RESPIRABLE DUST AND QUARTZ IN MEDIUM SIZED MAIZE AND ROOT PLANT FARMING IN SOUTHERN MOZAMBIQUE

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A RESEARCH REPORT SUBMITTED TO THE FACULTY OF HEALTH SCIENCES, UNIVERSITY OF THE WITWATERSRAND, IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF PUBLIC HEALTH/OCCUPATIONAL HYGIENE

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UNIVERSITY OF THE WITWATERSRAND

I, JOSE CHICO FRANQUE MIREMBO, HEREBY DECLARE THAT "RESPIRABLE DUST AND QUARTZ IN MEDIUM SIZED MAIZE AND ROOT PLANT FARMS IN SOUTHERN MOZAMBIQUE" IS AN ORIGINAL DOCUMENT WRITTEN FOR THE FIRST TIME IN COUNTRY AS PART OF THE REQUIREMENTS FOR THE DEGREE OF MPH AND OCCUPATIONAL HYGIENE IN THE FACULTY OF HEALTH SCIENCE, DEPARTMENT OF PUBLIC HEALTH.

THE RESEARCH AND DOCUMENT REPORT WERE SUPERVISED AND ASSISTED BY:

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STUDENT SIGNATURE

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DEDICATION

Having successfully completed the writing of this research report of my MPH course, I wish to firstly dedicate to the University of Michigan/Fogarty International Center for their involvement in EOH capacity building programme in the SADC, and all the SADC ITREOH PRC members for their support in my scholarship application.

To my family for the support, love and attention given in difficult moments, particularly my wife and my two wonderful kids who in many cases inspired me to go ahead and work on this research.

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ABSTRACT

INTRODUCTION

According to ILO (2000), in developing countries about 59 per cent of labour force belongs to the agriculture sector. This is a particularly serious concern from the viewpoint of promoting the health of a population and reduction of social vulnerability in a country like Mozambique where more than half of the population depends on agriculture as their means of survival and wage earning.

The current study attempts to address the agriculture mineral dust as occupational hygiene and health risk factors among agriculture workers, taking into account that dust that is breathed in may contain quartz, known as a carcinogenic and pathogenic agent.

OBJECTIVE OF THE STUDY

The study aims to pinpoint risk potential to health that may be caused by mineral dust through assessing occupational exposure doses to respirable dust and quartz during plowing, and primary and secondary tilling operations identified in the study, as the major dust risk operations; and the more prevailing operations in maize and root plant on medium sized farms' production cycle.

MATERIALS AND METHODS

Sampling of dust was conducted on 2 medium sized farms selected by convenience in the district of Boane (study setting) based on geological map soil characterisation of the study area. Full-time period dust samples were collected from 4 different tractor operators. The tractor operators were identified as the risky group. In total were taken seventy valid samples; thirty-nine from maize and thirty-one from root plant. Three tractor operators were fully engaged in maize cultivation and 1 was engaged in root plant during the period of the study data collection. In all occasions, the 'open-cabbed' tractor machines were observed and used by tractor operators. The involved sampling subjects' operators were informed in advance about the study purpose and they accepted participation in the research. Nineteen dust samples were randomly selected for determination of the quartz fraction using the MDHS 101 Infrared Spectrophotometer Method. Active dust sampling MDHS 14/3 HD-cyclone method was applied with GLA 5000 filter type. All quality control procedures applied in active dust sampling method and gravimetric determination of concentration were checked in order to accept or reject samples for further analysis and determination of exposure concentration.

RESULTS

Standard statistical procedures and sampling strategy data analysis and interpretation procedures, including the SPSS software version 11.5 were used to produce valid results and findings. In the specific case of the agriculture sector, workers are found in changeable conditions and working time, therefore the effective working time distribution was estimated varying at a level of 311.6 min., 95 per cent CI (294-329.7). The observed minimal and maximal values were 179 and 500 min., respectively.

The filter medium potential contamination was checked out through determination of the mass variation of the blank samples. The filter contamination was assumed possible through absorption and/or adsorption of humidity at level of minus 0.00407 mg with lower limit of minus 0.01 and upper limit of 0.00183 mg. The results on exposure indicate high exposure dose in maize crop cultivation in contrast to root plant crop cultivation.

The findings show that in medium-sized farming, the average exposure to respirable dust is 0.702 (SD 0.571) and the average exposure for respirable quartz is 0.074 (SD 0.06). About 96 per cent of respirable dust exposure measurements were found in compliance with the South Africa standard for respirable dust; and for respirable quartz 74 per cent, 45 per cent and 17 per cent of exposure measurements were in compliance with the SA, NIOSH and ACGIH occupational exposure limits respectively. Each tractor operator’s measurements showed a significant variation of the exposure concentration, probably due to the intraday and interday variation. The exposure measurements geometric standard deviation (GSD) was found equal or above 2.0 for both maize and root plant measurements and this indicates the influence of environmental factors in the exposure profile variation.

CONCLUSION

The research is supportive of some international published studies in which respirable quartz exposure in agriculture sector, although highly variable, has potential significance for over-exposure. The measurements of exposure to respirable quartz have shown over-exposure scenarios. However some were found below the permitted exposure limits.

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I wish to acknowledge the developers of the SPSS, a statistical package which performs highly complex data manipulation and analysis with simple instructions. I also acknowledge the UK government, Health and Safety Executive (HSE) for the publication of the MDHS 101 methods for crystalline silica determination and the MDHS 14/3, general methods for sampling and gravimetric analysis of respirable and inhalable dust.

Above all, I thank God for the wisdom and love He gave to my family. God bless you all who directly or indirectly contributed to the success of this work.

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TERMS AND DEFINITIONS

ILO	INTERNATIONAL LABOUR ORGANIZATION
SA	SOUTH AFRICA
NIOSH	AMERICAN INSTITUTE OF OCCUPATIONAL HEALTH
ACGIH	AMERICAN CONGRESS GOVERNMENT OF INDUSTRIAL HYGIENISTS
SD	STANDARD DEVIATION
NIOH	JHB, NATIONAL INSTITUTE OF OCCUPATIONAL HEALTH
FTIR	FOURIER TRANSFORMER INFRARED
XRD	X-RAY DIFFRACTOMETER
TWA	TIME WEIGHT AVERAGE
GDB	GROSS DOMESTIC PRODUCT
LOD	LIMIT OF DETECTION
PBZ	PERSONAL BREATHING ZONE

PART I

INTRODUCTION AND LITERATURE REVIEW

1. BACKGROUND INTRODUCTION

Agricultural activity and the concept of agricultural workers is understood differently in varied settings. Worldwide concepts and understanding of agriculture and agricultural workers exists. In an attempt to create a common understanding on the concept of agricultural activity and agricultural workers, the International Labor Organization (ILO) committee has the following definition[1]:

'Agriculture is all forms of activities connected with growing, harvesting and primary processing of all types of crops, along with the breeding, raising and caring for animals, and tending gardens and nurseries. In its turn, the agricultural worker by definition is any person engaged either permanently or temporarily, irrespective of his legal status, in activities related to agriculture.'

Due to inadequate recording and notification systems in developing countries, official data on the incidence of occupational accidents and diseases are imprecise and notoriously underestimated in all sectors of the economy. In the case of the agricultural sector, under-reporting is even more evident. Under-reporting is partially explained by the difficulties involved in the diagnosis of occupational and work-related diseases due to serious difficulties in establishing the employment history of agricultural workers. In agriculture, self-employed, piece-rate and/or seasonal and full-time or part-time workers are the employment status categories commonly encountered.

Agricultural workers pose enormous difficulties in assessing the occupational hygiene risk and evaluation of health outcomes due to possible variation of personal exposure, introduced by employment status categories. Piece-rate, seasonal and part-time workers may be exposed to other occupational hygiene risks or situations of exposure, and working time may exceeds the permissible workload, even during agricultural related activities.

The agricultural contribution to the southern Africa region GDP is currently estimated at a level of 35 per cent and about 70 per cent of the population of the region depends on agriculture for food, income and employment.[2] In Mozambique, nearly 70 per cent of the population relies on agriculture; basically non-commercial agriculture.[3]

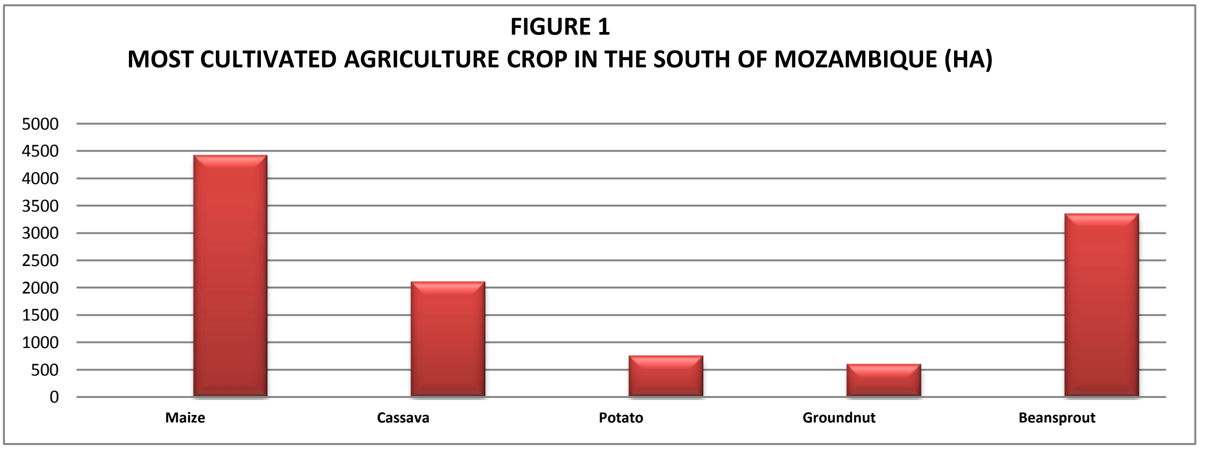
Mozambique's agricultural sector in comparison to other southern Africa countries, such as South Africa and Botswana, is labor intensive probably due to the low level of mechanization. This situation in association with the low level of productivity of agricultural crops and cultivation, gives chance of exposing many people to mineral dust and quartz from agricultural activities. Epidemiologic surveillance on respiratory complications and tuberculosis has shown that respiratory complications are seen to be a common health concern in rural areas.[4] Since the rural population are mainly doing agricultural work for survival and to earn a wage, silica dust exposure and farming practices could be probable causes for respiratory complications and diseases and these conditions are exacerbating the health outcome of the population, particularly of immune-compromised people.

Medium and small sized farms represent predominant forms of land use in agriculture in Mozambique, employing the majority of workforce in rural areas. Mineral dust from farming activities could be present in the daily life of these workers, threatening their health and quality of life.

1.1. INTRODUCTION

Agriculture is about disturbing the soil through a wide range of soil cultivation processes. Exposure to both mineral and organic dust may be considered as everyday life of farm workers. Neglected by scientists and occupational hygiene experts, including labor protection bodies, the dust in agriculture may pose a serious threat to the health of workers and could be a public health issue, particularly in countries where more than half the population live in rural areas, agriculture being their only means of livelihood.

Among the farming crops and cultivation products in Boane District, maize in a group of cereals and potato in a group of root plants are the 2 most cultivated farming products.[3] According to Figure 1, in the south of Mozambique during an agriculture inventory, maize among the cereal crop was found as the most cultivated crop, followed by the root plant crops as a combination of potato, cassava and groundnut. They were therefore selected as the farming crop products of interest for this particular study on occupational exposure assessment to agricultural mineral dust. Figure 1 shows the main farming products and the currently cultivated area. Maize is among the cereal crops - the most cultivated - followed by the root plant crops as combination of potato, cassava and groundnut.



