Respirable dust and quartz exposure at coal fired power stations in the Mpumalanga Province during 2012 - 2015

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Student Declaration

I, Sandile Nkosinathi Knowledge Mabanga declare that this Research report is my own, unaided work. It is being submitted for the Degree of Master of Public Health: Occupational Hygiene at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

Signature: ____________________________

______________ Day of ______________ 20_______ in ___________________________

Dedication

This research report is dedicated to the Almighty God, my keeper. To my parents, Mr. and Mrs. Mbango and Phumleleni Mabanga for their undying love and support. To my dear wife, Mrs. Philippine Mabanga for being my pillar of strength throughout this research project. To my children, Asanda, Amahle, Olwethu and Oluhle. To my former lecturer, Joy Kistnasamy for instilling in me self-belief and for being my source of inspiration.

Abstract

Introduction

Exposure to respirable crystalline silica (commonly known as quartz) is primarily from dust containing quartz which occurs in a variety of occupational settings. The occupational setting in which dust containing quartz occurs includes: quarry and mining, mineral processing, foundry, construction, ceramic, and brick and tile industries.

The International Agency for Research on Cancer (IARC) classified quartz as a human carcinogen. Occupational exposure to respirable quartz is a well-established hazard in mining, sandblasting, foundry work, agriculture, and construction, but not in power station processes. The coal handling process at power station involves activities such as coal stock piling, coal conveying and coal pulverising which generate coal dust. It is during these activities where occupational exposure to coal dust may occur among workers.

Objectives

The overall objective of this study was to determine if workers at coal fired power stations in Mpumalanga province are exposed to respirable coal dust and quartz at levels above the Department of Labour's Occupational Exposure Limit (DoL OEL) 2mg/m^3 for respirable coal dust and 0.1mg/m^3 for quartz, Occupational Safety and Health Administration Permissible Exposure Limit (OSHA PEL) 2.4mg/m^3 for respirable coal dust and 0.05mg/m^3 for quartz and American Conference of Governmental Industrial Hygienists Threshold Limit Value (ACGIH TLV) 0.025mg/m^3 for quartz.

Methods

The study used a retrospective record review of respirable dust and quartz data collected from seven coal fired power stations during a 4-year period (2012 to 2015). The study analysed this secondary occupational hygiene data collected by the occupational hygiene officers working in the selected power stations.

Results

One site (PS6) had the highest mean respirable quartz concentration (0.036) and a median value of 0.03mg/m^3 which exceeded the TLV of 0.025mg/m^3 but was within the OSHA PEL of 0.05mg/m^3 and DoL OEL of 0.1mg/m^3. The site PS1 had the lowest mean respirable quartz concentration of 0.017mg/m^3 and a median value of 0.01mg/m^3.

Out of all occupations 7.31% (n=55) were exposed to quartz concentrations equal to or exceeding the DoL OEL of 0.1mg/m^3 and 29.39% (n=221) of all occupations exceeded the ACGIH TLV of 0.025mg/m^3 but were below the DoL OEL 0.1mg/m^3. Only 4.63% (n=35) of all occupations were exposed to respirable dust concentrations equal to or exceeding the DoL OEL of 2mg/m^3. Majority of all occupations 95.37% (n=721) were below the DoL OEL.

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Nomenclature

ACGIH - American Conference of Governmental Industrial Hygienists

ANOVA - Aanalysis of Variances

DoL – Department of Labour (Department of Labour)

NIOSH - National Institute of Occupational Safety and Health

OEL - Occupational Exposure Limit

OEL-TWA - Occupational Exposure Limit-Time Weighted Average

OHS Act - Occupational Health and Safety Act (Act 85 of 1993)

OSHA - Occupational Safety and Health Administration

PEL - Permissible Exposure Limit

SAIOH - South African Institute for Occupational Hygiene

SANAS - South African Accreditation System

TLV - Threshold Limit Value

TLV-TWA - Threshold Limit Value-Time Weighted Average

XRD - X-ray diffraction

CHAPTER 1

1. INTRODUCTION

This chapter describes coal dust exposure as an occupational hazard, as well as the short description of a coal power plant process. International as well as South African perspectives with regards to coal dust exposure and silicosis in other dust generating industries and power plants are briefly discussed. It further states the reason for this research.

1.1. Background

Several million people around the world are presently employed in the extraction and processing of coal and other minerals. Thus, these workers are potentially exposed to the hazardous respirable mineral dust from these occupational settings (Miller *et al.*, 2015). Coal dust contains calcium, magnesium, aluminium, iron and has up to 10% of free crystalline silica quartz (Grové *et al*., 2013, Miller *et al.*, 2015). The free quartz content is the most hazardous of all these substances and therefore there is a need to establish the exposure to respirable quartz from coal dust at power stations (Grové *et al*., 2013, Miller *et al.*, 2015).

Silica or silica dioxide (SiO_2) is a group of metal oxide, which occurs naturally in both crystalline and amorphous forms. The various forms of crystalline silica are alpha and beta quartz, cristobalite, tridymite, coesite, stishovite and moganite (NIOSH, 2012). The most abundant form of silica is alpha quartz and the term quartz is interchangeable with the general term crystalline silica (NIOSH, 2012). Mineral dust particles, such as quartz particles, are typically described by diameter size and aerodynamic diameter. Both characteristics are important in determining whether the particle is respirable (IARC, 1997). Respirable fraction is defined as a sub fraction of the inhaled particles with a diameter of less than 10µm, that penetrates the alveolar region of the lung and it is pertinent to the development of chronic diseases such as pneumoconiosis and emphysema (Grové *et al*., 2013).

Analysis for airborne quartz is usually by X-ray diffraction or infrared spectrophotometry in combination with filter collection methods (IARC, 1997). Dust levels can be based on counts on mass collected on a filter through a cyclone (IARC, 1997). Currently the filter collection method is more commonly used nationally and in most counties international countries and requires that, the sample be restricted to the respirable fraction (IARC, 1997). The estimated detection limit for quartz in respirable dust sample is 0.002mg/m^3 using the US National Institute for Occupational Safety and Health (NIOSH) method 7500 for X-ray powder respirable dust samples with NIOSH method 7602 for infrared absorption spectrophotometry is also 0.003mg/m^3 (NIOSH, 1994).

Exposure to respirable crystalline silica or quartz is primarily from dust containing quartz which occurs in a variety of occupational settings (Scarselli *et al*., 2014). The main occupational settings in which dust that contain quartz occurs includes activities where earth moving is involved, such as mining, quarrying, farming, construction, as well as activities that involves handling and or use of sand or coal and other silica containing mineral processing such as foundries, construction, ceramic production, gas fracking, brick and tile industries (Scarselli *et al*., 2014).

The International Agency for Research on Cancer (IARC) classified quartz as a human carcinogens (Finocchiaro *et al.*, 1997) and other lung diseases such as chronic bronchitis and emphysema (Naidoo *et al*.,2006). The health risks associated with quartz dust increase with the quantity and duration of exposure. The American Conference of Governmental Industrial Hygienists (ACGIH) has placed the 8-hour working exposure Threshold Limit Value – Time Weighted Average (TLV-TWA) for quartz to be 0.025mg/m^3 (ACGIH, 2014), the British Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 0.05mg/m^3 for respirable crystalline silica, as an 8-hour Time Weighted Average (TWA). In South Africa, the Occupational Health and Safety Act 85 of 1993 (OHS Act), Hazardous Chemical Substances Regulations of 1995 as amended has published a Time Weighted Average Occupational Exposure Limit (TWA-OEL) of 0.1mg/m^3. These limits are based on an 8-hour work shift of a 40-hour workweek time-weighted average (TWA) exposure that an employee may be exposed to for a working lifetime without adverse health effects.

Occupational exposure to respirable quartz is a well-established hazard in mining, sandblasting, foundry work, agriculture, and construction, but not in power station processes (Finocchiaro *et al*., 1997). The coal handling process at power stations involves activities such as coal stock piling, coal conveying and coal pulverising which generate coal dust. It is during these activities where occupational exposure to coal dust may occur among workers (Finocchiaro *et al*., 1997).

According to the Eskom website (accessed 18 April 2015) In South Africa, most of the electricity is generated from thermal power stations, fuelled by coal. Most of these coal fired power stations comprise of six generating units, with each production unit having a boiler, a turbine that drives a generator and auxiliary support systems.

The main source of exposure to coal dust at a power station is the coal handling plant which comprises of a coal truck or train weighbridge, coal stock yard, coal conveyer systems, coal bunkers and coal pulverising. Although the process of producing electricity from coal is complex (see Figure 1). The basic principle is that, coal combustion heats water in the boiler to produce steam that drives the turbine (Eskom, 2015). To properly fire the boiler, the coal is pulverised to a fine powder in giant grinding mills. This is because pulverised coal burns quickly, like gas (Eskom, 2015). The powdered coal is blown into the boiler furnace where it burns. The boiler is lined by a network of thousands of tubes filled with water, and it has been designed to use the energy released by the burning coal to heat water as efficiently as possible to produce superheated steam that turns the turbine (Eskom, 2015). In the turbine, kinetic energy from the steam is converted to mechanical energy which turns the generator that converts the energy to produce electricity (Eskom, 2015).

