon was 50.8 % as shown in Table 4. Actual coke, which along with high carbon content, is useful and important for coke making purposes in industries (Diez et al. 2002). All twenty (20) coal samples had high content of fixed carbon (%) and were appreciably good coals. Moisture in Shahkot was lower as compared to Dak Ismael Khel, Jabba Khushk and Jabba Tar; whereas Volatile matter in all four areas was close to mean (ranges = 16.4 to 22.4 db%; mean = 19.0 wt %).

On the basis of low moisture (wt %) of Shahkot and Jabba Tar; and high fixed carbon (%), they were good quality of coals. If there is more moisture in coal, it will lead to reduction in capacity of coal plant and thus causing loss of economic resources. Moreover, the Volatile matter (db %) and ash (db%) values were close to normal range of values and showed the proximity of all coal samples in the study areas. Volatile matter content of all the four study areas were lower and has high rank coal and thus has less volatile matter (Jauro et al. 2008). VM helps in the application of coal determination and for allotting the coal rank. There was low moisture content in Shahkot and Jabba Tar coal samples; and more fixed carbon (db %) in all twenty (20) coal samples as shown in Table 4.

Coal was classified on the basis of Volatile Matter (wt %), fixed carbon (wt %) and moisture (wt %) . Based on the classification of American Standards Association, American Society for Testing and Materials (ASTM) and M.S. Krishnan classification of coal; the coal samples of the cherat study areas were of class High Volatile Bituminous-A; and according to M.S. Krishnan classification of coal; to sub-bituminous on the basis of % fixed carbon investigated during the ultimate analysis of coal samples. Based on the USGS (United States Geological Survey) and Parr's classification of coal; the coal samples of the cherat study areas were of class Bituminous-A on the basis of % unit Volatile Matter assed during the ultimate analysis of coal samples (USGS ; ASTM).

5.1.3. XRD analysis of coal samples

Eight (08) rock coal samples each collected from the four study areas were qualitatively analyzed by XRD to assess the major mineralogical aspect of coal samples and revealed quartz, calcite and kaolinite as major dominant minerals and thus this study correlated various respiratory health problems among coal miners with pneumoconiosis and silicosis as were supported by XRD of the coal mine air dust samples; CXR-P/A view and pulmonary function tests of coal miners.

5.2. Coal Miner's Environment

5.2.1. Coal Mines Air Dust Samples PM10 Concentration

The results revealed high levels of PM₁₀ concentrations of coal dust, having mean of 441.1 mg/m³ with wide range of 235.57-837.59 µg/m³; which was comparatively higher than the U.S. standard for PM₁₀ (150 µg/m³). The coal dust concentrations investigated in all the study areas

were found high as compared to international standards. High levels of PMs were related to adverse effects on the human health. High PMs levels causing reduction in life expectancy and is associated with potential negative effects on human health (Pope et al., 2009). More and consistent PM¹⁰ exposure is strongly related to mortality and morbidity related to cardiovascular and respiratory system (Zanobetti and Schwartz, (2009) and Aneja et al., (2012).

The USA Department (EPA) has formulated PMs PEL's standards of 150µg/m³ for ambient air quality monitoring and assessment. Besides this the USA, has drafted a new range of PM₁₀ of 65-85 µg/m³ for 24 hours period in order to address the growing trend of occupational health problems among the miners (U.S. EPA, 2010). Continuous exposure to PMs is considered as one of the fatal and hazardous condition and poses great amount of risk to miners (Hendryx et al., 2008).

The results of air monitoring in Cherat, District Nowshera, KPK, have revealed that coal miners worked continuously and without any break for years and years to high PMs levels with coal mine air dust and thus poses major risks. Moreover, the health problems assessed, along with the high prevalence of pneumoconiosis among the coal miners strongly supported our health hazards data. The high concentration of PM₁₀ in and near the vicinity of coal mines, were found more than the PMs of opencast coal mines (197.5 µg/m³) in study of Appalachia, USA by Aneja et al., (2012); and the (194 µg/m³) Indian study of Dubey and Pal, (2012) conducted at Dhanbad; and the (1848 µg/m³) Turkish study of Tecer et al., (2008) conducted at Zonguldak as shown in Table 6.

5.2.2. Scanning Electron Microscopy of Air Samples Collected Through PM₁₀

The monitoring and investigation of Cherat coal mine air dust showed that the PM₁₀ levels and concentrations were 2-6 times as compared to the federal standards (Table 5). The measured PM values support the coal mine dust study, of Turkey conducted by Onder and Yigit, (2009) which has concentration of 1848 $\mu\text{g}/\text{m}^3$. In this study, out of all 24 samples; 16 (sixteen) had 2-3 times, 7 (seven) had 4-times and only one (01) had 5.5 times more concentration of coal mine air dust collected through PM₁₀ as shown in Tables 5. The coal mine air dust investigated in this study had less mean values of concentrations as 466.15 $\mu\text{g}/\text{m}^3$, as compared to studies of Ghose and Majee, (2007) which has 780 $\mu\text{g}/\text{m}^3$ in India; and in Onder and Yigit, (2009), which had 1848 $\mu\text{g}/\text{m}^3$ mean value of coal mine air dust concentration in Turkey as shown in Table 6.

5.2.3. Analysis of Concentrations of Coal Mine Air Dust Collected Through PM₁₀

Coal is labeled as a complex material of heterogeneous characteristics; and thus due to coal fundamental properties; is responsible for adverse health problems. For instance, oxidation of coal with toxic chemicals causes sulfates and sulfuric acid, which initiates the pneumoconiosis and other pathological lung conditions, and environmental issues.