SOURCE: MAE, PORTAL DO GOVERNO[3]

Maize is the major food and cash crop in the study area as well as in the entire country. Potato cultivation is an emerging crop for local consumption aimed to make the country self-sustainable in the potato market. With no intensive use of an irrigation system, the land preparation for both maize and potato crops has been influenced by the onset of the rain season. Farmers rely mainly on the use of tractors and occasionally on manual means for preparing and maintaining land for planting maize and potatoes.

1.1.1. THE PURPOSE OF THE STUDY

This study attempts to address respirable dust as a occupational hygiene and health risk, particularly in the agricultural sector, considering that the breathed dust may contain quartz, known as a serious pathogenic agent and the cause of lung disease and other pulmonary complications. This is a pioneer study in the country and the aim is to understand and characterize the exposure to respirable dust and quartz in the major and dust risk operations during maize and root plants crop production cycle. Some international scientific studies, including one done on South African sandy soils, has found quartz concentration exceeding the generally accepted occupational exposure limits and therefore confirmed quartz as a health risk.

1.1.2. MAJOR OPERATIONS IN MEDIUM-SIZED FARMS

In dry climate regions the soil-disturbing operations of plowing and primary and secondary tilling are the most dust risky operations; the most frequent and time-consuming tasks performed by farmers, regardless of farm size, technology, geographical location and employment status categories.

The primary purpose of plowing is to turn over the upper layer of the soil, bringing fresh nutrients to the surface while burying weeds and the remains of previous crops, thus allowing them to break down. It aerates the soil and allows for improved moisture retention. The dust generated by plowing operations may vary according to the weather, climate conditions and plough designs and techniques.

The purpose of tilling is to plow, loosen and aerate the soil which in turn facilitates deeper penetration of roots, thus improving the compaction of the lower layers of the soil, distributing organic matters and nutrients evenly throughout the soil. Tilling is very important in destroying weeds and homogenizing the soil for planting and seeding. Tilling operations can be one of two types, i.e. primary tilling intended to loosen the soil and mix in fertilizer and/or plant material resulting in soil with a rough texture, and secondary tilling intended to produce finer soil and sometimes shape the rows, and this is done by various equipment combinations.

1.1.3. AGRICULTURAL DUST

Agricultural dust varies in composition and is made up of mineral and organic components which make it difficult to study.[5] The mineral and organic components differ in terms of their percentage in given dust matter due to soil characterization, type of crop used in certain farming areas, the technology used to prepare the soil and the use of chemical and fertilizers.[5,6]

Organic dust originates from plant and animal sources and is commonly known as the source of allergic diseases such as asthma. Inorganic dust originates predominantly from the soil and tends to result in non-allergic reactions in the lung and human respiratory system.[5]

The quartz, also known as silica, is a component of the mineral agricultural dust. This is of interest from the point of view of occupational hygiene, due to its high toxicity for the lungs and the probability of causing serious respiratory problems that may lead to lung cancer. The quartz contained in soil is known as largely varying even within the same study area. Therefore, in occupational exposure assessments, the qualitative identification of soil type is recommended before any attempt to embark in quartz determination using quantitative methods.[6]

Several studies on the mineralogical and geological characterization of soils have concluded that sandy and silty soil types have significant portions of quartz.[7,8] The study which has been done to characterize the mineralogical composition of soils at the Boane District found quartz fraction in soil ranging from 8 up to 24 per cent.[9]

1.1.4. RESPIRABLE QUARTZ

Quartz is the most common polymorphs of free crystalline silica, a constituent of many sands, stones and rocks.[10] Ubiquitous in the environment, silica is part of the small particulate fraction of air pollution and may comprise a significant fraction of environmental dust levels in some geographic regions.[11] Crystalline silica can be harmful when inhaled as a dust in the respirable range (< 5-µm particles) and silicosis, a form of pulmonary fibrosis, is a well-known occupational disease which results from acute or chronic high-level exposure to silica or silica-containing dust. Silicosis increases susceptibility to tuberculosis and other respiratory diseases. It has recently been categorized by the International Agency for Research on Cancer (IARC) as a known human carcinogen.[12]

During farming activities, workers may be exposed to dust containing quartz while performing almost all tasks which comprise and involve the entire cycle of crop cultivation, including final product packaging and maintenance of farming equipment. Mechanical plowing and tilling operations which include primary and secondary tilling have been found to be operations where workers are more likely to be exposed to respirable dust and quartz when compared to other means of soil cultivation, such as crop maintenance and sowing seed with sower.[13,5] Dry climate sandy soils farming is more critical in exposing workers to respirable quartz.[5]

1.1.5. OCCUPATIONAL EXPOSURE LIMIT

Despite the controversy about the establishment and early debates over the occupational exposure limit acceptability and usefulness in protecting the health of the workers exposed to occupational hazards agents, the occupational hygiene scientists agreed that occupational exposure limit are useful for occupational hygiene and health promotion because there are informed by the relevant toxicological and health risk assessment approach and, are important tools in protecting workers from occupational hazards.

The ACGIH defines occupational exposure limit as airborne concentration value and condition under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse health effect.

At the national level, the Republic of Mozambique has not yet established or officially adopted occupational exposure limit for exposure to dust. In the absence of national occupational exposure limit for dust, the international worldwide recognized occupational exposure limit including the regional one's based in SA Standard may be used to assess exposure compliance of workers to ***Respirable Quartz*** in the agriculture setting, namely:

- South African Occupational Exposure Limit (OEL) of 0.1 mg/m^3 ;
- National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) of 0.05 mg/m^3 ; and
- American Conference for Governmental and Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) of 0.025 $mg/m.^3$

1.2. THE STUDY RATIONALE

Many studies have appealed for the continuation of research on the exposure to dust during farming, in order to discover the exposure profile of the mineral and organic components of agriculture dust to help assess the risk in various farming scenarios and conditions. A comprehensive occupational exposure assessment regarding dust and quartz among farming workers is essential to estimate the risk and to help design appropriate intervention measures to mitigate and anticipate the potential of hazardous effects on health.

Considering international evidence on exposure to agriculture dust and related health problems and particularly the potential impact that exposure may cause to people with immunological compromised conditions, more attention should be given to mineral dust exposure in the agriculture sector. More especially, in a poor country such as Mozambique where efforts are being made to tackle poverty, hunger and disease towards the achievement of millennium development goals. The study on dust exposure doses may help in assessing and controlling the risk sources of pulmonary complications among agricultural workers, taking a stride towards dust occupational exposure and lung disease approach, and impact reduction on overall health outcomes.

1.2.1. OBJECTIVES OF THE STUDY

The objectives of the study are the following:

- To describe the respirable dust concentrations of farm workers in a medium-sized maize and root plant farm in southern Mozambique.

- To describe the respirable quartz concentrations of farm workers in a medium-sized maize and root plant farm in southern Mozambique.

- To compare the respirable quartz concentrations in a medium-sized maize and root plant farm in southern Mozambique to the South African Occupational Exposure Limit (OEL) of 0.1 mg/m^3, the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limit (REL) of 0.05 mg/m^3 and the American Conference for Governmental and Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) of 0.025 mg/m.^{3}

1.3. REVIEW OF RELATED LITERATURE

This chapter looks at literature reviews of scientifically recognized studies that have been done to study dust exposure characterization in the agriculture sector. Unlikely other sectors, mineral dust from agriculture and the related health effects were not recognized as much as, for example, mining dust. Previous studies on dust in the agriculture sector paid more attention to allergic health effects. Therefore the chapter is meant to display the recent efforts made by many scientific bodies and individual experts on dust and quartz exposure, in terms of factors that may affect dust and quartz exposure in the agriculture sector.

1.3.1. SOIL TYPE AND RESPIRABLE QUARTZ VARIATION

Internationally, several studies have been conducted, particularly in sandy loam and sandy and clay soil farms, attempting to address the risk to health due to exposure to agricultural dust and to call for action to prevent and control dust during farming activities, so that the exposure to respirable dust and quartz could be minimized.[14,15]

The percentage of respirable quartz in soil can be used to estimate the respirable quartz levels expected to be found in air under certain work conditions. Thus, the previous qualitative assessment of soil type is of great importance in the study of respirable quartz, no matter the fact that the mineral composition of soils, particularly in agriculture, may be affected by many man-made factors including purely climatic factors and conditions. Certain literature has stated possible factors which may affect the mineral composition of soil, the quartz composition and a variation, namely; the irrigation patterns, the use of fertilizer, the organic and mineral composition of the soils derived from the field farming practices and technologies of land use and used soil preparation and cultivation technological procedures.[16]

The particle size distribution characteristics of soils along with soils mineral composition and moisture content have a great significance in the respirable quartz fraction in the agricultural setting. A study using bulk dust samples surveyed the respirable quartz content variation with soil type and concluded that the respirable fraction of sandy loam soils averaged at 0.04 (SD 0.02) versus 0.13 (SD 0.03) for clay soils and 0.04 (SD 0.03) for sandy soils.[14] The quartz content in the range of 4.25 μm fraction of sandy-loam soils averaged at 15.2 (SD 4.1) per cent while for clay soils is 2.2 (SD 0.8) per cent and 29.0 (SD 11.1) per cent in sandy soils.[14] The sandy soils with a lower respirable fraction of dust due to high quartz content, is more likely to contribute to a high exposure to respirable quartz in comparison to clay soils, with a relatively high level of respirable fraction of dust. Another important finding from the study is that soil moisture would be a factor in the quartz respirable fraction. The soil moisture levels normally averaged at 10.1 (SD 3.9) per cent for clay soils, 2.5 (SD 3.6) per cent for sandy-loam soils, and 0.9 (SD 0.5) per cent for sandy soils. Thus, the sandy-loam soils and sandy soils are more likely to pose a potential hazard to respirable quartz due to the high quartz content and low moisture retaining capacity.

A study on personal respirable dust and quartz measurements collected on a sandy soil farm in the Free State Province found convincing scientific evidences of a respirable quartz risk in sandy soil farms.[15] In general, the measured respirable quartz exposures in the study exceed the occupational exposure limits and the respirable quartz concentration range from not detectable to 0.626 mg/m^3. Due to variability of exposure conditions, soil and crop cultivation types, the exposure to respirable quartz is used to be variable. General area measurements in sandy soils found high concentration of respirable quartz in the atmosphere of tractor cabs.[17] Personal Breathing Zone measurements in sandy soils farming during sweet potato transplanting, found quartz concentrations in the range of 3910 $\pm$ 2.07 µg/m^3.[18]

1.3.2. MEASUREMENT OF MINERAL DUST

There is no study that has been conducted within the country which attempts to determine and measure the mineral dust in the agricultural setting. At international level, several studies have been reported addressing the exposure to mineral dust in the agricultural setting. These studies have reported situations of over-exposure to dust above the permissible occupational exposure limits.

A study on dust characterization in agriculture has found the highest exposure to dust during soil preparation activities which include plowing, primary and secondary tilling, and that respirable quartz exposure in agriculture commonly exceed exposure limit standards. In this study, the soil type characterization of the study area is unknown.[5]

Differences in equipment, tasks and climate may affect exposure patterns of tractor operators. Enclosed cab on the tractor, higher relative humidity and lower tractor speed are associated with decrease in personal dust level.[5] A study on rice farming found respirable dust concentration in the range of 0.52-2.16 mg/m^3 outside the harvester and 1.77 to 5.24 mg/m^3 outside the tractor during field preparation.[5]

A comprehensive study based on the laser dust meter methodology concluded that the percentage of dust potentially deposited in the pulmonary alveoli remained within the range of 0.76-8.40 per cent of the total inhalable dust. The study does not measure respirable quartz and the farming soils types were not previously identified.[13]

Mechanical soil preparation and maintenance activities were proved as contributing to high concentration of respirable dust with significant percentage of quartz in the respirable range when compared to other farming activities[19,5]. For instance, a literature review on quartz content in dust generated during rice farming, the concentrations ranging from 20 to 90 μg/m^3 of respirable quartz were found with the highest levels observed during field preparation (soil preparation).[20]

In sampling dust, the effective exposure time to be sampled is a problematic issue due to changeable exposure conditions. In a study on respirable crystalline silica (quartz) a time length of approximately 4 hours (mean 230 min.) was used to collect personal breathing zone measurements.[18] Certain literature states that in occupational exposure measurements, employees may be sampled for a period that covers at least 70 per cent to 80 per cent of the TWA full period.[21]

The sample size is a critical factor which research needs to address to ensure statistical acceptable power of the measurement. There is no set of rules regarding the number of samples to collect. A study on personal exposure to respirable quartz in SA sandy soil farms considered a sample size of about 149 breathing zone measurements.[15] International study has considered a total of 77 respirable dust samples for respirable quartz exposure monitoring from a similar exposure group.[22] However, sample size procedures are available from selective publications.