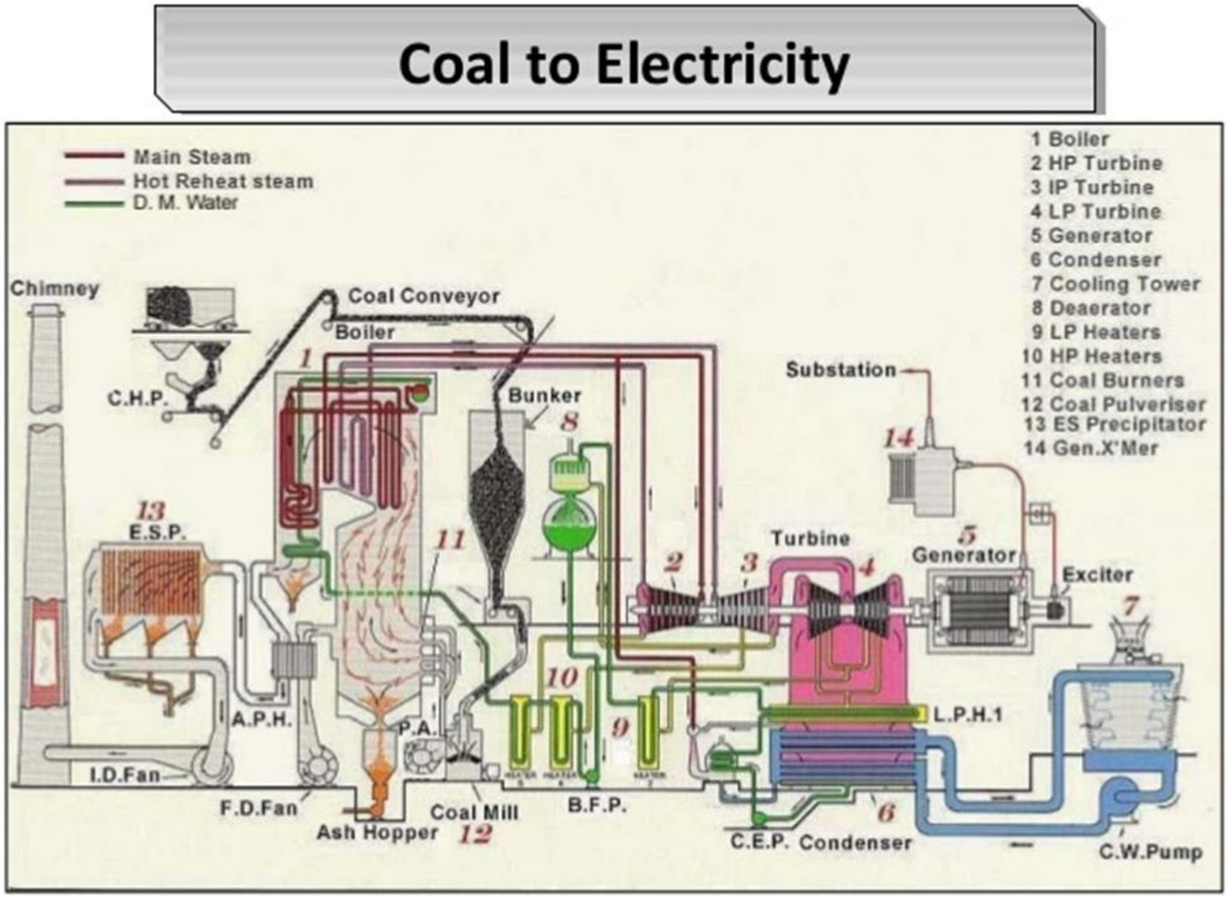

Figure 1: Typical process flow diagram for a coal fired power station

Source: http://www.tsasales.com/wp-content/uploads/2013/02/fig1-coal-fired-power-plant.jpg

There are multiple hazardous chemicals used or produced in a coal fired power station Sulphur dioxide, silica, arsenic, ammonia, and respirable dust are just a few examples (Bird *et al*., 2004). Workers are at risk of exposure to these chemicals during daily activities at coal fired power stations and respirable dust exposure is one that is important to monitor. In a power station, there are two main types of respirable dust, namely fly ash and coal dust. Fly ash and coal dust are both by-products of coal but may primarily be produced at different stages of electricity generation (Bird *et al*., 2004). Coal dust is found in areas where coal is present before the boiler, for example the coal stock yards, conveyor belts, coal milling or pulveriser. Fly ash is found in areas after the boiler, for example the bag house or electro-static precipitators.

Coal dust causes a variety of lung diseases including pneumoconiosis, bronchitis and emphysema. These diseases are generally chronic in nature, but even acute exposures can cause respiratory distress (Groneberg *et al*., 2006). There is a concern that several workers in the different coal handling processes of the power station can be exposed to unhealthy amounts of coal dust.

Approximately 80 employees are involved in the coal processing plant or operate equipment used for coal transport in each power station. These employees can be stratified into three main job categories.

- Maintenance
- Plant operators
- Cleaners

The power station can also be divided into three major areas; coal plant (including coal stock yard), power plant and ash handling plant. The coal plant consists of a series of conveyor belts, coal storage areas and coal bunkers. In some power stations the coal storage may be a horizontal structure known as a coal stathe or a vertical structure known as a coal silo. Although these structures may be different, they primarily serve the same purpose and operate the same in principle.

Employees are exposed to coal dust at various points of the coal plant. These include the coal stock piles while unloading the coal from transport vehicles, either trucks or train onto the first set of conveyor belts. From this point coal is transported by the belts into coal stathes or silos and via an incline conveyor belts into coal bunkers where it drops through chutes or feeders into the pulveriser where it is crushed to the proper size to enter the boiler.

Employees who are potentially exposed to coal dust are classified into three groups, namely, Plant operator; Maintenance and Cleaners. For this study, only thirteen different tasks were sampled to determine coal dust exposure. The tasks and job categories are identified in Table 1 and further explained below.

Table 1: Job task and categories at the coal plant with hours of exposure.

Job Category	Job Task	Shift Length (Hrs)
Plant operator	Spotter	8
Plant operator	Weight Bridge Plant operator	8
Plant operator	Supervisor	8 – 12
Plant operator	Belt Plant operator	8
Plant operator	Coalers	8
Plant operator	Yellow Plant operator	8-12
Maintenance	Artisan: Mechanical	8-12
Maintenance	Utilityman: Mechanical	8-12
Maintenance	Artisan: Electrical	8
Maintenance	Utilityman: Electrical	8
Cleaner	Weight bridge Cleaning	8
Cleaner	Conveyor belts Cleaning	8
Cleaner	Coal bankers Cleaning	8

Spotters

Spotters spend most of their shift at the coal stock piles assisting heavy equipment Plant operators (examples of these heavy equipment) by directing traffic of moving trucks while offloading coal. They also must ensure that, the truck buckets are empty and signal to the truck or train driver to move along.

Figure 2: Coal stockyard spotter doing inspections on the ground

Weigh Bridge Plant operator

The weigh bridge Plant operator sits in the operating room next to the weigh bridge with wide open window where he exchanges the coal manifesto documents with the truck driver. The weigh bridge Plant operator occupationally goes out of the operating room to assist the truck driver to position the truck correctly onto the weigh bridge.

Figure 3: Coal stockyard Weighbridge and Plant operator cubicle

Supervisor

The supervisors' duties are to ensure that all employees are properly doing their jobs in the coal stock yard. They are in various locations during different shifts, depending on the activities of the day.

Belt Plant operators

The responsibility of the belt Plant operators is run and stop conveyor belts that transport coal to and from various location. They have to do walk through inspections along the belts to identify and report any defects and potential problems on the conveyer system.

Figure 4: Belt Plant operator at the control panel

Coalers

Coalers operate tripper cars which funnel coal from different sections of the coal stathe onto different conveyer belts and ensure that coal is poured evenly into the coal bunkers from the conveyer belt.

Figure 5: Coaler operating tripper car to load coal bunker

<u>Yellow Plant operator</u>

The yellow plant operators are responsibility for operating the mobile plants such a bulldozer, frontend loader and compactor. They are responsible for pushing the coal onto the storage pile or to the feeders, which drop coal onto the conveyer belts.

Figure 6: Front end loader stock piling at coal stock yard

Figure 7: Compactor maintaining road surface for trucks at the coal stock yard

Maintenance workers

Mechanical and Electrical artisans assisted by their Utilityman can be the most complex exposure group because there are a wide variety of work tasks done. Mechanical utilityman and artisan are responsible for repairs of mechanical components of the plant including conveyer belt pullies and tensioners, valve and gearbox repairs and replacement, while electrical maintenance staff are responsible for repairs on electrical components of the plant such switch gears, control panels and electric motors.

Figure 8: Mechanical Maintenance worker inspecting a fault on the conveyor system

Cleaners

The cleaners are at various locations of the coal plant i.e. weigh bridge, conveyer belts and coal bunkers. Their task includes removing coal and debris from walkway, belts, and coal buildings. The cleaners primarily use shovels and push brooms to clean down the buildings.