The coal mine air dust particles exhibits their own morphology, mineral structure and chemical composition; and contributes to the pollution of the occupational environment of coal mines. These coal mine air dust particles were carbon-rich and were produced during various underground coal mining operations. After investigation of coal mine air dust concentrations, the SEM/EDX technology was utilized for air pollutants study in the coal mine air dust of cherat, Nowshera, KPK, Pakistan.

For the assessment and investigation of certain elements in coal mine air dust, the EDX along with SEM was used for the coal mine air dust samples, collected on wattman fiber filter papers (Haapala, 1998). So, SEM was done to assess morphology and size of coal mine air dust and XRD to find different crystals and mineral groups in coal mine air dust samples as investigated by Jones et al., (2010). During SEM microscopy of the coal mine air dust samples, the dust particles represented variable shapes. Photomicrographs of the coal air mine dust samples investigated showed various mineral groups particles and composition of elements as shown by the images and spectra in Figures 17 - 26.

5.2.4. XRD analysis of the coal mine air dust samples for mineralogical assessment

The XRD showed that coal mine air dust samples investigated had different groups of minerals; and were confirmed by XRD of the rock coal samples collected from the same study areas. The concentration as well as mineralogical features of the coal mine air dust particles collected from the coal mines, were essential and their identification of potentially dangerous components which had impacts on human as well as on the environment. The most dangerous and fatal fact was that silica (SiO_2) is present in all coal mine air dust samples and as were confirmed by the coal samples collected and supported by the high prevalence of respiratory health problems and pneumoconiosis among the coal miners. Scanning Electron micrographs showed the shapes and aggregates of the collected coal mine air dust samples by PM_{10} , from the four study areas of Cherat. Some particles were identified in fused form and showed complex nature in form of several minerals like kaolinite, calcite and silicates/quartz as shown in Figures 23 - 26.

The shape in various mineral groups investigated in coal mine air dust samples showed the presence from somewhat spherical, rounded particles, along with silica /quartz and Fe minerals; by XRD technique as shown in Figures 23 - 26; and were studied by Hower et al., (1999); Sokol et al., (2002); and Gieré et al., (2003); to complex irregular collection of several mineral particle sizes and shapes of coal mine air dust (Jones et al., 2002). Mineralogical analysis of deposited coal dust particles at the studied areas showed a similar mineral composition; in which quartz and aluminosilicates showed dominant levels along with other minerals which were present in trace amounts. In this study, silica / quartz showed high levels, and was supported by study of Ivanović (2002), which also 3.8 – 22 % of crystalline particles. As studied in this study, the various coal mining activities causing production of coal mine air dust, the primary source of mineral dust particles, as were confirmed by different tests which found various mineral groups and dust concentrations.

Coal mine air dust has major component of silicon dioxide (SiO_2), calcite (CaCO_3) and Kaolinite $\{\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4\}$. The study of coal dust confirmed that it has a number of associated minerals.

5.2.4.1. Major particle groups

Based on the elemental composition and morphology analyzed by SEM and EDX; the coal mine air dust particles were classified into: aluminosilicates, quartz/silica, and Calcite; these particles were supported by a study conducted by Huertas et al., (2012); in which the SEM micrographs showed irregular and smooth particles typically clay minerals and including quartz, and calcite.

In a study conducted by Bujak et al (2008) showed major composition of SiO_2 , followed by organic dust minerals, which were beyond the standards for coal mine air dusts, and thus

prone the workers to fibrosis of lungs parenchyma; Interestingly the aluminosilicates group of minerals was dominant in quantity, followed by quartz/silica, and then calcite.

5.2.4.2. Aluminosilicates/Kaolinite

The earth crust contain approximately 72 % of aluminosilicates by wt (Pachauri et al 2013); and interestingly in this study the aluminosilicates were nearly 68 % by wt. In this study the aluminosilicates showed that they are comprised of silicon, oxygen, and aluminum; along with varying amount of sodium, potassium, magnesium, calcium and iron. This showed that aluminosilicate mineral particles were derived from weathered rock surfaces and from soil sediments inside the coal mines. The most common source of these particles was crustal origin through digging, blasting, transportation and wind.

5.2.4.3. Quartz/silica

SiO₂ particles (silica) are characterized by high content of silicon (Si) and oxygen (O). The diameter of silica particles has tubular structure and the origin of this pure silica either may be natural or anthropogenic source. In earth surface, the silica/quartz has the major constituency as compared to other minerals; thus these silica particles were related to soil dust contaminations. In coal mines, the blasting, digging, transportation and other mining activities results in production of silica dust particles (Weeks and Rose, 2006).

5.2.4.4. Calcite

Ca-Co were the particles having high content of Calcium, Carbon and oxygen; having irregular morphology and having dust and crustal materials from coal mines during blasting, strong air movements, internal ventilation and digging activities. The presence of 7

different heavy metals in all rock coal samples were investigated and then confirmed via their assessment in coal mine air dust samples in the four study areas of Cherat District Nowshera (Table 7). These toxic HMs have detrimental effects on the human lungs, and can be confirmed by the various systemic health problems among coal miners. This study confirmed and supported the findings of Song et al., (2008); in which Quartz, kaolinite, and calcite were investigated. In a study conducted by Cprek et al (2007); the XRD measurements indicated that the coal dust samples contained quartz/silica; as were found in this study (Figures 23 to 26).