PART II

MATERIAL AND METHODS

2.1. DESCRIPTION OF STUDY AREA

This chapter describes the study area, research methods, sampling and measurement procedures. The description of study area includes the geographical and the socio-economic features of the district which dictated it's eligibility for the study.

2.1.1. LOCATION AND DESCRIPTION OF THE STUDY AREA

The study area, Boane District, is located in the south of Maputo Province, 30 km away from Maputo city. The size of the district is about 650 km^2, with a total population of approximately 55 000 inhabitants, according to the 2007 Population Census. Practically the entire population is engaged in subsistence agriculture for their survival, food and wage earning. It is known as being a predominantly agricultural based district.

Private and state farms enterprises are found developing commercial farming work attracted by soil fertility and above all, by the presence of water for irrigation.

2.1.2. STUDY AREA SELECTION CRITERIA

To study respirable quartz, the previous and qualitative characterization of soils quartz content is essential and a pre-condition to select a certain area as study area. The "*Soil Characterization Field Protocols*"[6] and the study on the mineralogical composition and mapping of soils in Boane[7] were used as criteria for the selection of the study area. The soil characterization field protocols was used for qualitative determination of soil type. It was found that the soils of the study setting was predominately sandy loam to silty soil type, and the geologist X-ray diffraction soil grain size analysis pointed out quartz as the most common and abundant mineral, ranging in main parts of the study setting from 8 per cent to 24 per cent.[9]

2.1.3. STUDY DESIGN

This is a descriptive cross-sectional study which involves direct workers personal respirable dust exposure sampling and measurement for further exposure compliance assessment, to set up a preliminary baseline for potential association of possible occurrence of respiratory symptoms due to exposure to dust in terms of respirable dust and quartz.

2.1.4. SELECTION OF FARMS

The National Research Institute of Agriculture (NRIA) has been involved and has supported the study and played an important role in the selection of the farms. The farms were selected by convenient sampling methods on the basis of the following points:

- Being medium-sized farming.
- Being in the process of cultivating the maize and/or root plants during the period of the study data collection.
- Farming soil characterization indicating loamy sand, sandy loam, sandy or silty soil type potential for occurrence of quartz.
- Activity schedule or tasks occurring for at least seventy per cent of average working time for personal sampling.

On the above selection basis and pre-conditions, farmers were conveniently selected and individual workers were asked for consent to be sampling subjects. The selected farms were divided into maize and root plant farms and dust samples were scheduled accordingly.

2.2. RESEARCH PROCEDURES

Due to the specific character of production processes in agriculture, workers employed in this sector of economy are exposed to dust in changeable manners determined by a variety of work activities, variability of concentrations and composition of dust, work site and daily time exposure. Thus, the study analyzed the duration of working cycle, technological distribution of occupations within the working cycle, their time-consuming character and variations in the level of dustiness accompanying each specific occupation. The variations in the level of dustiness were associated not only with the type of occupation, but also with the variability of conditions accompanying work, such as weather and soil characteristics. Therefore the study procedures should take into consideration characteristics such as job specificities, conditions characterizing farming work, and climate and soil conditions which make the study purpose and objectives achievable as desired.

2.2.1. ETHICS PROCEDURES

The study did not directly involve human subjects in terms of questionnaires or biological specimen. The study purpose was to build a set of dust exposure data. There was no intention to relate the dust sampling result to the health outcome of workers; therefore no confidentiality dispute issues were expected. However, to comply with internationally agreed research ethics principles, the following were considered:

i. ETHICS APROVAL

To comply with international ethics principles for research involving humans and the University of the Witwatersrand Ethics procedures, the ethics clearance application letter was submitted and approved by the University of the Witwatersrand Human Research Ethics Committee (Clearance Certificate nr. M10945).

II. FORMAL INFORMED CONSENT

Informed consent is a mechanism to ensure that people understand what it means to participate in a particular research project, to enable them to consciously decide whether they want to participate or not. Due to the illiteracy of some of the study participants, written and oral individual consent was considered. **APPENDIX I** shows the participants' consent letters.

2.2.2. SAMPLING STRATEGY

One of the most important objectives of any occupational hygiene discipline is to accurately assess employees' occupational exposure to airborne contaminants or other health and safety hazards. This will ensure that effective intervention and control measures are considered to minimize the risk of adverse health effects due to exposure to airborne contaminants or other health hazardous agents.

The study sampling and measurement strategy are designed under the assumption that the research is assigned for comprehensive occupational exposure assessment of contaminants, for the ultimate goal of exposure compliance assessment and scientific findings.

i. SAMPLING SUBJECT SELECTION CRITERIA

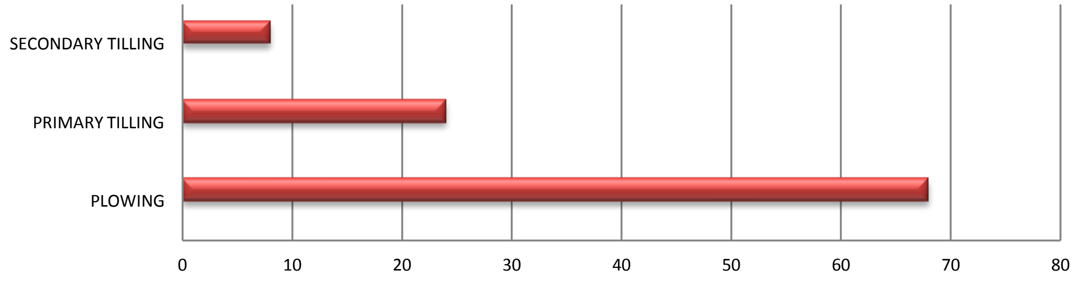
The concept was to sample the maximum risk group, as the group of employees believed to be most exposed was used as sampling subjects. Tractor operators were the maximum risk group. In an ideal situation, each potentially exposed worker and task performed should be individually sampled to make an informed decision.

The best procedure encountered to determine the maximum risk employee was through observation of various farming tasks and working conditions. The procedure was based on the observation of the cloud of dust generation, the dust build-up on the workers surface body and clothes, journey duration of task and prevailing cycle of the task in year schedule and specific task frequency. The following most solicited tasks and operations were observed prior to the commencement of the data collection process, namely:

- Crop cultivation.
- Soil preparation comprising the plowing, primary and secondary tilling.
- Fertilization which is essentially about using fertilizer and other chemicals for soil enrichment to ensure perfect growth of plants.
- Sowing and planting which comprises a variety of seeding and planting of crop and farming products.
- Plant protection which involves the use of pesticides, chemicals and maintenance of crop.

Due to time limitation certain tasks such as harvesting and other minor and occasional infrequent tasks were not observed. Based on the observed tasks and according to **FIGURE 2**, plowing is the most potential dust generation task with a more prevailing time cycle in the overall farming production cycle.

FIGURE 2
TRACTOR OPERATORS TIME FREQUENCY DISTRIBUTION IN THE MAJOR FARMING TASKS IN PERCENTAGE



On the basis of the above mentioned, the Tractor Operator doing soil preparation and maintenance is the maximum risky job and therefore the employees whose exposure was sampled and measured in the present study. In this context for dust sampling, 4 different tractor operators were involved and requested to wear dust sampling devices during their working time.

ii. DUST RISKY ACTIVITIES

The soils preparation in the categories of plowing, primary and secondary tilling are the most frequent tasks in the entire farming production cycle and therefore they are high risk tasks in terms of dust generation to be subjected to dust sampling and measurement.

iii. PERSONAL BREATHING ZONE SAMPLING

The intention of the regulation is that samples taken for the purpose of measuring employee exposure and occupational exposure comprehensive evaluation must be taken only by personal and breathing zone samples. Assuming that great exposure variability may occur due to environmental and work condition factors causing changeable exposure conditions, the personal samples are recommended and used in this study.

FIGURE 3: EARING OF SAMPLING DEVICE IN PREPARATION TO DUST SAMPLING PROCESS

FIGURE 4: TRACTOR OPERATOR DOING PLOUGHING, THE MOST FREQUENT FARMING OPERATION

On using personal sampling, the sampling device was directly attached to the employee who wore it continuously during work. The sampling device was attached closer to 30 cm employee breathing zone. Incorrect positioning of the sampling device may affect the measurement results and this need to be checked from time to time since the workers movement may change the position of the sampling device.

2.2.3. SAMPLING AND MEASUREMENT OF DUST

Clear procedure of sampling and measurement of dust is the essential component of the study. Sampling was done through direct and on-field samples collection from exposed workers using appropriate dust collection devices, available and recommended in occupational hygiene. The weighing laboratory was used to weigh the sampling medium before and after on-field sampling and this was kept under controlled indoor environmental conditions and restricted to unauthorized people.

The environmental and weather factors measurement and monitoring were guaranteed by the weather forecasting station managed by the Agriculture Research Institute, who kindly accepted to co-operate in providing dates on weather forecasting.

i. MATERIAL AND METHODS

The study covered a group of 4 tractor operators working in the area either as full-time employees or piece-rate/seasonal employees. The samples were taken in the farmer's respiratory zone while performing individual work activities. A total of seventy valid personal respirable dust samples were collected using SKC personal air sampling pumps operating at a flow rate of 2.2 L/min and drawn through SKC respirable dust cyclones for size-collection sampling and Polyvinyl chloride (PVC) membrane filter of 25 mm in diameter and a pore size of 5 µm as sampling medium. The flow rates were checked prior to, and at the completion of the sampling period using a Gillian calibrator.

The sampling filters were pre-weighed and sampling cassette prepared at Weighing Lab of the Eduardo Mondlane University, Chemical Engineering Department (EMU/CED). The samples, after field collection, were taken back to the EMU/CED where the filters were removed from the sampling heads and stored in labeled cassettes and allowed to acclimatize for twenty-four hours before being weighed on a calibrated 4 decimal microbalance. After weighing, filter medium containing the respirable dust were then kept acclimatized in appropriate "preti dish" and awaited further sending to NIOH, Occupational Hygiene Unity for analysis of respirable quartz content.

Blank samples were taken for each sampling scenario to assess the influence of weather specific conditions and possible sampling filter contamination that may occur during handling, preparation and transportation of samples and equipment. To comply with sampling and measurement quality procedure, the obtained data were adjusted for correctness regarding the blank samples contamination and sampling pump volume variation.