Figure 9: Cleaner sweeping coal underneath a conveyor belt

1.2. Literature Review

1.2.1. International Perspective

Due to the extensive natural occurrence of crystalline silica in the earth's crust and the wide uses of materials in which it is a constituent, workers may be exposed to crystalline silica in a large variety of industries and occupations (IARC, 1997). Table 2 lists the main industries and activities in which workers could be exposed to crystalline silica. This list includes earth moving activities (e.g. mining, farming, construction, quarrying), as well as activities including the handling or use of sand and other silica containing products (e.g. foundry processes, coal fired power plant processes, furnace installation, abrasive blasting, production of glass, ceramics, abrasives, cement, etc.)

Table 2. Main activities in which workers may be exposed to crystalline silica (IARC, 1997)

Industry/Activity	Specific Operation/task	Source material
Agriculture	Ploughing, harvesting, use of machinery	Soil
Mining and related milling operations	Most occupations (underground, surface, mill) and mines (coal, metals and non-metals)	Ores and associate rock
Quarrying and related milling operation	Crushing stones and sand and gravel processing, monumental stone cutting and abrasive blasting, slate work, diatomite calcination	Sandstone, granite, flint, sand. Gravel, slate, coal
Construction	Construction of buildings, roads, tunnels, Abrasive blasting of structures.	Sand, Concrete, Rocks
Glass, Including fiberglass	Raw material processing Refractory installation and repair	Sand, crushed quartz Refractory materials or
Cement	Raw materials processing	Clay, sand, limestone, diatomaceous earth
Abrasives	Silicon carbide production Abrasive products fabrication	Sand Tripoli, sandstone
Ceramics, including bricks, tiles, sanitary ware, porcelain, pottery, refractories, vitreous enamels	Mixing, molding, glaze or enamel spraying, finishing.	Clay, shale, flint, sand, quartzite, diatomaceous earth

Industry/Activity	Specific Operation/task	Source material
Iron and steel mills	Refractory preparation and furnace repair	Refractory material
Silicon and Ferro-silicon	Raw materials handling	Sand
Foundries (ferrous and non-ferrous)	Casting, shaking out Abrasive blasting, fettling Furnace installation and repair	Sand Sand Refractory material
Metal production including structural metal, machinery, transportation equipment	Abrasive blasting	Sand
Shipbuilding and repair	Abrasive blasting	Sand
Rubber and plastics	Raw material handling	Fillers (Tripoli, diatomaceous earth)
Paint	Raw material handling	Fillers (Tripoli, diatomaceous earth)
Soaps and cosmetics	Abrasive soaps, scouring powders	Silica flour
Asphalt and roofing felt	Filling and granule application	Sand and aggregate, diatomaceous earth
Agricultural chemicals	Raw material crushing, handling	Phosphate ores ad rock
Jewelry	Cutting, grinding, polishing, buffing	Semiprecious gems or stones, abrasives
Dental material	Sandblasting, polishing	Sand, abrasives
Electricity generation (Coal boilers)	Coal processing and milling Ash handling	Coal dust Fly ash
Automobile repair	Abrasive blasting	Sand
Boiler scaling	Coal-fired boiler	Ash and concretions

Estimates of the number of workers potentially exposed to respirable crystalline silica have been developed by the NIOSH in the USA and by CAREX (CARcinigen Exposure) in Europe. Based on the NIOSH national occupational exposure survey, conducted during 1981 to 1983, it is estimated that about 1.7 million workers in the USA were potentially exposed to respirable dust and silica (NIOSH, 2002). CAREX database on occupational exposure to known and suspected carcinogens collected during 1990 to 1993, estimates that more than 3.2 million workers in the then 15-member state of the European Union were exposed to respirable crystalline silica above the permissible exposure limit.

In a study conducted by (Bird *et al*., 2004) at a coal fired power station in Pennsylvania, West Virginia, it is said that power station workers involved in plant operation activities such as coal conveyors, stock piling and coal pulverising were exposed to airborne coal dust and airborne exposures were likely to occur during some work activities and processes of coal handling. The respirable fractions of coal dust have a relatively small particle size, ranging between 2 μm and 10 μm. The presence of detectable quartz in the airborne coal dust, together with elevated dust concentrations encountered in some power plant work areas, could present the risk of silicosis and other adverse health effects, such as lung cancer, in chronically exposed workers (Bird *et al*., 2004). A National Institute for Occupational Safety and Health (NIOSH) report evaluating occupational safety and health implications of the increased use of coal in the United States concluded that coal dust is amongst other potential occupational hazards in coal fuelled power plants (Bird *et al*., 2004). This study also reported an overexposure to respirable coal dust from the Instrument and Control (I&C) SEG with an exposure of 5.3mg/m^3 which exceeded the OSHA's PEL of 2.4mg/m^3 (Bird *et al*., 2004).

In a study conducted by Hicks and Yager (2006), on airborne concentrations of respirable crystalline silica in fly ash during normal operations at various coal fired power stations in California found that, airborne concentrations of respirable quartz in fly ash during activities exceeded the then current TLV of 0.05 mg/m^3 in 41% of the air samples, and 54% exceeded the current TLV of 0.025 mg/m^3. The study also revealed that the highest airborne fly ash concentrations are encountered during maintenance activities: 0.008mg/m^3 to 96mg/m^3 (mean of 1.8mg/m^3). This group exceeded the TLV of 0.05mg/m^3 as it was in 2006 in 60% of the air samples (Hicks and Yager, 2006). During normal production activities, airborne concentrations of crystalline silica in fly ash ranged from nondetectable to 0.18 mg/m^3 (mean value of 0.048 mg/m^3). Air samples collected during these activities exceeded the previous (0.05mg/m^3) and current (0.025mg/m^3) TLVs in approximately 54% and 65% of samples, respectively (Hicks and Yager, 2006).

1.2.2. South African Perspective

Inadequate dust control and high disease rates in traditional “silica industries” in South Africa cause a potentially serious silicosis problem (Rees, 2006, Rees *et al*., 1992). The elimination of silicosis is an important public health issue for South Africa because of the strong association between silicosis and TB, combined with the HIV epidemic (Motshelanoka, 2006, Rees *et al*., 1992). Silicosis is common in industrial workers and gold miners, with an attendant high TB risk (Motshelanoka, 2006). Silicosis has long been associated with non-mining industries in other countries; however, there has been a scarcity of studies regarding silica dust exposure in South Africa.

The South African Department of Labour’s (DoL) initiatives to plug the scourge of silicosis brought about the introduction of the National Programme for the Elimination of

Silicosis in 2004 (Rees, 2006), the reduction of Department of Labour's Occupational Exposure Limit (DoL OEL) for silica dust from 0.4 mg/m³ to 0.1 mg/m³ in 2008 (Department of Labour, 2010), and the commissioning of various research projects to establish the extent of workers' exposure to silica dust in non-mining industries.

There is limited toxicology and epidemiologic data concerning the potential of silicosis and possible lung cancer hazards associated with coal dust exposures at a power station as most studies emerge from the coal mining environment (Naidoo *et al*., 2006). Potential silica exposure at power stations has been widely documented nationally and internationally as emanating from coal fly ash. Coal fly ashes are complex particles of a variable composition, which is mainly dependent on the combustion process, the source of coal and the precipitation technique. Toxic constituents in these particles are metals, polycyclic aromatic hydrocarbons and silica. Epidemiological studies in coal fly ash exposed working populations have found no evidence for effects commonly seen in coal mine workers (pneumoconiosis, emphysema) except for airway obstruction at high exposure (Naidoo *et al*., 2006). Studies have shown that when compared with coal dust, coal fly ash has lower silica quartz content and may pose a lower risk of health effect. Coal dust poses a greater toxicity, although fly ash does appear to have some potential of causing tissue damage at high levels of exposure (Hicks and Yager, 2006).

Coal dust exposures occurs at various locations and during various tasks routinely performed at power stations, which can be easily divided into maintenance and normal production activities (Hicks and Yager, 2006). Normal production activities are primarily associated with normal day-to-day operations, including coal delivery, stock piling, lashing of coal stathes, coal conveyer and bunker operation and coal milling (pulverising) (www.eskom.co.za, 2012). Maintenance activities that result in exposures to airborne coal dust occur when the generating unit is operating, as well as when the unit is shut down and workers enter interior chambers of the coal processing equipment (Bird *et al*., 2004). Major maintenance outages often engage hundreds of workers who clean interior surfaces during the first or second week of the outage. These cleaning and initial maintenance activities, which might include erection of scaffolding inside various compartments, may often require working around considerable quantities of accumulated coal dust in areas with limited ventilation (Bird *et al*., 2004). Once the initial cleaning of the accumulated ash is performed, airborne dust concentrations are considerably lower than the pre-cleaning activities.

Identifying the primary dust generating tasks and major dust sources within the power station, assessing and ranking these tasks according to their contribution to the total amount of respirable dust and quartz dust concentrations generated in the power station environment may lead to the implementation of interventions that prevent the high exposures which may occur (Grové *et al*., 2013).

1.3. Justification for the study

Information and literature on occupational exposure to respirable dust and quartz in industries such as mining, sandblasting, foundries, agriculture and construction is widely available. Similar studies were conducted at coal power station focusing on ash handling and fly ash processes, but no studies found that described the extent of respirable coal dust and crystalline silica on coal handling processes with in a power station hence this study.

The study was conducted to establish, by analysing the existing data reported annually to the Department of Labour (DoL) as it is not statistically analysed, the extent and severity of respirable coal dust and quartz exposure at coal fired power stations in Mpumalanga Province.