5.2.5. Heavy Metal Concentrations of Coal Mine Air Dust Samples Collected Through PM₁₀ Through Wattman Fiber Filter Paper

Analysis of heavy metals in coal dust air samples collected on wattman fiber filter paper at various sites of study areas revealed the presence of chromium, zinc, lead, copper, cobalt, nickel and cadmium and showed variations. Interestingly all of the investigated metals in coal mine air dust were confirmed and found in coal samples as studied by Aneja et al, (2012); these heavy metals were also present in the coal samples collected from the study areas. The selected heavy metals concentrations along with mean values in all the four sites of the study areas were shown in Table 7.

The mean values of Cr, Zn, Pb, Cu, Co, Ni and Cd concentrations investigated in coal mine air dust were: 1.13, 2.15, 16.05, 2.34, 0.37, 0.64 and 0.30 mg/m³ respectively as shown in Table 7. These toxic heavy metals were also studied by Polyák et al., (1994). In a study conducted by Zhu et al., (2010) the coal samples investigated by Atomic Absorption Spectroscopy (AAS) to have Pb concentrations of 79.1 ± 38.3 ng/m³. Zinc, Copper, Cadmium,

and Nickel were also determined directly by atomic absorption spectrophotometry by Rawat et al., (1982).

5.2.6. Analysis of coal mines air dust samples for heavy metals by AAS

The AAS of the coal samples investigated from the study area and their confirmation as well presence in coal mine air dusts showed that coal miners were prone to various occupational health problems associated with HMs and toxic elements in coal mine air dust particles as investigated through wattman fiber filter papers. The basis for such representation is that coal mine air dust is produced at mine source and directly collected near the vicinity of coal mines as investigated accordingly by SEM, XRD, EDX and AAS. The concentrations of Zn, and Ni in all air samples were within while concentrations of Pb, Cr, Co and Cd; were more than the Recommended Exposure Limits (RELs)/ Permissible Exposure Limits (PELs), of American Conference of Governmental Industrial Hygienists (ACGIH), Threshold Limit Value (TLV) and National Institute for Occupational Safety and Health (NIOSH) as shown in Table 7.

5.3. Health Problems

5.3.1. Demographics of Coal Miners

During the medical examinations of 400 coal miners showed that n=21(5.3%) miners were < 20 years of age while n=116(29%) miners were in the age range of 36 and above. Mean age was 30 years with standard deviation ± 1.26 . Marital status was analyzed as n=237(59.3%) coal miners were married. About n=188(47%) miners had 61-70 Kg weight (Table 8). Mean weight was 65 Kg with standard deviation ± 0.76 . n=112(28%) of the coal miners had 1-3 years coal mining job; while 108(27%) had 15 or more working years (Kuempel et al., 2009). Working years also affect the occupational diseases among workers as described by Wilczyńska et al., (2005) and was also observed to be an important risk factor for various occupational health problems among coal miners. Mean job duration was 8 years with standard deviation ± 1.12 . n=180(45%) miners were satisfied from their job and the main reason was the purity and the responsibilities of their families. 72 % (n=288) coal miners gave smoking history; n=108 miners smoke 1-5 and only n=24 smoke 16 or more than 16 cigarettes per day. Mean number of cigarettes was 10 cigarettes per day with standard deviation ± 2.36 . Out of 288; n=148(51.4%) miners were smoking from 1-4, n=88(30.6%) miners 5-8, n=52(18.1%) miners 9 years and above. Mean no of smoking years was 8 years with standard deviation ± 0.86 . Due to the harsh, humid and difficult environment, coal miners use drugs and thus are prone to smoking and nicotine addiction as pointed by Unalacak M et al., (2004) and these findings were confirmed by this study in which 72% of coal miners gave positive smoking history. Only n=113(28.3%) miners had mine accidents and injuries as shown in Table 8; also studied by Wang et al., (2011). The International Labor Organization (ILO) reported that in third world countries, the fatality prevalence rate is approximately 90% higher as compared to the developed countries. Under-

ground coal mining, throughout the globe is a risky profession and many coal miners lose their lives, and thus injuries and accidents are two or many fold in underground coal workers as compared to other profession workers. In Pakistan no data is available to assess the burden and prevalence of occupational injuries and accidents, moreover no industry bothers to report to the concerned labor department regarding injuries and accidents occurrence (Ashraf et al., 2005). Moreover, among 400 coal miners 28.3% (n=113) had mine accidents/injuries while in another study reported that accident frequency rate in Pakistan was 2.1% while in KPK it is 4.8%. In china for example, it is estimated that more than 6,000 fatalities occur each year in small scale coal mines (Mamuya et al., 2007). Many of these mine are uncertified and having abysmal safety records. Most of these mines are at risk but cannot be abandoned as 50% of china's output is provided by such mines. Another interesting finding in our study is that despite modernization and technology advancement, the workers working in coal mines are using primitive methods of mining. Indicating poor physical and technical standards and use of equipment considered obsolete in this developed world, and leading to less production as well as to high prevalence of occupational injuries and accidents (Mamuya et al., 2007).