The quartz fraction in the respirable dust was determined through the MDHS 101 method for the determination of crystalline silica (quartz) by infrared absorption spectrophotometer. The method requires an FTIR or a double beam dispersive instrument. According to the NIOSH, the XRD and IR based methods for determination of crystalline silica are the most common technique used for crystalline silica analysis with the quantitative limit of detection ranging from 5 to 10 µg per sample.[18]

The Johannesburg National Institute of Occupational Health (NIOH) through the Occupational Hygiene Unit kindly accepted to do the analytical determination of quartz based on the specified in the FTIR MDHS 101 HSE analytical method.

ii. DURATION AND TIMING

A long sampling time ensures a heavier deposit of dust on the filter, thus reducing measurement inaccuracies. Sampling times should therefore be as long as is reasonably practicable (preferably not less than 4 hours), and should be representative of the working periods of the individuals being monitored.[21]

In the specific case of farming activities in medium-sized farming in the south of the country, it is difficult to obtain the 8 hour time average consecutive samples. Job schedules of 3 different tractor operators were monitored for a period of 1 month and revealed that a time frequency of 47 per cent of effective working time is achieved on average by each tractor permanently employed. For the seasonal tractor operators this figure may reduce to 35 per cent of time frequency. Depending on the job demand and solicitation, the tractor operator no matter his employment status, may work more than daily obligatory working hours, including weekend work.

Considering the time length of the worker exposure to dust, the 35 to 47 per cent effective exposure time was assumed as the 8 hour time average of the tractor operator’s job function. This figure was assumed in the study measurement strategy as the acceptable duration of sampling.

Thus, the duration of sampling was kept to a minimum of 3 hours and half continuous sampling timing. Sampling time less than the minimum assumed in this study was rejected and not considered for the purpose of data analysis and interpretation.

iii. QUALITY CONTROL PROCEDURE

To ensure quality of the data, the potential systematic errors from the study were kept under control by managing the following potential sources of errors:

- Sampling pumps were calibrated and checked for flow rate correction due to variation during sampling. The flow rate variation range before and after sampling of less than 5 per cent was considered acceptable, otherwise the samples demonstrating flow rate variation equal and more than 5 per cent were rejected and repeated.

- The pumps were visually checked several times when possible during the sampling process so that any deviation could be detected, ensuring that the pump and entire process of sampling is operating properly.

- During dust sampling, the head/cyclone may be found dirty and this can cause problems in dust sampling, blocking the passage of dust through the orifice of the cyclone. Thus, to keep the dust sampling process and the passage of respirable fraction of dust through the cyclone, after sampling and during the preparation to the next sampling session, the head and cyclone were cleaned using a proper device existing in the microbalance weighing laboratory room.

- The pump operational condition was kept under control to check for possible pump malfunctioning. To avoid insufficient samples, a sampling plan was scheduled in a manner that only dusty, dry climate conditions were considered for dust sampling.

- By courtesy of the weather forecasting station, data on sampling day temperature, humidity and wind velocity were collected and analyzed to seek any possible association and influence on the collected data.

The weighing and gravimetric laboratory were sponsored and established through the work and health in the southern Africa program under assistance and technical support of the Johannesburg National Institute of Occupational Health (NIOH).

iv. DATA MANAGEMENT AND ANALYSIS

Sampling and measurement data generated from the study were analyzed using the SSPS statistical software package (Version 11.5) and other means of statistical calculation, data interpretation and analysis methods. For instance, standard statistical methods and procedures for sampling and measurements were used to clearly pinpoint the employee's exposure average in compliance with the occupational exposure limits; and to estimate long-term exposure based on several exposure measurement daily averages. The potential discrepancy between the measured and the true exposure averages due to unpredicted random sampling errors and random occupational environmental fluctuation within a working day, was statistically assessed, aiming to calculate the intervals limit containing the true value of exposure.

To make preliminary judgment about the suitability of a lognormal model distribution of the data and improved description of the occupational exposure data measurements, the lognormal probability plots of exposure measurement data and exposure average were used to provide quick estimates of the geometric mean and the geometric standard deviation of fitted lognormal model.

v. SAMPLE SIZE

The tractor operators were identified as the maximum risk homogeneous exposure group for the study. Since the exposure group is small, all the workers were subjected to sampling. The important issue to be addressed in this specific case is deciding on how many samples need to be collected to meet the minimal statistical requirements for occupational hygiene sampling and measurement of environmental stressors. Thus, seventy (70) PBZ samples divided into the maize and root plant farming were considered. According to the online software for sample size determination, the seventy personal breathing zone samples are computed for significance level and absolute error of 0.05 and 0.266 respectively.[23]

PART III

RESULTS OF THE STUDY

This chapter aims to highlight the main results of the studies and compare the findings with similar international research studies on respirable dust and quartz in the agricultural setting.

The experimental sampling and measurement data are printed out and graphically exploited to assess and discuss occupational exposure distribution and variability.

The sampling and measurement data were subjected to data exploration and analysis grounded on the SPSS computerized statistical software. The true average exposures of various measurement scenarios for respirable dust and quartz were statistical and graphically visualized to assess the level of compliance and non compliance on behalf of the relevant standards.

3.1. DISTRIBUTION OF WORKING TIME IN PRODUCTION CYCLE

One of the flexible working conditions in the agricultural setting is the average daily working time which employees may spend on a specific task. The national obligatory working limit is estimated at about 2 104 hours annually.[24] The working time assessment results indicate that the effective working time frequency for the tractor operators varies from 35 per cent to 47 per cent of the daily permitted time for seasonal and full-time employment status tractor operators respectively, and the plowing accounts for about 68 per cent of the total effective time followed by primary tilling with 24 per cent and secondary tilling with 8 per cent.

The descriptive statistical approach to the sampling time data shows that the average sampling time which is also the effective day exposure time to dust by the tractor operators, estimated for 95 per cent interval confidence, is equal to 311.6 minutes, 95 per cent CI (294 – 329.7). The minimum and the maximum observed values were 179 and 500 minutes respectively.

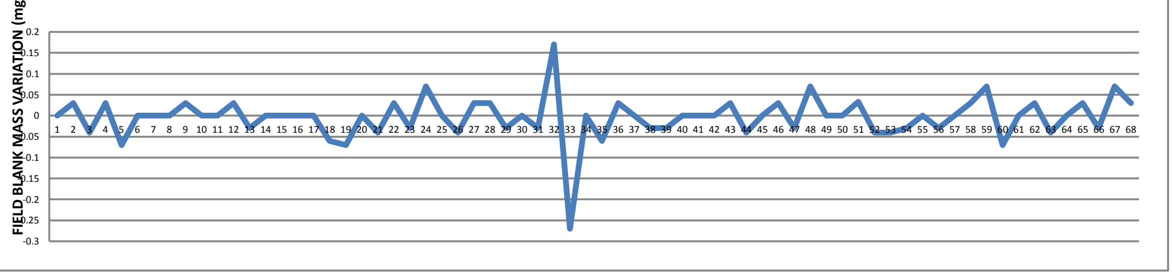
The Steam & Leaf plot include the Box Plot of data (See Annex I) shows the extreme and outlier values of exposure sampling time. The outlier value is above the obligatory working time with an excess of about 4.2 per cent. The mean and the median are counted for 311.6 minutes and 307 minutes respectively, showing that the sampling time of the exposure to dust is not normally distributed.

3.2. WEATHER AND FILTER MEDIUM CONTAMINATION

Relative humidity may affect the mass weight deposited in filter due to moisture absorption. High humidity conditions are known to increase the chance of filter absorbing the moisture. High wind velocity normally leads to unstable weather conditions that may cause and provoke the possibility of contamination of filter by perturbing the process of dust sampling and measurement.

Weather conditions' influence on the sampled and measured data could be assessed by checking for blank samples contamination mass difference, before and after exposure to certain environmental conditions. According to **FIGURE 5** a potential contamination of filter medium due to environmental conditions may occur.

FIGURE 5
BLANK SAMPLES MASS VARIATION



The difference between the mean and median of the descriptive statistics of blank samples mass variation shows that the variation is not normally distributed and that the non-parametric parameter may describe the filter blank mass distribution. From the descriptive statistics data, the assumption is that the filter contamination may be possible through absorption or adsorption of humidity. Assuming normal distribution of data, the mean value of possible contamination is minus 0.00407, and the upper and lower confidence limit of the mean value may be assumed as varying between the lower limit of minus 0.01 and the upper limit of 0.00183.

Considering that data on blank samples mass variation are skewed and non-normal distributed data, the median is the best parameter to describe the average value. Then the true value of filter blank mass variation could be taken as being close to 'zero' the median of the data, meaning that there is no significant contamination of sample due to environmental and weather conditions.

3.3. CONCENTRATION OF RESPIRABLE DUST

The airborne concentration is the amount of the contaminant of interest present in certain volume of air, usually given by milligrams per cubic meter. The concentration of airborne contaminants may also be referred to as micrograms per cubic meter of air.

APPENDICES II, III, and **IV** give the database for quality determination of concentration of respirable dust, namely; the environmental condition recording sheet data, the on-field data recording, and dust exposure calculation sheet respectively. These **APPENDICES** summarise the entire data recording sheet for the process of data collection, computing and calculation of airborne dust concentration. The detection limit of the cyclone filters was 0.022 mg per filter. Measurements with value below the detection limit were assigned half the value of the detection limit for statistical analysis.[24]

3.4. DUSTINESS IN INDIVIDUAL FARMING ACTIVITIES

The exposure sampling and measurement were conducted in 2 different farming crops aimed at describing the exposure profile and variability governing the worker exposure to respirable agricultural dust in these 2 most common farming crops and cultivation.

The measurements data and dust concentrations were printed out and analyzed per crop cultivation, individual operators and all measurements included. Descriptive statistical procedure, graphic visualization of data distribution and the SPSS inferential statistics procedure were used to show the exposure behavior as much as possible, profile and variability.

3.4.1. MAIZE FARMING EXPOSURE PROFILE

About thirty-nine direct continuous samples of tractor operators daily exposed were taken to compile a respirable dust exposure profile for maize crop farming. Three tractor operators were involved. Two of the tractor operators were working as full-time operators, namely the operators entitled number 1 and number 3, while one of the operators, i.e. number 2 operator was working as piece-rate and seasonal tractor operator.

The thirty-nine dust samples and measurements taken from the 3 operators from maize cultivation crops were plotted together graphically to point out the exposure profile and variability. **APPENDIX V** shows the graphical distribution of the thirty-nine samples from a maize crop and cultivation based on individual sampling of the 3 tractors.

From the assumption that the exposure measurements are normally distributed, the average concentration of the exposure to respirable dust at the maize crop cultivation for 95 per cent confidence interval is equal to 0.8096 mg/m^3 95 per cent CI (0.5960 – 1.0231).

3.4.2. ROOT PLANT CROP EXPOSURE PROFILE

A single full-time employee status category tractor operator was involved and daily working exposure was measured. About thirty-one personal samples were collected and the result presented in a histogram chart. Great variability of exposure concentration was observed for the same individual according to **APPENDIX VI.**

All thirty measurements except one, fit in the statistical range and the zero concentration was observed which for statistical purposes was assigned half of the detection limit of the method. The true value of the exposure measurement for significant level of 0.05 and 95 per cent confident interval is found as being 0.567 mg/m^3, 95 per cent CI (0.417-0.716).

3.5. RESPIRABLE DUST IN MEDIUM-SIZED FARMS

APPENDIX VII shows the respirable dust exposure concentration and distribution for the entire sample size which represents the exposure measurements in the medium-sized maize and root plant farms in the south of Mozambique.

For the entire sample's size, the highest observed exposure concentration was 2.88 $mg/m^{3,}$ and this was related to the piece-rate and seasonal worker exposure measurement. The lowest observed measurement was 0.0104 mg/m^3 and it is related to the root plant tractor operator.

The statistical approach to the measurement data indicates that the true average respirable dust exposure concentration in medium-sized maize and crop cultivation farms in the south of Mozambique can be estimated for confidence level of 0.05 as: 0.702 mg/m^3; 95 per cent CI (0.567 - 0.836) with a standard error of the mean estimated at 0.068, which is in the same range of the assumption made for the sample size standard error.

3.6. EXPOSURE DISTRIBUTION ANALYSIS

Plotting data on lognormal paper is the procedure recommended in the occupational hygiene field to make preliminary judgment of data on exposure concentration in terms of their suitability to the lognormal distribution model and compliance analysis to the relevant occupational exposure limits.