The study will serve as a stepping stone for assessing exposure to respirable coal dust and crystalline silica and the development of technically feasible and cost effective controls for the electricity utility industry by simply answering the following two questions:

- What concentrations of respirable coal dust and quartz do workers encounter during the operation and maintenance of coal fired power stations?
- What occupations and tasks are associated with elevated respirable coal dust and quartz exposure concentrations within this industry?

Addressing these questions will assist the electricity utility industry to channel efforts and control measures to the high risk tasks and activities where identified, thereby protecting worker's health from a range of health effects associated with exposure to coal dust and crystalline silica.

1.4. Study aim

The aim of this proposed study is to determine if workers at coal fired power stations are exposed to respirable dust and quartz at levels above the OEL and TLV.

1.5. Study objectives

The objectives of this study are:

1) To describe respirable coal dust and quartz concentrations among coal processing plant workers in seven coal fired power stations during 2012 to 2015.
2) To compare respirable coal dust and quartz concentrations from coal processing plants in seven coal fired power stations during 2012 to 2015 to the DoL OEL of 0.1mg/m^3, the OSHA PEL of 0.05mg/m^3 and the ACGIH TLV of 0.025mg/m^3.
3) To determine the difference in exposure to respirable dust and quartz between occupational groups at the seven coal fired power stations with the most exceedances over the DoL OEL and the ACGIH TLV during 2012 to 2015.

CHAPTER 2

2. METHODS

This chapter will describe the methodology used starting with the type of study that was done, the population selection, sampling strategy, measuring methods and the manner in which the data was captured.

2.1. Study Design

The study used a retrospective record review of respirable dust and quartz data collected during a 4-year period (2012 -2015). The data analysis was conducted to determine the respirable quartz exposure amongst coal processing plant workers in seven coal fired power stations. The data analysed in this study had been captured and stored in Microsoft Office Excel 2007. Personal gravimetric sampling was done between January 2012 and December 2015. The samples were collected by the mine occupational hygienists employed at the seven power stations for legal compliance reporting, to comply with the Occupational Health and Safety Act 85 of 1993, Hazardous Chemical Substances regulations.

2.2. Study Setting

The South African DoL in terms of their strategy to eliminate silicosis requires that employers collect exposure data for respirable dust and quartz content and report to the Chief Inspector of DoL on an annual basis. The study was conducted by analysing this data from seven coal fired power stations located in the Mpumalanga province which were selected randomly using a simple random sampling technique to avoid selection bias. The study has described personal respirable dust exposure measurements/data taken during routine Occupational hygiene surveys conducted on the occupational exposer groups of interests for the purpose of annual reporting to the Department of Labour during the period 2012 to 2015.

2.3. Data Collection and analysis

Employers are required to report occupational hygiene data of exposed employees, and exposure levels. The information reported by the power utility company is standardised and it includes the site (power station name, which has been coded to the purpose of this study) and number of employees potentially exposed to respirable dust; worker's personal data and job type; date of measurement and level of exposure. The power station Occupational Hygiene and Safety department is responsible for the measurement procedures and air sampling methods in accordance with NIOSH method 7500, which provide technical guidance to implement a dust monitoring strategy. The workers are stratified into homogeneous exposure groups (HEG) and are randomly selected per cycle of measure using a prescribed selection method as per the Occupational Exposure Sampling Strategy Manual (OESSM). The total respirable coal dust samples were analysed using gravimetric analysis and silica quartz samples were analysed using X-ray diffraction (XRD, method 7500) at a laboratory accredited by the South African National Standards.

The data was sourced from Occupational Hygiene Department at the power utility head office where all power stations report their respirable dust and quartz sampling results for annual submission to the DoL All data was collected by South African Institute for Occupational Hygiene (SAIOH) certified personnel from the Occupational Hygiene and Safety Department and all samples have been analysed by SANAS accredited laboratories, whose methods of analysis are traceable

The study analysed this secondary occupational hygiene data collected by the occupational hygiene officers working in the selected power stations. The data included in the study are, the results from personal air samples for respirable coal dust and quartz content, collected from coal plant operators, maintenance workers and cleaning staff at the coal processing plants of the seven-selected coal fired power stations.

The record contained 1352 respirable dust and silica quartz sample results, taken between 2012 and 2015 amongst power station employee for the purpose of annual reporting to the DoL. These exposure samples included samples taken from coal processing plant, power plant and ash handling employee. 759 samples from the coal processing plant were extracted and analysed for purpose of this study. The data was manually entered into an Excel spread sheet. Personal information of employees sampled, site coded sample numbers were excluded from the data. Only occupations sampled in the areas of interest data were analysed for the study.

Exposure data from the selected power stations was gathered, cleaned and analysed using STATA version 13.0. The data was first tested for normality by means of Skewness and Kurtosis test. A subsequent box and whisker plot was used to show the median, the 25 and 75% quartiles and the minimum and maximum values.

For the second and third objectives, the data was summarised using frequencies and percent, a Pearson Chi squared test was used to assess relationship between exposure and power station as well as between exposure and occupation.

2.4. Ethical considerations

The research protocol was submitted to the University of Witwatersrand Human Research Ethics Committee and approval was granted with certificate number M160736 (Annexure 1).

The ethical principles of research were upheld by obtaining permission from the relevant management structures at the power utility company to use the routinely collected data for research purposes. All prescriptive requirements from the power utility company were complied with, including signing of the confidentiality agreement, concealing the names of the employees that were sampled, as well as the names of the power stations used in this study.

CHAPTER 3

3. RESULTS

3.1. Introduction

The results presented in this chapter are the personal gravimetric sampling measurements taken between 2012 and 2015 in on power station employees. No samples were reported to be below the limit of detection during the quartz analysis. This chapter presents the results of personal respirable coal dust and quartz concentration under each objective. The results are presented in tables and graphically where appropriate. The box and whisker plots are used to show the difference between sites and occupations.

Exclusions

Seven samples were excluded due to incomplete information and sampling errors on the data received. The errors included:

- Missing sampling time on field sheet
- Flow rate(s) missing on field sheet
- Sample filter overloaded
- Before and after flow rate differ more than 5%

3.2. To describe respirable dust and quartz concentrations among processing plant workers in seven coal fired power stations during 2012 to 2015

The respirable coal dust concentration and quartz concentration variables data were tested for normal distribution using a Skewness and Kurtosis test and was found normally distributed (skewness = 0.0) (Kurtosis = 0.0) (Prob>chi2 = 0.0) for both variables. The results were therefore presented as minimum and maximum concentrations, mean, standard deviation, medians, geometric mean, interquartile range and 90th percentile, see tables 3 and 4 as well as Box and whisker plots Figure 10 and 11.

Table 3: Summary for variables: Respirable coal dust concentration (TWA) mg/m^3 by categories of Site (Power Station)

SITE	n	MIN	MAX	MEAN	SD	P50	GM	IQR	P90
PS1	103	0.1	1.8	0.424	0.286	0.3	0.340	0.4	0.6
PS2	103	0.1	2.3	0.650	0.538	0.5	0.484	0.5	1.3
PS3	106	0.1	3.6	0.620	0.561	0.5	0.450	0.5	1.2
PS4	108	0.1	3.4	0.561	0.543	0.5	0.410	0.3	1.2
PS5	103	0.1	2.3	0.650	0.557	0.5	0.473	0.5	1.3
PS6	113	0.1	3.1	0.622	0.645	0.5	0.432	0.4	1.3
PS7	116	0.1	2.2	0.620	0.562	0.5	0.420	0.4	1.7
TOTAL	752	0.1	3.6	0.593	0.543	0.5	0.427	0.3	1.3

The sites PS3 had the highest maximum respirable coal dust concentration (3.6mg/m^3) and range (0.1mg/m^3 to 3.6mg/m^3) and the median value was similar at all sites (0.5mg/m^3) except site PS1 (0.3mg/m^3) which also had the lowest maximum respirable coal dust concentration of (1.8mg/m^3) and range (0.1 mg/m^3 to 1.8mg/m^3) as indicated in Table 3 above. Mean respirable coal dust concentrations range between 0.424mg/m^3 (PS1) to 0.650mg/m^3 (PS2 and PS5).