5.3.2. Occupational Health Problems Among Cherat Coal Miners

Out of all chest problems assessed during the medical examinations; are related to coal dust exposure during coal mining as reported by Wang and Christiani, (2000) the coal miners showed high prevalence of dry cough (Baur, 2011) and productive cough i.e. n=106 and n=44 respectively as reported by Kang and Kim, (2010) and Vearrier and Greenberg, (2011). n=50 miners complaint of dyspnoea/shortness of breath and only few miners' (n=16) complaint of chest pain as studied by Graber et al., (2011). A study was conducted by Rushton, (2007) in which exposure to coal dust and COPD were reported; in this study there were also coal miners

who had exposure to coal dust and had history of smoking and thus supports findings by having cough and obstructive pattern of diseases (Tables 8, 9, 10 and 11). Hypertension and palpitations as reported by Vearrier and Greenberg, (2011); were n=12 and n=28, respectively; all of these coal miners are needed to be further investigated for major acute and chronic health problems through blood tests, urine tests, Echocardiography (ECG), and exercise tolerance test (ETT) etc. Headache (n=51), Stress / Anxieties (n=50) and Disturbed Sleep (n=35) were also reported. Gastro-Esophageal-Reflex-Disease/ GERD (n=115) is at the top, followed by diarrhea (n=33), the anorexia (n=32), constipation (n=8) and maleena (n=4). As the coal miners are exposed to different kinds of noise due to the various operations in the coal mines; therefore a thorough ear examinations and investigations were done to assess ear and associated problems. The hearing impairment (n=58) is at the peak and showed correlation with findings as reported by Viljoen et al., (2006). Due to exposure to coal dust, silica and improper coal mine ventilation and exhaust systems, nose/throat problems were also reported by coal miners as Nasal Block (n=21), Common Cold/Flu (n=38), Sore Throat (n=16) and Rhinitis/ Rhinorrhea (n=49). Harsh, humid and improper lightening system in coal mines had its impact on coal miner's and thus miner's complaint of dimness of vision (n=53), eye discharge (n=37), eye watering (n=26) and eyes redness (n=24); these findings were also reported by Vearrier and Greenberg, (2011). Interestingly about n=74 coal miners had nail problems, n=43 had foot problems, n=41 had skin allergy, while n=2 had skin discoloration/Vitilago, these findings were also reported by Wood et al., (1999). Due to the presence of various chemicals which shows high bio-accumulation and bio-concentration in human body; therefore coal miners also complain of Dysuria/Burning Micturation (n=18), kidney stones (n=8) and Pyuria/Pus in Urine (n=6) and these findings were also highlighted by Vearrier and Greenberg, (2011) and Hendryx, (2009). In the same study

conducted by Hendryx, (2009); in which health problems were observed in respiratory, heart and kidneys; and all of these findings were confirmed and supported by this study (Table 9). As the coal miners were used to heavy work during coal mining; loading and uploading, therefore Musculo-Skeleton health Problems showed an increased prevalence rate as described by Vearrier and Greenberg, (2011). Apart from the high prevalence, the musculo-skeleton system problems were the major complaints observed in almost all of the coal miners. Body aches (n=101) and knee joint pain (n=48) were the main complaints as were also confirmed by Gallagher et al., (2009); upper limbs/shoulder pain was reported by Bhattacharjee et al., (2007) and was also (n=38) in this study; lower limbs pain (n=22); backache was n=35 and was also reported by Widanarko et al., (2012) and Gallagher et al., (2009). In this study there is high prevalence of pneumoconiosis, and in pneumoconiosis there is reduced bone mineral density and thus the coal miners complaints of body aches and musculo-skeleton problems as reported by Li et al., (2012) and this finding was confirmed by this study in which there was high prevalence of pneumoconiosis and associated muscular and bone pains in the form of upper, lower, backache and body-aches. Apart from these systematic health problems; Fever (n=6), Weight Loss (n=16), Weakness (n=10) and hepatitis (n=4) were also reported by the coal miners (Table 9). A study was conducted by Vearrier and Greenberg, (2011) in which occupational health problems in different systems of the body were assessed i.e. Cardio-vascular effects, Pulmonary effects, Neurological effects, Ophthalmological effects, Renal effects and Musculoskeletal effects; and all these health problems were confirmed in this study (Table 9).

5.3.2.1. Analysis of Pneumoconiosis Among Coal Miners By Pulmonary Function Tests (PFTs)

The PFTs were conducted for 400 coal miners in the medical examinations at the study areas i.e. Shahkot, Jabba tar, Jabba Khushk and Dak Ismail Khel. Before conducting pulmonary function tests; age and height of the coal miners were entered on a designed proforma. The pulmonary function tests showed the following pattern; n=210 (52.50%) showed restrictive pattern of respiratory diseases as studied by Graber et al, (2011) and Kang and Kim, (2010); n=63 (15.75%) showed obstructive pattern of respiratory diseases as studied by Santo Tomas, (2011) and Baur, (2011) and only n=127 (31.75%) showed normal pulmonary function tests. The restrictive pattern of the PFTs can be labeled as having the following health problems; SCWP, CCWP, Silicosis, Tuberculosis, Sarcoidosis, Interstitial, Lungs Diseases, Lung Cancer, Metastatic Lung Diseases as labeled by Graber et al., (2011) and Wang et al., (2007). In SCWP, there is airway obstruction and resistance to respiratory air flow as studied by Yang and Lin, (2009) and these were supported in this study by the changes in the PFTs and restrictive pattern of diseases. FEV(1)% and FEV(1)/FVC ratio is used to measure the air flow limitation i.e. the restrictive pattern, when individuals have exposure to coal dust inside the coal mines as was studied by Wang et al., (2007) and these findings were confirmed and supported by this study which had prevalence of 52.5% (Table 10). In this study, the obstructive disease pattern of the PFTs was found as 15.75% whereas study conducted by Lin et al. (2001) had 52.9% obstructive disease pattern by PFTs. The high prevalence of obstructive disease pattern was also reported by Santo, (2011) and Baur, (2011). The obstructive pattern of the PFTs can be labeled as having the following health problems; Asthma and COPD i.e. Chronic Bronchitis, Emphysema; these findings were also confirmed by Graber et al, 2011 and Santo, (2011). In the same study, which was conducted by Graber et al., (2011) had disordered pulmonary ventilation in 53.3% of coal

miners and these findings were supported by this study; which has high prevalence of restrictive and obstructive diseases (Table 10).