Lognormal plotting is useful in the sense that it can help research perform quick determination of the geometric mean and geometric standard deviation of distribution, which is a measure of the variation or dispersion of the data. **APPENDIX VII** shows the lognormal distribution plot of the measurement altogether.

The lognormal distribution plot in **APPENDIX VII** of all seventy measurements indicates that the data distribution line appears to be 2 distinct line segments, suggesting that the data are from a mixture of 2 distribution or 2 different population data; in this specific case the population data from Maize cultivation and Root Plant crop cultivation. The outlier's data appears at the right side of the distribution.

The Geometric Mean determined graphically from lognormal distribution plot at 50 per cent probability value is found as being 0.515 mg/m^3 while the Geometric Standard Deviation determined from 84 per cent concentration divided by the geometric mean is 2.29 dimensionless numbers.

Exposure profile variation due to environmental factors could be expressed by the Geometric Standard Deviation.[19] A Geometric Standard Deviation (GSD) of 1.0 represents absolutely no variation of exposure profile due to environmental factors and the GSD of 2.0 and above represents exposure profile variation due to environmental factors.

3.6.1. MAIZE CROP EXPOSURE DISTRIBUTION

The lognormal exposure distribution for maize crops seems to have 2 potentially different populations when observing the distribution curve. This suggests that systematic changes in the contaminant exposure concentration for each tractor operator, whose exposure was measured, may play a role in exposure profile. **APPENDIX VII** shows the probability exposure distribution.

Direct reading of the distribution best fit line indicates a Geometric Mean of 0.593 mg/m^3 and a Geometric Standard Deviation of 2.36. This means that there is a considerable variation of environmental and weather conditions during the sampling process.

3.6.2. ROOT PLANT EXPOSURE DISTRIBUTION

The exposure measurements data distribution plotted in a lognormal chart shows a best fit distribution curve that indicates outliers measurements data at the right side of the graph (see **APPENDIX IX**). Direct reading of the best fit line gives the Geometric Mean of 0.449 mg/m^3 and a Geometric Standard Deviation of 2.00. The calculated Geometric Standard Deviation is between 1.0 and 2.0. From this fact, it is believed that in the root plant cultivation exposure measurements there were environmental and working conditions variations which influenced the exposure measurements, but probably not too much compared with the variation in maize crop. This could probably be explained by the fact that in root plant cultivation a single tractor operator was involved in all measurements.

3.6.3. RESPIRABLE QUARTZ DETERMINATION

The Johannesburg National Institute of Occupational Health, division of occupational hygiene, accepted to take the analytical determination of quartz. The analytical determinations of quartz were made from samples randomly selected from all seventy measurements. Table 1 shows the randomly selected samples for respirable quartz determination and the analytical determination of quartz.

Nineteen random samples were analyzed using the MDHS 101 method for the determination of crystalline silica in respirable dust by infrared spectroscopy direct on filter analysis. Although some international literature refers the quantitative detection of the XRD and IR methods in the range of 5 to 10 μg per samples, the lab is not completely sure about what the detection limit of the method is and therefore, all the values below 40 μg are treated with caution and assigned to square root two $\left(\sqrt{2}\right)$ for the purpose of calculation. One sample was not considered for the statistical determination of the average quartz content in respirable dust due to the failure in coding of the result from the lab. The exposure concentrations of respirable quartz were obtained directly from the 8-hour TWA exposure concentration of respirable dust, multiplied by the percentage of mass of quartz contained in the sampled dust and the results are detailed in **APPENDIX X**. The lognormal distribution of exposure measurements for respirable quartz were plotted and posted for each crop cultivation type and for medium-sized maize and root plant farming in **APPENDICES XI - XIII.**

TABLE 1: RANDOM SELECTION OF SAMPLES AND QUARTZ ANALYSIS

MAIZE CULTIVATION					ROOT PLANT CULTIVATION				
NR.	SAMPLE ORDER NO.	SAMPLE REFERENCE NO.	AVERAGE MASS OF QUARTZ (μg)	QUARTZ PERCENTAGE	NO.	SAMPLE ORDER NO.	SAMPLE REFERENCE NO.	AVERAGE MASS OF QUARTZ (μg)	QUARTZ PERCENTAGE
01	4	M04.402	0.028	4.23	10	29	R29.204	0.028	20
02	10	M10.101	0.028	5.66	11	58	M58.401	0.028	9.3
03	14	M14.301	0.028	2.39	12	39	R39.404	51.83	19.2
04	15	M15.202	109.265	29.5	13	40	R40.104	0.028	6.43
05	19	M19.101	42.49	11.48	14	47	R47.104	43.12	5.4
06	21	M21.301	0.020	2.32	15	54	R54.404	0.028	5.28
07	49	M49.203	114.29	11.43	16	55	R55.204	242.225	15.12
08	69	M69.302	0.028	9.40	17	57	R57.304	43.845	3.01
09	53	M53.402	0.028	28	18	67	M67.402	0.028	2.15

N.B: THE PERCENTAGE OF QUARTZ WAS OBTAINED DIVIDING THE ACTUAL MASS OF QUARTZ PER CORRECTED MASS IN THE FILTER MEDIUM

3.6.4. RESPIRABLE QUARTZ EXPOSURE

Statistical analysis of the data in Table 1, in terms of percentage shows quartz content in respirable dust averaged at 0.105 (SD 0.097) for samples collected from maize farms and 0.106 (SD 0.07) for samples collected from root plants. Therefore, considering that the research is directed to medium-sized maize and root plant farming in the south of Mozambique, the percentage of quartz in respirable range of the mineral dust from Medium Sized Maize and Root Plant Farming located in Boane District is averaged at 0.106 (SD 0.086), which is the true mean maize and root plant farms quartz content analysis according to the descriptive statistical parameters presented below.

TABLE 2: DESCRIPTIVE STATISTICAL

SAMPLES DESCRIPTION	DESCRIPTIVE STATISTICAL PARAMETERS (10^{-2})						
	MEAN	MEDIAN	MIN.	MAX.	STD. DEV	VARIANCE	GM
MAIZE FARM	10.53	9.30	2.15	29.50	9.67	93.6	2.45
ROOT PLANT FARM	10.63	6.44	3.01	20.00	7.22	52.2	2.00
STUDY SETTING	10.57	7.86	2.15	29.50	8.57	73.5	2.28

The respirable quartz concentrations in maize and root plant cultivation were calculated multiplying the concentrations of respirable dust by the respirable quartz fraction of the sampled dust.

The respirable quartz exposure concentration in medium sized maize and root plant farming range from 0.001 up to 0.31 mg/m^3 and the true value of exposure concentration is averaged at 0.074 (SD 0.06) mg/m^3.

3.7. EXPOSURE COMPLIANCE ANALYSIS

Data on respirable quartz were treated and analyzed based on the relevant statistical parameter and recommended procedure for occupational hygiene exposure data analysis. Relevant occupational exposure limits were used to assess exposure measurement compliance. **APPENDIX XIV** prints out, graphically, the exposure compliance against the SA, NIOSH and ACGIH occupational exposure limits for quartz. Meanwhile, data on exposure measurements compliance were best described with a lognormal distribution, and the results for respirable dust and quartz were summarized in Table 3. Geometric means and geometric standard deviations were used to present the average and distribution of concentrations and above all, the analysis, interpretation and discussion of occupational exposure distribution. Table 3 summarizes the exposure measurements statistical and compliance assessment analysis and interpretation. It prints out in a systematic way, the exposure evaluation and profile in regard to respirable dust and quartz in medium- sized maize and root plants in the south of Mozambique.

The results summarized in the Table 3 indicates that Seventy Four (74%) percent of the exposure measurements are in compliance with the South African Department of Labor standard of the 0.1 mg/m^3, Fourth Five (45%) are in compliance with the National Institute for Occupational Health and Safety (NIOSH) recommended exposure limit of 0.05 mg/m^3 and Seventeen (17%) are in compliance with the globally used reference value of the American Conference of Governmental Industrial Hygienists (ACGIH) of 0.025 mg/m^3.

The minimal average value of exposure to respirable quartz is 0.06 mg/m^3(SD 0.04) observed in the root plant tractor operator (Operator 4) and the maximum average value of exposure to respirable quartz is 0.117 mg/m^3(SD 0.08) observed in the maize crop cultivation tractor operators (Operator 4).

The geometric mean and geometric standard deviation were determined graphically, therefore some inaccuracy may occur due to observer error when the data is compared with one determined electronically from statistical software. The geometric standard deviation of exposure measurements tends to be significant high in maize crop cultivation when compared with the geometric standard deviation in root plant crop cultivation.

TABLE 3: SUMMARY OF EXPOSURE MEASUREMENTS AND STATISTICS

SUBJECT NAME	SAMPLE SIZE (n)	RANGE VARIATION (mg/m^3)	EXPOSURE MEAN ±SD (mg/m^3)	MEDIAN (mg/m^3)	GEOMETRIC MEAN (mg/m^3)	GSD	INTERQUARTILE RANGE (mg/m^3)	OCCUPATIONAL EXPOSURE LIMITS (mg/m^3)			
								$\% \leq 2$[1]	$\% \leq 0.1$[2]	$\% \leq 0.05$[3]	$\% \leq 0.025$[4]
RESPIRABLE DUST STATISTICS											
OPERATOR 1	15	1.48	0.759 (SD 0.479)	0.7572	0.64	2.03	0.7910	96	NA	NA	NA
OPERATOR 2	14	2.78	0.649 (SD 0.724)	0.4245	0.44	2.52	0.4975	96		NA	NA
OPERATOR 3	10	2.13	1.100 (SD 0.759)	0.9600	0.90	2.43	1.4010	82		NA	NA
OPERATOR 4	31	1.5	0.567 (SD 0.408)	0.4660	0.45	2.00	0.4960	100		NA	NA
ALL SAMPLES	70	2.88	0.7021 (SD 0.571)	0.4920	0.48	2.29	0.688	96		NA	NA
RESPIRABLE QUARTZ STATISTICS											
OPERATOR 1	15	0.16	0.080 (SD 0.05)	0.0850	0.0600	2.7	0.0838	NA	70	45	18
OPERATOR 2	14	0.30	0.069 (SD 0.08)	0.0450	0.0540	2.4	0.0527	NA	77	48	22
OPERATOR 3	10	0.23	0.117 (SD 0.08)	0.1013	0.0990	5.0	0.1493	NA	50	30	18
OPERATOR 4	31	0.16	0.06 (SD 0.04)	0.0494	0.0450	2.0	0.0526	NA	86	55	19
ALL SAMPLES	70	0.31	0.074 (SD 0.06)	0.0522	0.0570	2.3	0.073	NA	74	45	17

NA = NOT APPLICABLE

[1] SOUTH AFRICA EXPOSURE LIMIT FOR RESPIRABLE DUST
[2] SOUTH AFRICA EXPOSURE LIMIT FOR RESPIRABLE QUARTZ
[3] NIOSH RECOMMENDED OCCUPATIONAL EXPOSURE LIMIT FOR RESPIRABLE QUARTZ
[4] ACGIH THRESHOLD LIMIT VALUE FOR RESPIRABLE QUARTZ

PART IV

DISCUSSION OF THE RESULTS

This chapter aims to discuss the results of the study and compare it with similar studies. The measurement and analytical methods used in the present research are also discussed in this chapter.

The degree of accuracy and statistical significance of the measurement are discussed based on the standard statistical methods.

4.1. MAIZE AND ROOT PLANT EXPOSURE STATISTICAL SIGNIFICANCE

The mean differences and exposure concentration distribution between the maize and root plant group samples show a difference on exposure measurements and profile. In the root plant crop cultivation the exposure tends to be lower compared to the maize crop exposure measurements.