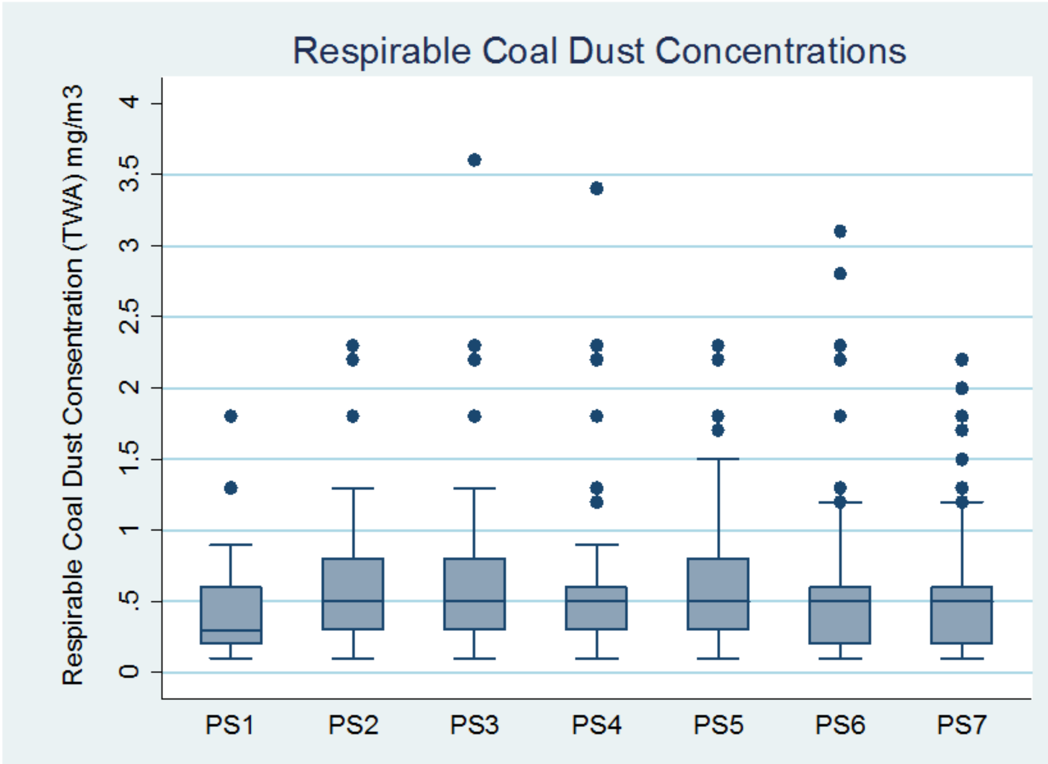

Figure 10: Box and whisker plot indicating personal respirable coal dust exposures (TWA) concentrations per power station between 2012 and 2015.

Figure 10 above also shows that the site PS3 had the highest respirable coal dust concentration.

Table 4: Summary for variables: Alpha Quartz Concentration (TWA) mg/m^3 by categories of Site (Power Station)

SITE	n	MIN	MAX	MEAN	SD	P50	GM	IQR	P90
PS1	103	0.003	0.12	0.017	0.022	0.01	0.011	0.015	0.03
PS2	103	0.004	0.11	0.023	0.027	0.01	0.014	0.02	0.05
PS3	106	0.004	0.16	0.029	0.032	0.016	0.018	0.02	0.07
PS4	108	0.003	0.16	0.029	0.031	0.02	0.019	0.02	0.08
PS5	103	0.004	0.12	0.030	0.032	0.02	0.019	0.02	0.1
PS6	113	0.01	0.16	0.036	0.033	0.03	0.026	0.04	0.09
PS7	116	0.01	0.11	0.034	0.028	0.02	0.025	0.04	0.08
TOTAL	752	0.003	0.16	0.029	0.030	0.02	0.018	0.02	0.07

The sites PS3, PS4 and PS6 equivalently had the highest maximum alpha quartz concentration (0.16mg/m^3) and range (PS3= 0.004mg/m^3 to 3.6mg/m^3) (PS4= 0.003mg/m^3 to 3.6mg/m^3) (PS6= 0.01mg/m^3 to 3.6mg/m^3) and the median values were (PS3 = 0.016mg/m^3) (PS4 = 0.02mg/m^3) (PS6= 0.03mg/m^3) as indicated in Table 3 above. Sites PS2 and PS7 equivalently had the lowest maximum alpha quartz concentration (0.11mg/m^3) and range (PS2= 0.004mg/m^3 to 0.11mg/m^3) (PS7= 0.01mg/m^3 to 0.11mg/m^3) and the median values were (PS2 = 0.01mg/m^3) (PS7 = 0.02mg/m^3). Mean respirable quartz concentrations range between 0.017mg/m^3 (PS1) to 0.036mg/m^3 (PS6).

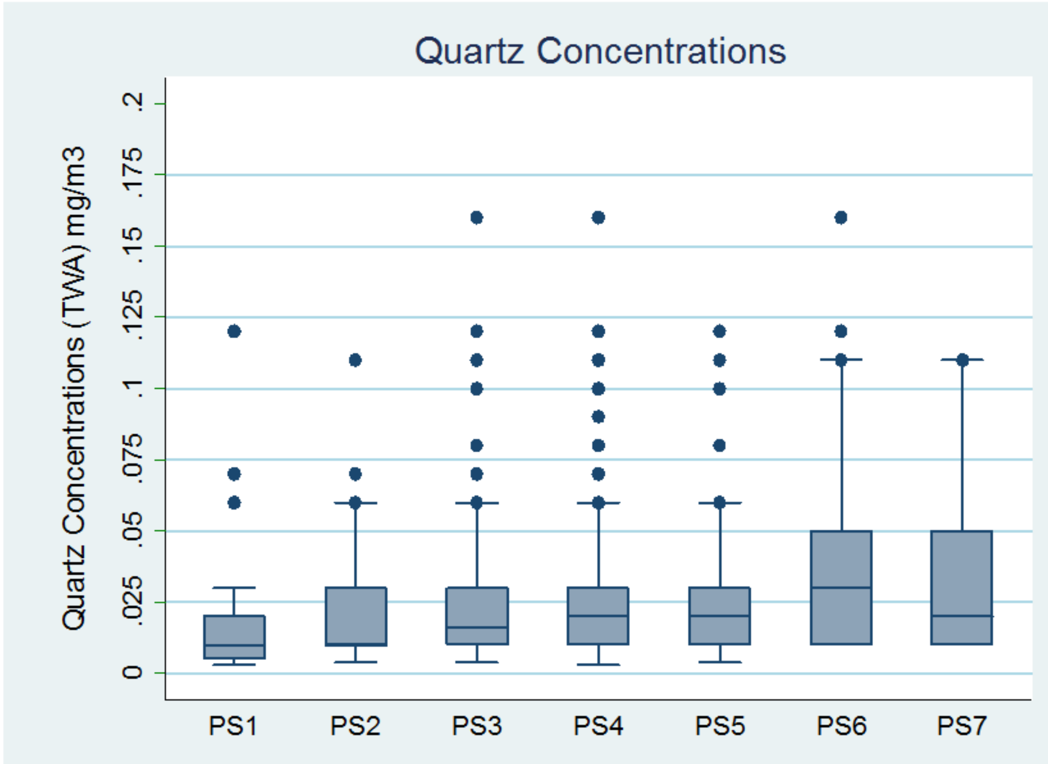

Figure 11: Box and whisker plot indicating personal quartz exposures (TWA) concentrations per power station between 2012 and 2015.

Figure 11 above also shows that the sites PS3, PS4 and PS6 had the highest quartz exposure.

3.3. Comparing quartz concentrations to the South African (DoL) OEL of 0.1mg/m^3, OSHA PEL of 0.05mg/m^3 and the ACGIH TLV of 0.025mg/m^3.

The mean exposure concentration of quartz were compared to the DoL OEL of 0.1mg/m^3, OSHA PEL of 0.05mg/m^3 and the ACGIH TLV of 0.025mg/m^3 to determine over exposures amongst different occupational groups (Table 5), work areas (Table 6) and different power stations or sites (Table 7).

Table: 5: Mean Alpha Quartz Concentration TWA in mg/m^3 amongst different occupational groups at a coal fired power stations.

OCCUPATION	*N*	MEAN	STD. ERR.	95% CONF.	INTERVAL	% ≥ DoL OEL	% ≥ OSHA PEL	% ≥ ACGIH TLV
CLEANERS	131	0.033	0.003	0.028	0.039	7.63	29,76	51.9
MAINTENANCE WORKERS	363	0.031	0.002	0.028	0.035	10.46	22.31	40.76
PLANT OPERATOR	258	0.022	0.001	0.019	0.025	2.71	12.4	23.25

Table 5. above shows mean exposure concentrations per occupation were found to be below the DoL OEL of 0.1mg/m^3, OSHA PEL 0.05mg/m^3 for all occupational groups but exceeded ACGIH TLV of 0.025mg/m^3 for maintenance workers and cleaners. Cleaners had the highest mean concentration 0.033mg/m^3 and the highest percentage of samples exceeding OSHA PEL 0.05mg/m^3 (29.76%) and ACGIH TLV of 0.025mg/m^3 (51.9%). Maintenance worker had the highest percentage of samples exceeding the DoL OEL of

0.1mg/m^3 (10.46%) and Plant operators had the lowest mean exposure concentration 0.022mg/m^3 which was below national and international exposure limits and the lowest percentage of samples exceeding the DoL OEL of 0.1mg/m^3 (2.71%) and OSHA PEL 0.05mg/m^3 (12.4%) and ACGIH TLV of 0.025mg/m^3 (23.25%)

Table: 6: Mean Alpha Quartz Concentration TWA in mg/m^3 amongst different work areas at coal fired power stations

WORK AREA	*n*	MEAN	STD. ERR.	95% CONF.	INTERVAL	% ≥ DoL OEL	% ≥ OSHA PEL	% ≥ ACGIH TLV
COAL CONVEYERS	290	0.038	0.002	0.034	0.042	9.31	36.9	51.38
COAL MILLING	260	0.018	0.001	0.015	0.020	1.92	6.53	21.91
COAL STATHE	47	0.039	0.006	0.027	0.050	19,15	19,15	55.32
COAL STOCK PILE	155	0.024	0.002	0.020	0.029	9.03	12.26	28.39

Table 6 above shows mean exposure concentrations per work area were found to be below the DoL OEL of 0.1mg/m^3 and OSHA PEL 0.05mg/m^3, but exceeded the ACGIH TLV of 0.025mg/m^3 for coal conveyers and coal stathe work areas. The coal stathes had the highest mean concentration 0.039mg/m^3 and the highest percentage of samples exceeding the DoL OEL of 0.1mg/m^3 (19.15%) and OSHA PEL 0.05mg/m^3 (19.15%) and ACGIH TLV of 0.025mg/m^3 (55.32%). Coal milling had the lowest mean exposure concentration 0.018mg/m^3 which was below national and international exposure limits and the lowest percentage of samples exceeding the DoL OEL of 0.1mg/m^3 (1.92%) and OSHA PEL 0.05mg/m^3 (6.53%) and ACGIH TLV of 0.025mg/m^3 (21.91%)

Table 7: Mean Alpha Quartz Concentration TWA in mg/m^3 amongst sites (Power Stations).