On the basis of restrictive disease pattern of Pulmonary Function Tests, we can assess that 210 (52.50%) of the coal miners may have pneumoconiosis i.e. SCWP or CCWP as analyzed from Table 10.

5.3.2.2. Analysis of occupational respiratory health problems/ Pneumoconiosis among coal miners (400) by chest x-rays (P/A View)

The chest x-rays (P/A View) of 400 coal miners during medical examinations showed the following findings; Micro Nodular Opacities (1 - 5 mm) were found in n=119 (29.75%) of coal miners (Figure 27 a); which was also reported by Onder and Onder, (2009); Bilateral or unilateral Calcifications in n=54 (13.5%), Macro Nodular Opacities (>1 cm), in n=15 (3.75%) of coal miners (Figure 27 b), Hyper Inflated Lung Fields in n=72 (18%) of coal miners (Figures 29 and 30); as reported by Santo, (2011) and Kang and Kim, (2010); and normal chest x-ray findings were observed in (35%) n=140 (Table 11; Figure 28). The hyper inflated lung fields can be labeled as COPD or asthma; has prevalence of about 18% in this study, and thus confirms Baur X, (2011) study which had 5-25% COPD prevalence. On the basis of CXR P/A view findings, the following diseases can be labeled (Table 11); SCWP, CCWP, Silicosis, Tuberculosis, Sarcoidosis, Interstitial, Lungs Diseases, Lung Cancer, Metastatic Lung Diseases, Bronchial Asthma and COPD i.e. Chronic Bronchitis, Emphysema, as labeled and reported by Graber et al, 2011 and Wang et al., (2007). A study was conducted by Goldyn et al., (2008) in which there were findings in lungs parenchymal tissue and had diffuse lung diseases and was confirmed by this study; which showed high prevalence of restrictive diseases on CXR findings

and on PFTs (Table 11). In SCWP, there were micro-nodular opacities as were noticed by Laney and Peterson, (2012); and these findings on CXR were confirmed and supported by this study which had 29.75% (Table 11 and Figure 27 a). In another study conducted by Dos S Antao et al., (2005); which showed 35.4% of rapidly progressive CWP and was confirmed by this study as 29.75% (Table 11 and Figure 27 b). A study was conducted by Santo, (2011); in which there were hyper-inflated lung fields and labeled as COPD, emphysema or asthma; and all these findings were supported and confirmed by this study as shown in Table 11; and Figures 27 c and 27 d. The prevalence of pneumoconiosis as calculated was higher in this study (47%) but it is far less (2-4%) in study of Naidoo et al., (2004) and in other study conducted by Cimrin et al., (2005) in which the pneumoconiosis prevalence was found as 13.5%. In Cimrin et al (2005) study, the prevalence of CCWP was 7.5%; whereas in this study it was approximately 3.75% as shown in Table 11; and Figure 27 b. There was significant and positive association between worked years and respiratory health problems (Table 8, 9, 10 and 11). The prevalence of the occupational pneumoconiosis is also high as there was exposure to coal dust and have clinical presentation of CWP as diagnosed on pulmonary function tests and chest x-rays (Table 10 and 11). So ultimately most of the coal miners contract occupational diseases earlier and end with malignancy or fatal health problems or die prematurely. Leikin et al., (2009) in a study estimated that 2% of coal miners developed CCWP whereas in this study 3.75% of coal miners had SCWP/CCWP or PMF as shown in Table 10 and 11; and Figures 27 b. A study was conducted by Laney et al., (2012) which had higher prevalence of CWP in 3 states (Kentucky, 9.0%; Virginia, 8.0%; West Virginia, 4.8%); but advanced CWP and PMF was more prevalent among them, whereas in this study the prevalence was more high (approx 47%) and had 3.75% of CCWP prevalence as evident from Table 10 and 11; and Figure 27 b.

On the basis of Restrictive Lung Disease findings of Chest X-rays (P/A View), it can be estimated that 188 (47%) of the coal miners may have pneumoconiosis i.e. SCWP or CCWP as analyzed from Table 11.

5.4. Frequency Of Musculoskeleton Health Problems And Its Relation With Demographic Variables Among Cherat Coal Miners District Nowshera Khyber Pukhtunkhwa Pakistan

Musculo-skeleton problems are one of the most common occupational problems experienced by the coal miners. The frequency of musculo-skeleton problems are increasing and are mainly due to awkward posture and unhygienic practices by coal miners due various mining activities.

According to our study results, the frequency of musculo-skeleton problems among coal miners were 61% (n=266) while in international research studies the prevalence calculated was 65.45% and 78.4% (Xu et al., 2011 and Bandyopadhyay et al., 2012). The highest frequency of musculo-skeleton problems as observed were Bodyache n=101, followed by knee joint, and upper limb/shoulder pain while lower frequency were of lower limbs pain as n=22. This showed that the prevalence of musculo-skeleton problems were similar as compared to other countries. Approximately 55.25% (n=221) of the coal miners had 1-8 years of coal mining job and in these coal miners nearly 44.67% (n=109) of musculo-skeleton problems had taken place; in previous studies it was confirmed that there was strong relation between occupational musculo-skeleton problems in initial years of coal mining job.