In the occupational hygiene approach, it is important to learn whether the encountered differences are statistically significant or not. The T-Test statistical significance may be used to assess the statistical significance for 95 per cent confidence interval. **TABLE 4** gives the summary of descriptive statistical data of the 2 groups' measurements.

TABLE 4: TWO GROUP DESCRIPTIVE STATISTICS

DESCRIPTIVE STATISTICS PARAMETERS		N	MEAN	MEDIAN	ST. DEVIATION	VARIANCE	SKEWNESS	GEOMETRIC MEAN
CROP TYPE	MAIZE	39	0.8096	0.6300	0.6590	0.434	1.246	0.5477
	ROOT PLANT	31	0.5668	0.4660	0.4077	0.166	1.020	0.4061

The calculated T-value for the 2 measurements' group is equal to 14.7. The Tabled T-value of P-value of 0.05, confidence interval of 95 per cent and degree of freedom of 68 is equal to 2.00. This means that with the calculated T-value greater than the Tabled

T-value, the exposure measurements differences between the 2 groups; maize crop and root plant crop cultivation are proved to be statistically significant. Thus, during ploughing, primary and secondary tilling, the tractor operators are more exposed to mineral dust in maize crop cultivation than in root plant cultivation in medium-sized maize and root plant farming.

4.2. RESPIRABLE DUST RESULTS

The operator's number 1 exposure measurement is characterized by a mean average concentration with less variation compared to all maize exposure measurements average mean, and less standard deviation from the group measurements' standard deviation. In general, the operators' number 1, 2 and 4 exposure measurements compared to maize and root plants exposure measurements, appear more precise and accurate in terms of the true mean average, compared to the mean average deviation of all measurements. The operator's number 3 measurements appear to be less precise and accurate compared to measurements total mean average and standard deviation. Great exposure variation is observed in the present study on occupational exposure to dust in farming and this may be explained by many factors ranging from operational to environmental factors. Many studies on respirable dust and quartz have stated that the concentration of dust in various agricultural activities can be variable. Mark, J. et al.[25] observed respirable dust ranging from values below the limit of detection with the highest level observed during machine harvesting of tree crops. Swanepoel[15] observed respirable dust in the range of 0.09 – 2.23 mg/m^3. Kiyoung, L. et al.[26] has observed respirable dust in the range of 0.04-2.39 mg/m^3.

In the current study on respirable dust and quartz in medium-sized maize and root plant farming, the exposure concentrations to respirable dust were observed varying in the range of 0.010 to 2.88 mg/m^3 with the highest exposure measurement observed during maize farming soil preparation. One measurement from all the measurements was below the detection limit of the method and this was found in the root plant crop exposure measurement.

The geometric standard deviation of the measurements were found out of the range of 1.0-2.0 Geometric Standard Deviation, meaning that there were significant influences of intraday and interday factors in exposure measurements in maize and root plant medium-sized farms in the south of Mozambique.

Assuming that the exposure samples were taken from tractor operator job category, the study findings are that the maize crop open cab tractor operators are more exposed to respirable dust averaged at 0.8096 mg/m^3 and the true value of exposure within 95 per cent confidence intervals lies between the minimum of 0.596 mg/m^3 to the maximum of 1.023 mg/m^3 compared to the root plant open cab tractor, which is 0.567 mg/m^3 with the true value of exposure within 95 per cent confidence intervals, lying from the minimum of 0.417 mg/m^3 to the highest of 0.716 mg/m^3.

The finding shows that the respirable dust exposure concentration in medium-sized maize and root plant farming in the south of Mozambique computed from the study sample size, is estimated at 0.702 mg/m^3 and the true value for 95 per cent confident intervals lying between 0.567 mg/m^3 to the highest value of 0.836 mg/m^3.

4.3. RESPIRABLE QUARTZ RESULTS

Based on the quartz analysis results and according to the descriptive statistical parameters for the study setting, is attributed a quartz fraction in respirable dust ranging from the minimum value of 2.15 per cent to the maximum value of 29.5 per cent of mass of quartz averaged at 10.57 per cent. Swanepoel, Andrew et al., in a respirable quartz study in sandy soils farms in the Free State Province of SA, found quartz fraction in the respirable dust ranged from 0.3 to 94.4 per cent with an average of 13.4 per cent.[15] A study to assess respirable silica exposure in sandy soils in eastern North Carolina[18] has observed the highest percentage of silica at a level of 20.5 per cent during field preparation. In a study on characterization of airborne mineral dusts in rural Alberta, Canada cited by Swanepoel A, et al[15], the percentage of quartz was found ranging from 0.85 to 17 per cent.

The exposure concentration in maize farming is averaged at 0.086 mg/m^3 of respirable quartz, and the true value of exposure for 95 per cent confidence interval lies between the lowest value of 0.063 mg/m^3 to the highest value of 0.109 mg/m^3. In the root plant farming the exposure tends to be relatively low with an average of 0.060 mg/m3 and the true value for 95 per cent confidence interval lies between the lowest value of 0.044 mg/m^3 to the highest value of 0.076 mg/m^3. The study found respirable quartz exposure concentration varying between 0.001 mg/m^3 to 0.300 mg/m^3 and 0.001mg/m^3 to 0.160 mg/m^3 in maize and root plant farming, respectively.

Some studies have found relatively low concentrations and some relatively high. For instance, Lawson et al.[20] observed respirable concentration ranging from 0.02 to 0.09 mg/m^3 in a study of crystalline silica sandy soil during rice farming operations in California. Swanepoel,[15] in the study of respirable quartz exposure in sandy soil found respirable quartz ranging from non-detectable to the highest concentration of 0.626 mg/m^3.

Based on lognormal distribution exposure compliance assessment, the respirable quartz exposure in maize and root plant medium-sized farms are:

- 74 per cent in compliance with the South Africa standard for respirable quartz
- 45 per cent in compliance with the NIOSH exposure limit for respirable quartz
- 17 per cent in compliance with the ACGIH threshold limit value for respirable quartz.

During the field preparation and cultivation activities in medium-sized farms, maize farm workers tend to be more exposed to respirable dust and quartz compared to root plant cultivation. The study is conclusive that the spread or dispersion of data from the true value tends to be more pronounced in maize cultivation (SD 0.070) than in root plant cultivation (SD 0.043). However, assuming that in both maize and root plant cultivation there are occurrences of some outlier values, the interquartile range is the robust standard deviation of the measurements and these are (SD 0.090) and (SD 0.0526) for maize and root plant cultivation respectively.

Based on the principles that in exposure measurements with occurrence of outlier values, the interquartile range best described the spread and dispersion of data, in medium-sized maize and root plant farming in the south of Mozambique, the respirable quartz exposure is averaged at 0.0744 (SD 0.073) and the true value of exposure for 95 per cent confidence intervals is 0.0744 mg/m^3 95 per cent CI (0.06 - 0.09) and the standard error of 0.00724.

4.4. DISCUSSION OF THE METHOD USED

4.4.1. GRAVIMETRIC ACTIVE SAMPLING METHOD

Known as integrated sampling method, this is greatly recommended for employee's comprehensive occupational exposure assessments to workplace contaminants, particularly when the determination of full-shift employee exposure levels is desired. A cyclone size-selecting device is always used when sampling for respirable dust. Made of different materials and sized to fit the filter cassette diameter, the aluminium-made cyclone specified in NIOSH respirable dust methods is the most recommended cyclone for sampling dust for respirable quartz.

The MDHS 14/3, general methods for sampling and gravimetric analysis of respirable and inhalable dust based on the HD cyclone samplers with 25 mm diameter at a flow rate of 2.2 ℓ/min. NIOSH,[21] refers to the coefficient of variation of the sampling and gravimetric method as being equal to 0.1020 computed from the coefficient of variation of the rotameter on personal sampling and sampling/weighting of respirable dust. This is considered acceptable for the purpose of quality sampling and measurement of dust. For quality dust sampling and further quartz analysis, the following need to be taken into consideration:

- The capture efficiency of the filter medium needs to be not less than 90 per cent, and for this purpose, the GLA5000 is recommended.

- The sampling pumps must comply with the provisions of BS EN 1232.

Using the abovementioned method, the cyclone detection limit for the filter medium may be assumed as 0.022 mg[24] and for the purpose of statistical analysis, measurements below the detection limit may be assigned for half of the detection limit.

4.4.2. DISCUSSION OF THE ANALYTICAL METHOD

Infrared Spectroscopy (IR) and XRD are the crystalline silica determination techniques included in the MDHS 101 methods. The use of IR requires either an FTIR or a double beam dispersion instrument. The choice of one of the MDHS 101 methods depends largely on other potential elements that can be found present in the dust on the filter which may interfere in the analysis. Both techniques are suitable for the determination of quartz within the approximate range of 20 μg to 1.0 mg and on 25 mm filter medium, the IR technique is suitable for quartz determination in the range of 10μg to 1.0 mg. The IR analysis technique based on direct-on-filter analyses is used because of its speed and lower cost compared to XRD, the other widely accepted analytical technique for determination of quartz. The term “on-filter analysis” refers to the ideal situation of being able to analyze material deposited on a filter with minimal or no sample preparation.

One of the limitations of the FT-IR is that the infrared absorption response to the quartz is particle size dependent, meaning that for accurate results the standard reference sample for infrared analysis should therefore have the same particle size distribution as the sample under consideration, and this is a serious source of uncertainty. The lower limit of detection and accuracy depends upon a number of parameters including particle size, other constituents and type of spectrophotometer. The LOD discussion of the techniques raises various scenarios and the qualitative LOD of about 20μg, 30μg and 50μg for the weaker diffraction peaks were reported.

Experience has shown that errors of about 20 to 30μg in weighing of filters are common with conventional analytical balances. The detection limit of FTIR at the beam focus is approximately 2μg of quartz. The detection limit with the custom accessory is approximately 20μg.[27] Therefore, in the present study, because of uncertainty of the detection limit of the method, all measurements of quartz below 40μg were treated with caution and assumed as below the detection limit of the method, and were assigned ($\sqrt{2}$) for the purpose of statistical analysis. Andrew[15] in quartz analysis using XRD; a limit of detection of 22 μg was reported by NIOH and data on quartz measurement below detection limit of the 22 μg of quartz in the filter medium were assigned a value of ($\sqrt{2}$) for the calculation of average exposure. Indeed, the limit of detection of the method for determination of quartz may be influenced by many parameters. Mark, J. et al.[25] and

Archer, J.D. et al.,[18] using the NIOSH 7500 method for determination of quartz have assumed the LOD of the method in the range of 10μg and 5μg.

PART V

CONCLUSIONS AND RECOMMENDATIONS

5.1. STUDY CONCLUSION

Medium-sized and familiar farming are the predominant and common forms of land use and agricultural practices in the country. Being labor intensive agriculture, the exposure to respirable dust and quartz may be a problem for many people, particularly those living in rural farming areas.

The study on respirable dust and quartz in medium-sized maize and root plant in the south of Mozambique is the first attempt to understand exposure to hazardous agents in the agricultural sector, particularly in maize and root crop farming which are, for instance, the primary and most cultivated crop in the country. Being the maize and root plant, the most cultivated crop, study findings are therefore relevant from the point of view of the promotion of occupational health and hygiene in the agricultural setting.

The measurements of exposure to respirable dust and quartz have shown over-exposure scenarios, although some of the exposure measurements were found below the permitted exposure limits for respirable dust and quartz. In general, exposure measurements were observed exceeding the permitted exposure limit, particularly for quartz, the critical agent in the exposure to mineral dust. With exposure concentration in the range of 0.010 – 2.88 mg/m^3 for respirable dust and 0.001- 0.31 mg/m^3 for respirable quartz, the conclusion is that workers in medium-sized farming may be over-exposed to health hazardous agents, particularly to respirable quartz.