SITE	*n*	MEAN	STD. ERR.	95% CONF.	INTERVAL	% ≥ DoL OEL	% ≥ OSHA PEL	% ≥ ACGIH TLV
PS1	103	0.017	0.002	0.0132	0.022	2.91	6.79	17.47
PS2	103	0.023	0.0027	0.017	0.028	6.8	12.62	27.18
PS3	106	0.029	0.003	0.023	0.035	8.48	20.75	35.84
PS4	108	0.029	0.003	0.023	0.035	6.49	18.53	36.12
PS5	103	0.030	0.003	0.024	0.036	10.68	21.29	37.79
PS6	113	0.036	0.003	0.030	0.043	7.95	29.19	50,42
PS7	116	0.034	0.003	0.029	0.039	7,76	30.18	49.51

Table 7 above shows mean exposure concentrations per site ranged between 0.017mg/m^3 to 0.036mg/m^3 and were found to be below the DoL OEL of 0.1mg/m^3 and OSHA PEL 0.05mg/m^3 across all sites, but exceeded the ACGIH TLV of 0.025mg/m^3 for five power station sites, i.e. PS3, PS4, PS5, PS6 and PS7. PS6 had the highest mean concentration 0.036mg/m^3 with 50.42% samples exceeding the ACGIH TLV 0.025mg/m^3. PS1 had the lowest mean exposure concentration 0.017mg/m^3 was below national and international exposure limits and the lowest percentage exceedance of DoL

OEL $0.1 mg/m^3$ (2.91%), OSHA $0.05 mg/m^3$ (6.79%) and ACGIH TLV $0.025 mg/m^3$ (17.47%).

3.4. Difference in exposure to respirable dust and quartz between occupational groups

The data was summarised using frequencies and percent and a Chi squared test was done to evaluate relationship between quartz concentrations and occupational groups. It was also compared to national and international standards. In Table 8 the only international standard used to compare concentration levels for respirable coal dust was the OSHA PEL of $2.4 mg/m^3$. This is because the ACGIH TLV has various limit values for respirable coal dust which is dependent on the type of coal that was sampled e.g. Anthracite - $0.4 mg/m^3$, Bituminous - $0.9 mg/m^3$, etc. This study did not look at the different coal types and as a result this comparison could not be achieved.

Table 8: Summary of frequencies and percentage of respirable dust concentrations per occupation and association of exposure.

Occupation	**Year Sample**	***n* of samples**	***n* ≥ DoL OEL $2mg/m^3$**	**% ≥ DoL OEL $2mg/m^3$**	***n* ≥ OSHA PEL $2.4mg/m^3$**	**% ≥ OSHA PEL $2.4mg/m^3$**
Cleaners	2012	36	0	0	0	0
	2013	28	3	10.71	0	0
	2014	29	1	3.45	0	0
	2015	38	0	0	0	0
Maintenance Worker	2012	89	10	11.24	1	1.12
	2013	83	4	4.82	0	0
	2014	93	2	2.15	1	1.07
	2015	98	8	8.16	2	2.04
Plant Operator	2012	63	2	3.17	0	0
	2013	66	2	3.03	0	0
	2014	63	0	0	0	0
	2015	66	3	4.54	0	0
Pearson	**chi2(38)**	**=**	**92.7507**		**Pr =**	**0.000**

The highest percentage of measurements that exceeded the DoL OEL for respirable dust ($2mg/m^3$) was for maintenance workers (11.24%) in 2012 and the highest measurements that exceeded the OSHA PEL for respirable dust ($2.4mg/m^3$) was maintenance workers (2.04%) in 2015 as shown above in Table 8. No association of exposure between respirable coal dust concentrations and occupation (p-value = 0.00).

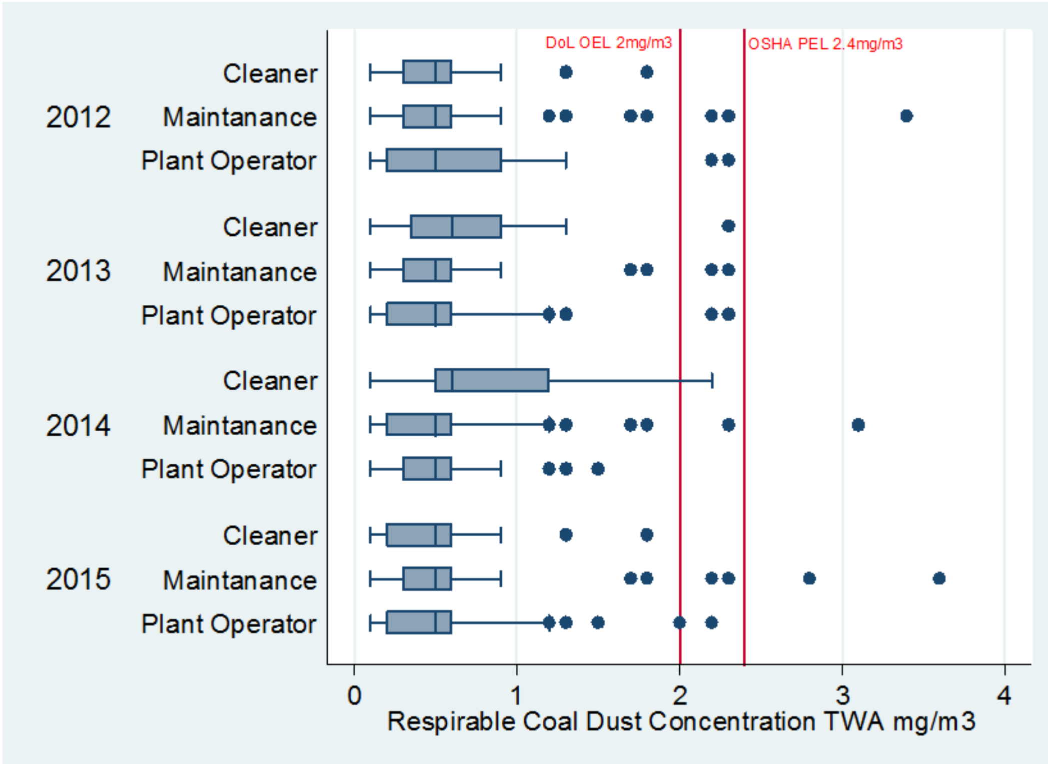

Figure 12: Illustration of respirable coal dust concentration distribution amongst occupations when compared to national and international standards.

Table 9: Summary of frequencies and percentage of quartz concentrations per occupational group at coal fired power station from 2012 to 2015 compared to national and international standards and association of exposure.

Occupation	Year Sample	*n* of samples	*n* ≥ DoL OEL 0.1 mg/m³	% ≥ DoL OEL 0.1 mg/m³	*n* ≥ OSHA PEL 0.05 mg/m³	% ≥ OSHA PEL 0.05 mg/m³	*n* ≥ ACGIH TLV 0.025 mg/m³	% ≥ ACGIH TLV 0.025 mg/m³
Cleaners	2012	36	2	5.55	11	30.55	18	50
	2013	28	6	21.43	10	35.71	16	57.14
	2014	29	1	3.45	8	27.59	15	51.72
	2015	38	1	2.63	10	26.32	19	50
Maintenance Worker	2012	89	12	13.48	21	23.60	38	42.70
	2013	83	6	7.23	12	14.46	30	36.14
	2014	93	9	9.68	26	27.96	38	40.86
	2015	98	11	11.22	20	20.41	40	40.82
Plant Operator	2012	63	2	3.17	7	11.11	12	19.04
	2013	66	2	3.03	7	10.60	15	22.72
	2014	63	0	0	8	12.70	14	22.22
	2015	66	3	4.54	10	15.15	19	28.78

Pearson chi2(34) = 134.5869 Pr = 0.000

Table 9 above shows that cleaners were generally the highest exposed group in 2013; 21.43% (n=6) exceeded the DoL OEL 0.1mg/m³, 35.71% (n=10) exceeded the OSHA PEL 0.05mg/m³ and 57.14% (n=16) exceeded the ACIGH TLV 0.025mg/m³. No association of exposure between quartz concentrations and occupation (p-value = 0.00).