Our study results revealed that musculo-skeleton problems were more prevalent in less than 30 years ages i.e. 60.23%, and the percentage of musculo-skeleton problems above 30 years age groups were 39.73% while internationally the musculo-skeleton problems were more in age

above 40 years (Bilski, 2003; Xu et al., 2011 and Bandyopadhyay et al., 2012). Our results also show that musculo-skeleton problems are least prevalent in the younger age groups i.e. below 20 years age and between 30-35 years as compared to other age groups. In our study, approximately 54.50% (n=218) of coal miners were not satisfied with their coal mining job and 66.25% (n=265) of coal miners do not have any sort of training regarding coal mining safety measures; and thus having 75% (n=183) and 76.64% (n=187) of occupational musculo-skeleton problems among coal miners; and these relationships were also confirmed and supported in various international studies. In our study, 72.25% (n=289) of the coal miners showed positive history of smoking and 67.62% (n=165) of musculo-skeleton problems occur in these coal miner smokers; the relationship of musculo-skeleton problems and smoking/substance abuse were also revealed in many studies. There is a strong relation between occupational musculo-skeleton problems and compliance of personnel protective equipments. In our study, 51.75% (n=207) of coal miners do not follow the standard personnel protective equipments and thus among these coal miners 52.87% (n=129) had history of occupational musculo-skeleton problems in past which was higher than the international rates of ILO and WHO. As investigated in the national and international research studies the musculo-skeleton problems were increased in later years of coal mining job whereas in our study the frequency was more in early years. The prevalence of musculo-skeleton problems between 25 to 30 years age almost doubled in the age ranges 30 and above as were revealed in various international (Bilski, 2003; Xu et al., 2011 and Bandyopadhyay et al., 2012).

5.5. Frequency Of Ear Problems Among Cherat Coal Miners Nowshera

Ear problems are one of the most common occupational problems experienced by the coal miners. The frequencies of ear problems are increasing and are mainly due to unhygienic occupational environment and noise during various mining activities. According to our study results, the frequency of ear problems among coal miners were 29% (n=116) while in international research studies the prevalence of hearing loss were calculated as 37%, 41% and 58.80% (Madsen et al., 1998; Kurmis et al., 2007 and Landen et al., 2011).

In our study, the highest frequency of ear problems as observed were impaired hearing 50% (n=58), followed by ear pain/ Otagia, and ear blockage while lower frequency were observed for tinnitus (n=11) and ear discharge (n=7). Coal miners are exposed to different kinds of noise due to the various operations in the coal mines; the hearing impairment was at the peak; 50% (n=58) and showed correlation with findings as reported in previous international studies (Viljoen et al., 2006).

Approximately 55.25% (n=221) of the coal miners had 1-8 years of coal mining job and in these coal miners nearly 59.48% (n=69) of coal miners gave positive history of ear problems; as revealed in previous national and international studies that there was strong relation between occupational ear problems in early and late years of coal mining job (Sulkowski et al., 2007). Our study results revealed that frequency of ear problems were more prevalent in less than 30 years ages i.e. 67.24%, and the percentage of ear problems above 30 years age groups were 32.76% while internationally the ear problems were approximately 30-43% among coal miners (Kurmis et al., 2007 and Landen et al., 2011). Our results also show that frequency of ear

problems were least prevalent in the younger age groups i.e. below 20 years age and between 30-35 years as compared to other age groups.

In our study, approximately 54.50% (n=218) of coal miners were not satisfied with their coal mining job and 66.25% (n=265) of coal miners had not any sort of training regarding coal mining safety measures; and thus having 57.76% (n=67) and 62.93% (n=73) of occupational ear problems respectively; and these relationships were also confirmed and supported in various international studies. In our study, 72.25% (n=289) of the coal miners gave positive history of smoking and 35.34% (n=41) of ear problems occur in these coal miners; and found that there was no strong relationship between high frequency of ear problems and smoking; which was supported by various international research studies. There was strong relation between high frequency of occupational ear problems and compliance of personnel protective equipments. In our study, 51.75% (n=207) of coal miners did not follow the standard personnel protective equipments and thus among them 67.24% (n=78) had history of occupational ear problems in past which was higher than the international rates of ILO. As investigated in the national and international research studies, the frequency of ear problems were high and more in later years of coal mining job whereas in our study the frequencies were similar in all age groups although 20-25 years age group had highest percentage (42.24%). The prevalence of ear problems in less than 20 years age group almost doubled in the age ranges 30-35 as were revealed in various international (Sulkowski et al., 2007).

5.6. Factors Associated With Occupational Injuries Among Cherat Coal Miners Of District Nowshera Khyber Pukhtunkhwa Pakistan

In various international studies there were positive relationship between injuries and young age of coal miners along with early years of life and thus these findings were confirmed in our study in which there were more than 65.74% (n=119) of occupational injuries among miners having age less than 30 years (Margolis, 2010; Paul et al., 2007 and Khanzode et al., (2012). Approximately 221 (54.25%) of the coal miners had 1-8 years of coal mining job and in these coal miners nearly 63.54% (n=115) of coal mining injuries and accidents had taken place; in previous studies it was confirmed that there was strong relation between occupational injuries and initial years of coal mining job (Paul et al., 2007; Khanzode et al., (2012) and Breslin et al., 2008). The mean job duration was 8 years with standard deviation of ± 1.12 .

In our study, 72.25% (n=289) of the coal miners showed positive history of smoking and 78.48% (n=142) of injuries occur in these coal miner smokers; the relationship of coal mining injuries and smoking/substance abuse were also revealed in Khanzode et al., (2012). In study of Poplin et al., (2008); a strong relation was found between occupational injuries and compliance of personnel protective equipments; in our study, 51.75% (n=207) of coal miners do not follow the standard personnel protective equipments and thus among these coal miners 71.27% (n=129) had history of occupational injuries in past which was higher than the international rates of ILO and WHO.