The observed exposure concentration values are below or in the same range as the observed values in some international recognized studies. This may be explained by many factors and exposure variability conditions such as the effective exposure time and intensity of mechanical mean use during soil cultivation and preparation.

The results obtained in the present study, point out quartz percentage in soil of the study setting ranging from 2.15 to 29.5 per cent of respirable dust, and this suggests that the exposure to respirable quartz in medium-sized maize and root plant in the south of Mozambique may be a risk to health of the exposed workers. Although the amount of quartz in the respirable fraction is highly variable, yet the conclusion is that the exposure can be significant.

Some differences may be found from various international studies on respirable quartz from the viewpoint of the TWA exposure concentration, and this is expected in occupational exposure; particularly occupational exposure in agricultural settings. In many international studies therefore, respirable quartz exposures were observed to be variable and strongly associated with agricultural activity and operation, soil moisture, relative humidity, farming agriculture crop and wind speed, including the observed percentage of quartz in soil.

Occupational exposure concentrations in farming operations have been proved as having great variability, probably due to operational and environmental factors. Mark, J. et al.[23] in the study on personal exposure to dust in various farming operations, found GSD of exposure measurements above 2.00, meaning that the exposures might have been affected by environmental factors. The highest GSD observed value was 11.81, and only the animal handling operation had a GSD of 1.65.

The current situation of medium-sized farms in the study setting is characterized by relatively reduced production use of mechanical cultivation means. It is believed that this could influence the exposure concentration. In increasing production, productivity and job demand and solicitation, the exposure concentration may be considerably high compared to the actual observed concentration. On the other hand, the actual data on exposure measurements were not representative of the entire production cycle and this could introduce variability in the effective exposure average concentration that the risk group is exposed to.

To a certain extent the research is supportive of some international published studies in which respirable quartz exposure in the agricultural sector, although highly variable, the potential significance for overexposure exists, particularly among farm workers. Therefore an epidemiological study approach on the potential health effects of the exposure to respirable quartz in rural agricultural areas needs to be considered.

The study revealed and has proved existing scientific evidences on the potential variability of the exposure concentration affected by various variability conditions accompanying the farming work such as; the weather and soil conditions including the type of machines and equipments used and the applied farming cultivation technology.

5.2 RECOMMENDATIONS

There is no doubt that the present study is an important kick-off point to consider exposure to mineral dust and health effects in the agricultural setting. In order to help build informed intervention plans toward promotion of occupational health among agricultural workers, the study recommendations are:

- The continuation of the efforts to understand the exposure to occupational hazards' agents in agriculture and to explore the potential association with the health status and outcomes of the farming workers.

- To consider the study on exposure to respirable dust and quartz in maize and root plant involving the entire production cycle, to clearly pinpoint various scenarios and variability conditions of the measurements.

- The study on exposure to mineral dust in the agriculture sector must be extended to other crop cultivation and farming size types, and also to other parts of the country which are more agriculture based.

- The study of soil type and mapping of farming area per soil type is recommended in the perspective of enlarging the study approach on the estimation of potential of quartz exposure in the agriculture sector across the country, which is vast and has agricultural potential. Therefore critical farming areas can be identified and appropriate preventive, exposure, and health monitoring actions would be considered for the benefit of population health.

Known as the major country economy sector where nearly more than 70 percent[3] of the population get their earning wage and employment and based on the health effect of the exposure to mineral dust in causing lung related disease and aggravation of the respiratory health condition of the exposed workers, particularly of the with immune-compromised condition, measures need to be taken to prevent exposure to respirable quartz in the agricultural sector to improve the overall health outcome of the population, particularly those busy with or employed in agriculture sector.

Based on the available evidences, the study recommendations to prevent and mitigate dust exposure in agricultural are:

- Campaigning on workers education and awareness rising on the hazards that quartz containing in the soil may represent to their health and the easy and practical solution to minimize the exposure while working

- Set up an ongoing program for occupational exposure assessment to evaluate the health risk among farming workers and look at informed regulation on agriculture exposure to respirable quartz concerning with pneumoniocosis prevention in agriculture sector

In the current study on Respirable Dust and Quartz in Medium Sized Farms in southern Mozambique, the tractor operator’s job category operating open cab was observed as the dust risky job category. The use of closed cab tractor machine could be considered as cost-effective solution to come down with unhealthy exposure to respirable dust to this particular group of farming workers.

REFERENCES

1. Valentina Fora. 88th International Labour Conference (2000); International Labour Office, Geneva; *The ILO Programme on occupational safety and health in agriculture* (1999); Geneva; June, 2000, Report VI(1).

2. Mickey Chopra, *food security, rural development and health equity in Southern Africa, Regional Network for Equity in Health in Southern Africa*; (2004); Discuss paper no. 22

3. Governo de Moçambique; *Informação do Distrito de Maputo-Boane*; http: \www.portaldogoverno.gov.mz/informação/distrito/p_maputo/Boane.pdf

4. Governo de Moçambique, Ministério de Saúde; *vigilância epidemiológica* http:\www.misau.gov.mz/pt/epidemias_endemias

5. Schenker MB, Pinkerston KE, Mitchell D, Vallyyathair V, Elvine-Kreis, Green FH; *Pneumoconiosis from agricultural dust exposure among young California farm workers* (2009); Volume 117(6); 988-94

6. H. Preetz, J.Igel, Leibniz Institute for Applied Geosciences (GGA); *Analysis of physical properties of soil samples from test sites for landmine detection in Mozambique*, Joint Research Center; Report (2006)

7. (http://www.eais.net/soil/).

9. Gabriel, P. José. *Characterization of mineralogy of sediments in the water damp,* in: course termination thesis; , UEM/Department of geology, Maputo, Mozambique, Research Report, 2007

11. Christine G. Parks, Karsten Conrad, Glinda S. Cooper; *Occupational Exposure to Crystalline Silica and Autoimmune disease* (1999); Environmental Health Perspective Supplements, Volume 107, Number S5, 793-802

12. Slavin RE, Swedo JL, Brandes D, et al; *Diseases Associated with exposure to silica and nonfibrous silicate minerals* (1988); Volume112:673-720

13. Buczaj Agnieszka. *Studies of the level of farmers' exposure to dust on private farms – based on fraction analyses* (2008). Ann Agric Environ Med, 15, 79–84.)

14. Stopford CM, Stopford W. *Potential for respirable quartz exposure from North Carolina farm soils* (1995) *Scand* J *Work Environ, Health*; 21 supplements 2:44-6.)

15. Andrew Swanepoel, et al. *Quartz Exposure in Agriculture: Literature Review and South African Survey* (2008); Annals of occupational hygiene (2010) Vol. 54, pp 281-292,

16. Green FHY, Tucker JM, Vallyathan V,. *Occupational disease of the lung. Lab Med* (1983): 14:103-111

17. Dynnik VI, Khizhniakova L.N. Baranenko AA, Makotchenko VM, Okseniuk IM. (1981); *Silicosis in Tractor Drives working on sandy soils on tree farms*; (12): 26-8

18. Archer JD, Cooper Gs Reist PC, Storm JF, Nylander-French La. *Exposure to Respirable Crystalline Silicosis in Eastern North Carolina farm workers*; (2002): AIHA J: 63(6): 750-5

19. Molocznik Anna. *Qualitative and Quantitative analysis of agricultural dust in working environment* (2002). Ann Agric Environ Med; 9: 71-78

20. Lawson R. Schenker M. Mc Curdy et al. *Exposure to amorphous silica fibers and other particulate matter during rice farming operations*; (1995); Appl. Occup. Environ. Hygiene; 10: 677-84

21. Nelson A. Leidel, Kenneth A. Busch, Jeremiah R. Lynch. *Occupational Exposure Sampling Strategy Manual,* Pub nr. 77-173; Cincinnati, Ohio, NIOSH (1977)

22. JParikh, LLy, and Mtkaczuk. Health safety environment; Canberra, ACT (ed): *Respirable quartz exposure monitoring in South Australia Quarries*; Australia; AIOH conference; 5-9 Dec 2009

23. http://www.mirrorservice.org/sites/home.ubalt.edu/ntsbarsh/Business-stat.

24. Governo de Moçambique, Lei do Trabalho. http://www.portaldogoverno.gov.mz/legisla/legisSectores/trabalho/

25. Mark J. Nievwenhuijsen, Marc B. Schenker. *Determinants of personal dust exposure during field crop operation in California Agriculture* (1998); Am Ind Hyg Assoc J 59 (1) : 9-13

26. Kiyoung Lee, Robert J. Lawson et al. *Journal of Occupational and Environmental Hygiene* (2008); 14(2): 131-3

27. Donaldo P. Tuchman. *Research toward Direct Analysis of Quartz Dust on Filter using FTIR Spectroscopy*, USA Bureau of Mines; Information circular; Supt. Docs no. I.28.27:9309:1992

APPENDICES

APPENDIX I
INFORMED CONSENT LETTER FROM PARTICIPANTS

CONSENT FORM

I agree to assist in this research to quantify the amount of dust I am exposed to as explained in the Information sheet. I understand that if I decide not to participate there will be no disadvantages to me as no one on the farm will know and I understand that I am entitled to stop my participation at any time without any disadvantages to me

Name:

Pedro Horacio [illegible]

Signature

[illegible]

CONSENT FORM

I agree to assist in this research to quantify the amount of dust I am exposed to as explained in the Information sheet. I understand that if I decide not to participate there will be no disadvantages to me as no one on the farm will know and I understand that I am entitled to stop my participation at any time without any disadvantages to me

Name:

[illegible] macane

Signature

[illegible] macane

CONSENT FORM

I agree to assist in this research to quantify the amount of dust I am exposed to as explained in the Information sheet. I understand that if I decide not to participate there will be no disadvantages to me as no one on the farm will know and I understand that I am entitled to stop my participation at any time without any disadvantages to me

Name:

Francisco José [illegible]

Signature

Francisco José [illegible]

CONSENT FORM

I agree to assist in this research to quantify the amount of dust I am exposed to as explained in the Information sheet. I understand that if I decide not to participate there will be no disadvantages to me as no one on the farm will know and I understand that I am entitled to stop my participation at any time without any disadvantages to me

Name:

[illegible]

Signature

[illegible]