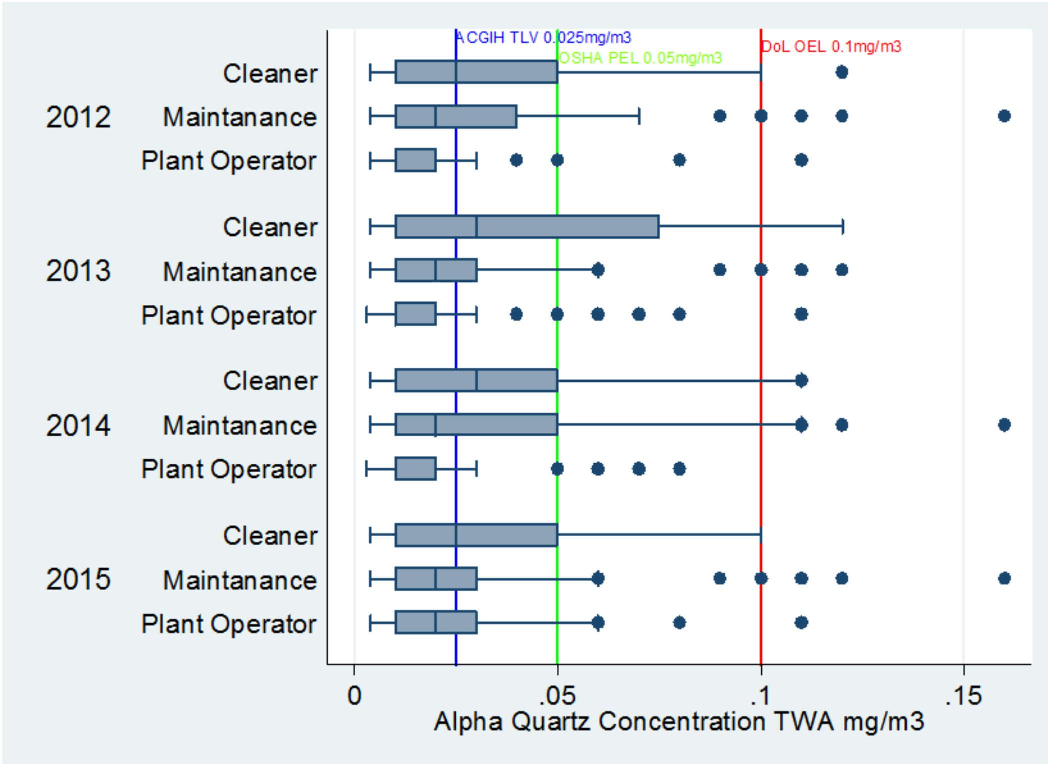

Figure 13: Illustration of quartz concentration distribution amongst occupations when compared to national and international standards.

CHAPTER 4

4. DISCUSSION

4.1. Introduction

In this chapter the major findings are summarized and possible limitations are discussed. Some of the results presented in this report indicated exposure levels higher than the national and international threshold limit value. The outcome of the study is discussed per objective.

The aim of this study was to determine if workers at coal fired power stations are exposed to respirable dust and quartz at levels above the DoL OEL, OSHA PEL and ACGIH TLV. The findings from this study indicated that some workers are exposed to levels above the OEL, PEL and TLV.

4.2. Limitations

In considering the findings of this study, it is important to bear in mind the following limitations.

- The study did not look at health effects or health outcome from exposure to coal dust at power stations;
- This study did not look at the quartz content (%), only quartz concentration.
- No similar studies were found that assessed the level of exposure to respirable coal dust and quartz at power stations, some of the objectives of the findings of this study could not be compared with other similar studies;
- The study did not consider the dust control / suppression methods implemented at various power stations;

- Possible reasons for exposures above the DoL OEL, OSHA PEL and ACGIH TLV were not considered as no record of such overexposure investigation were done;
- The study did not look at the quartz exposure during different work shifts i.e. morning, afternoon and night shifts;

4.3. Respirable dust and quartz concentrations among processing plant workers at coal fired power stations.

During normal production activities at coal fired power station, coal dust exposures are confined to locations where the coal is handled and processed. The number of workers engaged in these activities is approximately 80 per site, depending on the number of operating units and the size of the power station. Exposure periods are often regularly dispersed throughout the shift. Exposures to respirable crystalline silica during these day-to-day operations are associated with accidental releases from hoppers and valves that may be opened during servicing or repairs, and from fugitive releases emanating from open dump trucks or rail cars during loading, transport, and unloading.

This study revealed that site PS3 had the highest maximum respirable coal dust concentration (3.6mg/m^3) with the highest respirable coal dust mean concentrations (0.650mg/m^3) observed in two other power stations (PS2 and PS5). The maximum concentration was lower than the maximum concentration reported by Bird *et al* (2004) on respirable coal dust concentration observed at coal fired power in Pennsylvania of 5.3mg/m^3. The mean respirable coal dust concentration found in this study were also lower than the mean respirable coal dust concentrations at the rock face of three coal mine sites which were 0.9 mg/m^3, 1.3 mg/m^3, and 1.9 mg/m^3 at the three different mines (Naidoo *et al*., 2006).

The sites PS3, PS4 and PS6 equivalently had the highest maximum quartz concentration (0.16mg/m^3) and range (PS3= 0.004mg/m^3 to 3.6mg/m^3) (PS4= 0.003mg/m^3 to 3.6mg/m^3) (PS6= 0.01mg/m^3 to 3.6mg/m^3) and site PS6 had the highest mean respirable quartz concentration (0.036mg/m^3). This was lower than the reported concentration from coal fly ash studies which found that, for normal operations, mean exposure was 0.048mg/m^3; for maintenance operations, mean exposure was 0.23 mg/m^3 (Hicks and Yager, 2006). The finding of this study exceeds the ACGIH TLV of 0.025mg/m^3 but was below the OSHA PEL 0.05mg/m^3 and DoL OEL of 0.1mg/m^3.

4.4. Comparing of quartz concentrations to the South African (DoL) OEL of 0.1mg/m^3, OSHA PEL of 0.05mg/m^3 and the ACGIH TLV of 0.025mg/m^3.

Mean concentrations of quartz were compared to DoL OEL of 0.1mg/m3, OSHA PEL of 0.05mg/m3 and the ACGIH TLV of 0.025mg/m3 to determine over exposures amongst different occupational groups, work areas and different power stations or sites.

This study revealed that mean quartz concentrations amongst occupations were below the DoL OEL of 0.1mg/m^3 and OSHA PEL 0.05mg/m^3, for all occupations with the mean concentration for quartz range 0.022mg/m^3 to 0.033mg/m^3. However, the mean quartz concentration exceeded the ACGIH TLV of 0.025mg/m^3 for cleaners and maintenance workers. Cleaners had the highest mean concentration for quartz (0.033mg/m^3) when compared to Plant operators who had the lowest mean exposure concentration for quartz (0.022mg/m^3) which was below national and international exposure limits. This was similarly observed in the Hicks and Yager (2006) study on coal fly ash quartz concentration at coal fire power stations, where the mean respirable quartz concentration for vacuum cleanup workers was 0.87 mg/m^3, compared with a mean of 0.44 mg/m^3 for all other maintenance workers. As per the Hicks and Yager (2006) study, for all occupations, mean quartz concentrations exceeded the current ACGIH TLV of 0.025mg/m^3. Cleaners as a homogenous exposure group had the highest mean quartz concentration in both studies.

The mean quartz concentrations amongst work areas were found to be below the DoL OEL of 0.1mg/m^3 and OSHA PEL 0.05mg/m^3 with the mean concentration range from 0.018mg/m^3 to 0.039mg/m^3, The coal conveyers and coal stathe were the only work areas with quartz concentrations that exceeded the ACGIH TLV of 0.025mg/m^3. The coal stathes had the highest mean concentration (0.039mg/m^3) when compared to the coal milling had the lowest mean exposure concentration (0.018mg/m^3) which was below national and international exposure limits. The result of this study in such work areas at a coal fired power station are incomparable due to the lack of similar studies in work areas where coal is handled and processed.

The mean quartz concentrations amongst power stations (sites) were found to be below the DoL OEL of 0.1mg/m^3 and OSHA PEL 0.05mg/m^3 across all sites ranging between 0.017mg/m^3 to 0.036mg/m^3, but exceeded the ACGIH TLV of 0.025mg/m3 for five sites, i.e. PS3, PS4, PS5, PS6 and PS7. The site PS6 had the highest mean concentration (0.036mg/m3). PS1 had the lowest mean exposure concentration (0.017mg/m3) which was below national and international exposure limits. Unfortunately, Hicks and Yager (2006) did not make the contrast of quartz concentration in coal fly ash amongst the coal fired power stations in their study that could be compared to the results of this study.

4.5. Difference in exposure to respirable dust and quartz between occupational groups

The highest percentage of measurements that exceeded the DoL OEL for respirable dust 2mg/m^3 was for maintenance workers 11.24% in 2012 and the highest measurements that exceeded the OSHA PEL for respirable dust 2.4mg/m^3 was maintenance workers in 2015. The study also revealed that there is no association of exposure between respirable coal dust concentrations and type of occupation (p-value = 0.00). For respirable dust concentration, the study shows that 4.63% (n=35) of all occupations were exposed to respirable dust concentrations equal or exceeding the DoL OEL of 2mg/m^3 and only 2.51% (n=4) exceeded the OSHA PEL.