In our study 54.50% (n=218) of coal miners were not satisfied with their coal mining job. Approximately 66.25% (n=265) of coal miners do not have any sort of training regarding coal mining safety measures and 77.75% (n=311) do not have any knowledge/education regarding occupational safety and health measures and thus having 70.17% (n=127), 81.77% (n=148) and

85.08% (n=154) of occupational injuries among coal miners respectively; and these relationships were also confirmed and founded in various international studies (Paul et al., 2007; Khanzode et al., (2012) and Breslin et al., 2008). Beside these factors the coal miners belong to low socioeconomic status, less income and thus most of these coal miners were illiterate and poor and thus were not following the adequate protective measures.

5.7. Risk Factors associated with Occupational/ Respiratory Health Problems and Pneumoconiosis among Coal Miners

From the detailed research study, the following risk factors were found to have been associated with occupational/ respiratory health problems and Pneumoconiosis.

In most of the questionnaires there were more than 3–5 risk factors which contribute to the development of occupational respiratory health problems and Pneumoconiosis.

5.7.1. Age of coal miners

The ages of coal miners are directly proportional to respiratory health problems and pneumoconiosis. In less than 20 years only 5 (2.4%) has respiratory problems as compared to 36 and above years age which has 88 (42.8%) of respiratory health problems. Therefore the older the age of the coal miner, the more is the exposure to coal dust during coal mining, and thus causing more respiratory health problems as well other systemic problems (Table 8, 9 10 and 11).

5.7.2. Duration of coal mining job / Coal dust exposure years

The duration of coal miners job are also directly proportional to respiratory health problems and pneumoconiosis. The greater the duration of job, greater is the exposure to coal dust and vice versa. Coal miners having duration of job i.e. 1 – 3 Years have only 18 (8.7%) of the respiratory health problems or pneumoconiosis as compared to 99 (47.6%) who have 15 and above years of duration of coal mining job. If the coal miners have exposure to coal dust then causes respiratory health problems and pneumoconiosis among coal miners (Table 8, 9, 10 and 11).

5.7.3. Working hours per day per week

The coal miners also work for more than 8 hours per day or 60 – 70 hours per week which is also above the ILO/WHO standards (40-48 hours per week) and thus respiratory health problems and Pneumoconiosis are more among these coal miners.

5.7.4. Socio-economic status of coal miners

Most of the workers belong to Swat (Shangla) and a few from Nowshera and Dir Districts and the trend of coal mining runs in particular low socio-economic families and they bring their friends relatives and thus the cycle repeats itself. Due to the large family size and economic crises these young, new coal miners have early exposure to coal mine dust/silica as compared to other jobs and thus they ultimately ends up with a debilitating health problems and remains burden on their community or have pre-mature death due to consequences of coal mining hazards. Some of the coal miners are above 40-50 years of age and thus they earn money

for their families and children. Interestingly most of the coal miners who were married have 6-8 children which compel them to work and earn under dangerous coal mining environment.

5.7.5. Smoking history of coal miners

The smoking history among coal miners is also directly proportional to respiratory health problems, pneumoconiosis and other systemic problems like CNS problems, GIT problems etc. Out of 208 respiratory problems among coal miners, 176 (84.6%) of them are associated with smoking, while only 32 (15.4%) of the respiratory problems have no relations with smoking.

5.7.6. Pre-placement medical examinations

The importance of pre-placement medical checkup and examination cannot be ignored because the pre-placement medical examination helps in the assessment of health status of coal miners at the initial stage and thus helps us in the prevention and screening of respiratory and other systemic health problems.

5.7.7. Periodic medical examinations

The periodic medical examination has also importance due to early diagnosis and management of simple coal worker pneumoconiosis and other systemic health problems and thus one can substitute, replace his or her job and prevents the consequences of further exposure to hazardous coal mine dust. Although there is a dispensary for first aid as well for consultation, but the coal miners do not bother to visit for any health consultancy. Because if they work, they would be provided money and which is given to coal miners on the basis of amount of coal they brought to the surface opening of coal mines. Regular health surveillance is essential to ensure health of coal mine workers. In our study we found that routine medical checkup of miners is

also a highly neglected area. Only 13% had some sort of medical examination during their work period. Literature revealed the importance of regular health assessment that helps in not only in early detection of dust related respiratory illness but also to ascertain physical fitness of the miners in accordance with the nature of their jobs (Ashraf et al., 2005 and Saddiq, 2003).

5.7.8. Dust control measures

Proper, effective and adequate dust control measures also help in the prevention and control of coal dust in mines and thus prevent respiratory and other systemic health problems.

5.7.9. Ventilation of coal mines

The ventilation of the coal mines helps in the reduction in concentration of coal mine dust and thus coal miners have less exposure to air borne coal dust and ultimately less risk of respiratory health problems. There were no dust control measures inside coal mines except internal ventilation between adjacent mines and exhaust system which sucks the inside coal mine air.

5.7.10. Personal Protective Equipments PPEs

The personal protective equipments like face masks, Helmets, shoes, ear plugs, gloves and goggles etc has enormous importance and significance in the prevention of occupational hazards like pneumoconiosis. If there is free provision of PPEs and coal miners show positive compliance regarding usage of PPEs then there is less risk of developing respiratory health problems and pneumoconiosis. In most of the cases, neither the coal managers/owners have given importance to PPEs nor the coal miners show positive behavior regarding practice of PPEs during coal mining.

5.7.11. Regular coal mine surveillance/ Monitoring

Proper and strict surveillance and monitoring measures help in the prevention of respiratory health problems and other occupational diseases among coal miners. Mines inspection is an important pre-requisite to implement and monitor health and safety standards. Only 29% recalled any short of inspection by the government authority during work period. Responses to the nature of inspection were varied. These findings are comparable to national data and also reported from India, China, Vietnam and Poland. (Saddiq, 2003)

5.7.12. Underground coal mining

In comparison to the surface coal mining, underground coal mining has greater risk of respiratory health problems and pneumoconiosis among coal miners due to absence of free environment and air, which helps in the ventilation of coal dust, because if there are proper dust control measures, then it is impossible to cause respiratory health problems among coal miners. In Cherat coal mines also there is no proper monitoring and surveillance regarding the PELs of coal mine dust, which contains the silica, culprit of all respiratory health problems, and thus coal miners work under these hazardous mine environment.

5.7.13. Previous medical or surgical problem/s

If the coal miner has already some pre-disposing medical or surgical problems; then he/she is at greater risk of developing respiratory or other systemic health problems.

5.7.14. Type of coal mine work

The coal miners work under great stress/physical work, not knowing the importance of face-mask, ear plugs, goggles, gloves and shoes. Thus physical and chemical hazards are more common in them. The owners and managers also do not strictly obey the ILO and mine act regulations; and thus coal miner's work under these dusty environments which is a serious potential health threat.

CHAPTER # 6

CONCLUSIONS AND RECOMMENDATIONS

This environmental epidemiological study concludes that impacts of occupational and para-occupational determinants like coal geochemistry, hazardous minerals in coal and coal dust, heavy metals in coal and coal dust, their confirmation by XRD and SEM; and high prevalence of health hazards identified strong relationships between environmental exposures and hazardous problems among coal miners of Cherat, District Nowshera, Pakistan.

The raw coal samples investigation revealed the presence of Cr, Zn, Pb, Cu, Co, Ni and Cd, having significant values of; 2.7-74.1ppm, 6.3-26.1ppm, 17.2-42.1 ppm, 5.4-40.0ppm, 1.5-20.3ppm, 0.7-18.4ppm, and 1.1-5.1 ppm respectively. The XRD analysis of the Coal samples revealed major mineral groups of quartz, calcite, and kaolinite as were confirmed and investigated by Scanning Electron Microscopy (SEM), X-Ray Diffractometry (XRD) and Energy Dispersive X-ray (EDX) method in coal mine air dust samples collected from the study areas. The coal samples investigated from the study areas of coal mines showed presence of crystalline silica, in the form of silicon dioxide (SiO_2) in various groups of minerals along with other mineral particles, and that might be the factor responsible for high prevalence of pneumoconiosis and silicosis among the coal miners.

The assessment of air quality of the occupational environment was not in accordance with the International standards, and thus the concentration of coal mine air dust was greater than the permissible exposure limits (PELs); and therefore had potential effects on the health of coal miners. The results of all particulate matter samples analysis indicated that the environmental air quality in coal mines exceed the permissible exposure limits (PELs) compared to international

standards ($150 \mu\text{g}/\text{m}^3$). In some coal mines, even the Particulate Matter (PM^{10}) concentrations were higher than international standards of Occupational Safety and Health Administration/World Health Organization/ International Labor Organization/American Conference of Governmental Industrial Hygienists. Interestingly in our study all 24 samples exceed the national and international standards. The Scanning Electron Microscopy (SEM) and X-Ray Diffractometry (XRD) methods confirmed that the collected coal mine air dust samples had toxic minerals. Moreover, Coal mine air dust was responsible for various health problems among coal miners. The atomic absorption spectroscopy of the coal mines air dust samples revealed the presence of several heavy metals as were confirmed in the coal samples of the study areas. The heavy metals concentration detected in coal mine air dust was more as compared to heavy metal concentrations in coal samples; this may be due to various causes responsible for health problems among the coal miners.

The overall situation of occupational safety and health was discouraging and coal miners were at risks and showed signs and symptoms of various systemic health problems among coal miner's i.e. pulmonary hazards, lung cancer, pneumoconiosis and hazards involving most of the systems of the body.

On the basis of conclusions and results, I recommendations the following suggestions:

- The coal mines and workers are one of the neglected communities and needs proper and immediate attention of the concerned authorities.
- Awareness among the coal miners regarding heavy metals and toxic minerals along with the health problems should be created and should be educated that how they could

prevent themselves by adopting different protective measures along with legislative, medical, and engineering measures.

- Modern technological procedures may be adopted during coal mining and other processing, thus coal miners be educated adequately regarding occupational health and safety measures and health hazards.
- Pre-placement and periodic medical examinations of coal miners should be adopted.
- Regular and strict surveillance and monitoring of coal mines be conducted by the concerned authorities.
- Proper and effective dust control measures be implemented and followed like prevention of coal dust generation, prevent coal dust from becoming airborne, proper and effective natural and mechanical ventilation, exhaust system, water sprays, water infusion technique and to dilute coal dust as soon as possible etc.
- The Coal mines managers and concerned departments should constitute measures to reduce the burden of high mortality and morbidity.
- Proper approval and registration from the mining department should be compulsory for coal mining.
- Arrangements of seminars and training sessions among coal miners and public, regarding occupational hazards prevention and control.
- There should be communication of vital data regarding occupational health problems among coal miners and thus a coordinated effort from all concerned departments will help the decision makers and researchers during planning.

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