The cleaners were generally the highest exposed group in 2013, 21.43% (n=6) exceeded the DoL OEL 0.1mg/m^3, 35.71% (n=10) exceeded the OSHA PEL 0.05mg/m^3 and 57.14% (n=16) exceeded the ACIGH TLV 0.025mg/m^3. The results also revealed that there was no association of exposure between quartz concentrations and occupation (p-value = 0.00).

This study found that 7.31% (n=55) of all occupations were exposed to quartz concentrations equal or exceeding the DoL OEL of 0.1mg/m^3. 29.39% (n=221) of all occupations exceeded the ACGIH TLV of 0.025mg/m^3 but were below the OEL 0.1mg/m^3. This means that a total of 36.7% (n=276) exceeded the TLV. Maintenance worker were the most exposed group to quartz at 48.27% (n=363) and cleaners were the lowest exposed at 17.42% (n=131).

CHAPTER 5

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Respirable coal dust exposures at coal fired power station are typically limited to the coal receiving, handling and storage, coal conveyers and coal milling areas of the power generation process. At coal fired power stations in Mpumalanga province, mean airborne concentrations of respirable coal dust range between 0.424mg/m^3 (PS1) to 0.650mg/m^3 (PS2 and PS5) and were lower than the DoL OEL 2mg/m^3 and OSHA PEL 2.4mg/m^3.

Mean respirable quartz concentrations were considerably higher than the ACGIH TLV 0.025mg/m3 with 5 out of 7 power stations exceeding this limit; however all power stations had a mean quartz concentrations within the OSHA PEL 0.05mg/m^3 and DoL OEL 0.1mg/m^3.

The occupational group that is highly exposed to respirable coal dust and quartz is the cleaners. This is because their work regime requires that they are present in high dust areas during maintenance activities as well as normal production in areas with considerable amount of coal dust deposits. This study revealed that Cleaners are the more likely overexposed group with highest mean concentration 0.033mg/m^3 and the highest percentage of samples exceeding OSHA PEL 0.05mg/m^3 (29.76%) and ACGIH TLV of 0.025mg/m^3 (51.9%) when compared to other occupations.

There was a proportionally lower rate of air samples exceeding the respirable coal dust DoL OEL 2mg/m^3 on an annual basis from 2012 to 2015 amongst occupational groups with a maximum rate of samples at 11.24% in 2012 significantly lower rates exceeding OSHA PEL with a maximum 0.05mg/m^3 at 2.04% in 2015. On the other hand, quartz concentration had a considerably high rate of samples exceeding the respirable quartz concentrations with 57.14% over the TLV, 35.71% over the PEL 21.45% exceeding the OEL. It can be concluded that the coal used in the coal fired power station in Mpumalanga has a high percentage of alpha quartz content.

The study found no relation significance between respirable dust and quartz concentrations and occupation as well as the sites. The study results confirm the need to actively control worker exposures to coal dust, in part to prevent exposures above the crystalline silica exposure limits.

5.2. Recommendations

Although the data shows that most of the workers at selected power stations are not over the exposure levels, over thirty six percent of samples were found to be in the action level range. Control measures should be developed to reduce the coal dust exposure levels for workers at the power stations. These measures could include engineering controls, implementing an occupational safety and health program, improvements to housekeeping procedures, administrative controls, use of respiratory protection, and additional sampling. Implementing any one of these measures may not be sufficient to control coal dust exposure, but implementing a combination of these measures can decrease the likelihood of being overexposed to coal dust.

Additional Engineering Controls (Ventilation)

Ventilation could be used especially in transfer points. The best approach would be to enclose the transfer point with an exhaust hood. The dust would then need to be removed by either a dust collection system or filter (Kissell and Stachulak, 2003). The ventilation system would provide a slight negative pressure that would draft in ambient air. This draft should direct coal dust towards the hood instead of flowing to areas outside of the chute (Schonbach, 2003). Due to entrainment, dusty air is push out of the bottom of the chutes. Negative pressure will help to offset this effect. In addition, it is suggested that the hood openings are wide enough so the velocity of air exhausted is 2.45m/s or less. Also, the air velocity should be in the range of 15.24m/s to 20.32m/s so coal dust will not settle in the ducts (Kissell and Stachulak, 2003). Kissell and Stachulak suggest using a transfer point ventilation system similar to Figure 12.

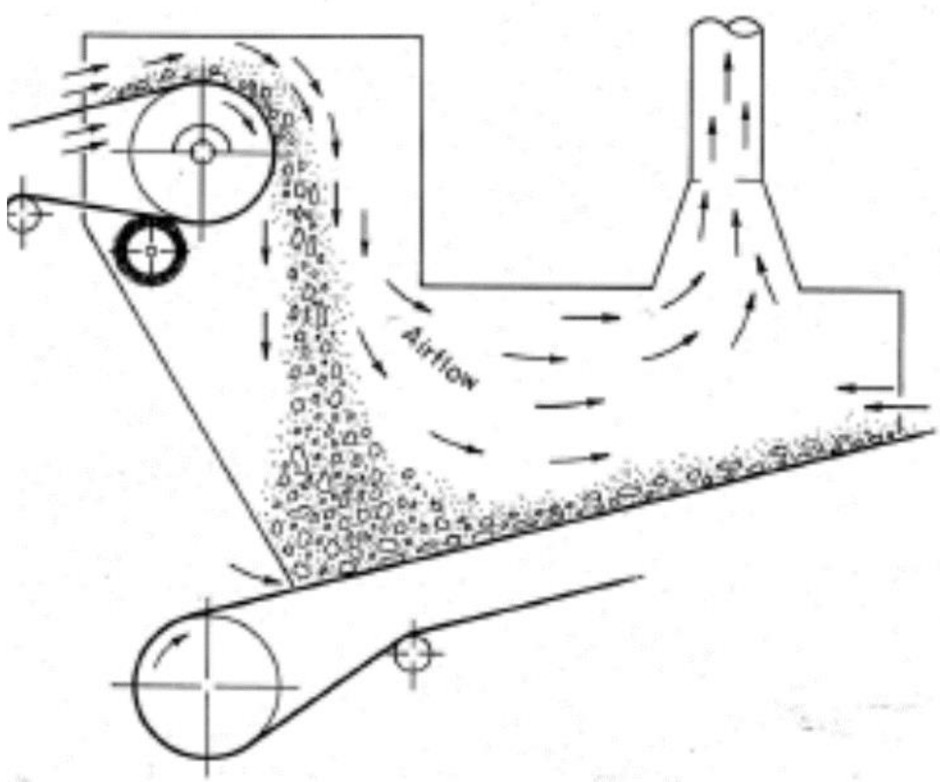

Figure 14: Ventilation design for coal transfer chute.

Source: Kissell and Stachulak, 2003

Administrative Controls

Administrative controls can also be used to reduce exposure, but cannot be used in lieu of ‘engineering out’ the problem. First, the procedures must be in place which to address the important part of the housekeeping plan, which is to maintain cleaning. In addition to the cleaning schedule, the employees need to use the proper techniques when cleaning to minimize coal dust. Dry sweeping is commonly used to clean up coal that has fallen out of the system. Dry sweeping can cause a greater amount of coal dust due to coal disturbance. The best method to collect coal dust is by wet dust suppression, airborne dust suppression. Wet dust suppression is when the entire area is saturated to prevent the dust from becoming airborne. This can be accomplished with plain water, water with additives, or foams. Using plain water would be the cheapest control and may work suitably without using the additives (Smandych *et al*, 1998). Using a wet dust clean-up system would need to be carefully monitored so water does not leak to electrical areas or other areas that cannot come into contact with water and the contaminated must be contained to prevent pollution of other water bodies.

This method of washing down a surface is used before maintenance activities and appears to be effective, as per the maintenance coal dust results. For example, before the pulverizer is worked on, the cleaners will go in with hoses and hose out the area. This practice should be continued to minimize coal dust exposure.

Respiratory Protection

Although personal protective equipment should be the last line of defence against a hazard, a respiratory protection program should be established. The following aspects of the respiratory protection program are important. Respirators shall be worn by all those individuals who were overexposed to coal dust.

According to the results of this study, a half-mask respirator or disposable respirator (FFP2) meets the minimum requirements of protection against the exposure. The assigned protection factor (APF) of these respirators is ten. Since the occupational exposure limit (OEL) for coal dust was 2mg/m^3, the maximum use concentration (MUC) for a half-mask respirator is 20mg/m^3. For this study, the maximum concentration was 3.6mg/m^3, so the half-mask or disposable respirator is appropriate protection (OSHA 2008).

In order for employees to wear respiratory protection, they must follow the respiratory protection program. This program must include fit-testing and training. Before any employee can wear a respirator, they must be cleared through a medical evaluation. Next, the employee must be fit-tested on any respirator they will need to wear during the course of the year. This fit-test will give a quantitative number, if a Porta-Count is used, that will show whether the user is getting a correct seal with that particular respirator. Following fit-testing, the user needs to be trained on “user seal checks.” These must be performed each time a respirator is donned for use to ensure the user that a proper seal is being maintained for that use and the proper respirator is either a half-mask or disposable respirator, the proper filter must also be chosen.

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