APPENDICE II: ENVIRONMENTAL CONDITION SHEET

SAMPLING AND ENVIRONMENTAL CONDITION OF SAMPLING

SAMPLE NO.	CASSETTE SERIE NO.	DAY AVERAGE TEMPERATURE (°C/%)	RELATIVE HUMIDITY (%)	WIND VELOCITY (KM/H)	BLANK FIELD CASSETTE						SAMPLING ACTIVITY NAME AND DESCRIPTION OF THE TASKS
					SERIE NUMBER	INITIAL MASS (IM)	INITIAL MASS AVG. (IMA)	FINAL MASS (FM)	FINAL MASS AVG. (FMA)	MASS VARIATION [ΔM]	
01	**M01.101**	32	57	8	B01	0.0059 0.0058 0.0058	0.00583	0.0058 0.0059 0.0058	0.00583	0.0000	
02	**M02.302**				B02	0.0061 0.0060 0.0059	0.0060	0.0060 0.0062 0.0059	0.00603	0.03	
03	**M03.203**				B03	0.0057 0.0059 0.0060	0.00587	0.0058 0.0060 0.0057	0.00583	- 0.04	
04	**M04.402**	31	65	1.5	B04	0.0059 0.0059 0.0058	0.00587	0.0059 0.0059 0.0059	0.0059	0.03	
05	**M05.101**				B05	0.0062 0.0061 0.0063	0.0062	0.0059 0.0062 0.0063	0.00613	- 0.07	
06	**M06.101**	31	58	1.5	B06	0.0055 0.0056 0.0055	0.00553	0.0056 0.0054 0.0056	0.00553	0.0000	
07	**M07.302**				B07	0.0058 0.0058 0.0058	0.0058	0.0059 0.0057 0.0058	0.0058	0.0000	
08	**R08.204**	31	65	7.5	B08	0.0061 0.0060 0.0060	0.00603	0.0059 0.0061 0.0061	0.00603	0.0000	
09	**R09.304**				BO9	0.0049 0.0050 0.0050	0.00497	0.0050 0.0050 0.0050	0.0050	0.0030	
10	**M10.101**	32	60	4.5	B10	0.0062 0.0062 0.0061	0.00617	0.0061 0.0062 0.0062	0.00617	0.0000	
11	**M11.203**				B11	0.0049 0.0049 0.0050	0.00493	0.0049 0.0050 0.0048	0.0049	- 0.03	
12	**M12.302**				B12	0.0050 0.0052 0.0051	0.0051	0.0053 0.0049 0.0050	0.00507	-0.03	
13	**R13.104**	30	64	6.5	B13	0.0053 0.0053 0.0052	0.00527	0.0052 0.0053 0.0053	0.00527	0.0000	
14	**M14.301**				B14	0.0056 0.0056 0.0057	0.005603	0.0056 0.0058 0.0055	0.005603	0.0000	
15	**M15.202**				B15	0.0061 0.0061 0.0061	0.0061	0.0062 0.0060 0.0061	0.0061	0.0000	
16	**M16.301**	31	58	4.5	B16	0.0063 0.0064 0.0064	0.00637	0.0065 0.0063 0.0063	0.00637	0.000	
17	**M17.302**	26	71	7	B17	0.0066 0.0066 0.0064	0.00653	0.0065 0.0064 0.0065	0.00647	- 0.06	

ENVIRONMENTAL CONDITION SHEET

SAMPLING AND ENVIRONMENTAL CONDITION OF SAMPLING

SAMPLE NO.	CASSETTE SERIE NO.	DAY AVERAGE TEMPERATUTE	RELATIVE HUMIDITY	WIND VELOCITY	BLANK FIELD CASSETTE						SAMPLING ACTIVITY NAME AND DESCRIPTION OF THE TASKS
					SERIE NUMBER	INITIAL MASS (IM)	INITIAL MASS AVG. (IMA)	FINAL MASS (FM)	FINAL MASS AVG. (FMA)	MASS VARIATION [ΔM]	
18	**M18.302**				B18	0.0060 0.0060 0.0059	0.00597	0.0060 0.0059 0.0058	0.0059	-0.07	
19	**M19.101**	30	69	4.5	B19	0.0063 0.0065 0.0064	0.00603	0.0060 0.0062 0.0059	0.00603	0.000	
20	**R20.204**				B20	0.0066 0.0066 0.0064	0.00587	0.0058 0.0060 0.0057	0.00583	- 0.04	
21	**M21.301**	28	61	6	B21	0.0059 0.0059 0.0058	0.00587	0.0059 0.0059 0.0059	0.0059	0.03	
22	**M22.301**	28	64	4.5	B22	0.0062 0.0061 0.0063	0.0062	0.0060 0.0062 0.0063	0.00617	- 0.03	
23	**R23.304**				B23	0.0055 0.0056 0.0055	0.00553	0.0056 0.0056 0.0056	0.0056	0.07	
24	**R24.204**	30	61	3	B24	0.0058 0.0058 0.0058	0.0058	0.0059 0.0057 0.0058	0.0058	0.0000	
25	**M25.402**				B25	0.0061 0.0061 0.0060	0.00607	0.0059 0.0061 0.0061	0.00603	- 0.04	
26	**R26.404**				B26	0.0049 0.0050 0.0050	0.00497	0.0050 0.0050 0.0050	0.0050	0.03	
27	**R27.204**	28	62	7	B27	0.0062 0.0062 0.0061	0.00617	0.0062 0.0062 0.0062	0.0062	0.03	
28	**M28.301**				B28	0.0049 0.0049 0.0050	0.00493	0.0049 0.0050 0.0048	0.0049	- 0.03	
29	**R29.204**				B29	0.0050 0.0052 0.0051	0.0051	0.0053 0.0050 0.0050	0.0051	0.000	
30	**M30.103**	28	68	4.5	B30	0.0053 0.0053 0.0053	0.0053	0.0052 0.0053 0.0053	0.00527	-0.03	
31	**R31.304**				B31	0.0056 0.0056 0.0057	0.005603	0.0056 0.0058 0.0055	0.005603	0.0000	
32	**R32.104**	22	88	2	B32	0.0059 0.0057 0.0058	0.0058	0.0060 0.0058 0.0061	0.00597	0.17	
33	**M33.203**				B33	0.0061 0.0060 0.0059	0.0060	0.0062 0.0059 0.0051	0.00573	- 0.27	
34	**R34.104**	24	68	3	B34	0.0063 0.0063 0.0064	0.00633	0.0064 0.0064 0.0064	0.0064	0.07	

ENVIRONMENTAL CONDITION SHEET

SAMPLING AND ENVIRONMENTAL CONDITION OF SAMPLING

SAMPLE NO.	CASSETTE SERIE NO.	DAY AVERAGE TEMPERATUTE	RELATIVE HUMIDITY	WIND VELOCITY	BLANK FIELD CASSETTE						SAMPLING ACTIVITY NAME AND DESCRIPTION OF THE TASKS
					SERIE NUMBER	INITIAL MASS (IM)	INITIAL MASS AVG. (IMA)	FINAL MASS (FM)	FINAL MASS AVG. (FMA)	MASS VARIATION [ΔM]	
35	**M35.301**	24	68	3	B35	0.0061 0.0061 0.0060	0.00607	0.0059 0.0061 0.0061	0.00603	- 0.04	
36	**R36.404**	28	62	8.5	B36	0.0063 0.0063 0.0064	0.00633	0.0064 0.0064 0.0064	0.0064	0.07	
37	**M37.103**				B37	0.0066 0.0066 0.0064	0.00653	0.0065 0.0064 0.0065	0.00647	- 0.06	
38	**R38.204**	27	66	4	B38	0.0062 0.0062 0.0061	0.00617	0.0062 0.0062 0.0062	0.0062	0.03	
39	**R39.404**				B39	0.0058 0.0058 0.0058	0.0058	0.0059 0.0057 0.0058	0.0058	0.0000	
40	**R40.104**				B40	0.0061 0.0061 0.0061	0.0061	0.0061 0.0060 0.0061	0.00607	- 0.03	
41	**R41.304**				B41	0.0049 0.0049 0.0050	0.00493	0.0049 0.0050 0.0048	0.0049	- 0.03	
42	**M42.202**	29	56	6.5	B42	0.0050 0.0052 0.0051	0.0051	0.0053 0.0050 0.0050	0.0051	0.000	
43	**M43.401**				B43	0.0053 0.0054 0.0053	0.005303	0.0052 0.0054 0.0054	0.005303	0.000	
44	**R44.104**				B44	0.0059 0.0058 0.0058	0.00583	0.0058 0.0059 0.0058	0.00583	0.0000	
45	**M45.303**				B45	0.0061 0.0060 0.0059	0.0060	0.0060 0.0062 0.0059	0.00603	0.03	
46	**M46.402**	30	57	1.5	B46	0.0057 0.0059 0.0060	0.00587	0.0058 0.0060 0.0057	0.00583	- 0.04	
47	**R47.104**				B47	0.0059 0.0061 0.0060	0.0060	0.0059 0.0060 0.0061	0.0060	0.000	
48	**R48.204**				B48	0.0059 0.0059 0.0058	0.00587	0.0059 0.0059 0.0059	0.0059	0.03	
49	**M49.203**	28	65	2.5	B49	0.0062 0.0061 0.0063	0.0062	0.0060 0.0062 0.0063	0.00617	- 0.03	
50	**R50.104**				B50	0.0055 0.0056 0.0055	0.00553	0.0056 0.0056 0.0056	0.0056	0.07	
51	**M51.303**				B51	0.0058 0.0058 0.0058	0.0058	0.0059 0.0057 0.0058	0.0058	0.0000	

ENVIRONMENTAL CONDITION SHEET

SAMPLING AND ENVIRONMENTAL CONDITION OF SAMPLING

SAMPLE NO.	CASSETTE SERIE NO.	DAY AVERAGE TEMPERATUTE	RELATIVE HUMIDITY	WIND VELOCITY	BLANK FIELD CASSETTE						SAMPLING ACTIVITY NAME AND DESCRIPTION OF THE TASKS
					SERIE NUMBER	INITIAL MASS (IM)	INITIAL MASS AVG. (IMA)	FINAL MASS (FM)	FINAL MASS AVG. (FMA)	MASS VARIATION [ΔM]	
52	**M52.401**	28	65	2.5	B52	0.0050 0.0052 0.0051	0.0051	0.0053 0.0050 0.0050	0.0051	0.000	
53	**M53.402**	29	59	1.5	B53	0.0053 0.0054 0.0053	0.005303	0.0052 0.0053 0.0053	0.00527	0.033	
54	**R54.404**	29	48	4	B54	0.0061 0.0061 0.0060	0.00607	0.0059 0.0061 0.0061	0.00603	- 0.04	
55	**R55.204**				B55	0.0063 0.0062 0.0061	0.0062	0.0061 0.0062 0.0062	0.00617	-0.03	
56	**M56.101**				B56	0.0058 0.0058 0.0058	0.0058	0.0059 0.0057 0.0058	0.0058	0.0000	
57	**R57.304**				B57	0.0061 0.0061 0.0061	0.0061	0.0061 0.0060 0.0061	0.00607	- 0.03	
58	**M58.401**	25	70	4.5	B58	0.0063 0.0063 0.0064	0.00633	0.0064 0.0064 0.0064	0.0064	0.07	
59	**R59.104**				B59	0.0052 0.0052 0.0051	0.00517	0.0053 0.0050 0.0050	0.0051	-0.07	
60	**M60.303**	26	68	5	B60	0.0053 0.0054 0.0053	0.005303	0.0052 0.0054 0.0054	0.005303	0.000	
61	**M61.202**				B61	0.0059 0.0058 0.0058	0.00583	0.0058 0.0059 0.0058	0.00583	0.0000	
62	**R62.404**	27	71	8	B62	0.0059 0.0059 0.0058	0.00587	0.0059 0.0059 0.0059	0.0059	0.03	
63	**R63.304**				B63	0.0057 0.0059 0.0060	0.00587	0.0058 0.0060 0.0057	0.00583	- 0.04	
64	**R64.104**				B64	0.0060 0.0060 0.0060	0.0060	0.0060 0.0059 0.0060	0.0060	0.000	
65	**M65.103**	25	67	8	B65	0.0059 0.0059 0.0058	0.00587	0.0059 0.0059 0.0059	0.0059	0.03	
66	**R66.304**				B66	0.0062 0.0061 0.0063	0.0062	0.0060 0.0062 0.0063	0.00617	- 0.03	
67	**M67.402**	25	38	4.5	B67	0.0055 0.0056 0.0055	0.00553	0.0056 0.0056 0.0056	0.0056	0.07	
68	**R68.204**				B68	0.0066 0.0066 0.0065	0.00657	0.0066 0.0066 0.0066	0.0066	0.03	

ENVIRONMENTAL CONDITION SHEET

SAMPLING AND ENVIRONMENTAL CONDITION OF SAMPLING												
SAMPLE NO.	**CASSETTE SERIE NO.**	**DAY AVERAGE TEMPERATUTE**	**RELATIVE HUMIDITY**	**WIND VELOCITY**	**BLANK FIELD CASSETTE**							**SAMPLING ACTIVITY NAME AND DESCRIPTION OF THE TASKS**
					SERIE NUMBER	INITIAL MASS (IM)	INITIAL MASS AVG. (IMA)	FINAL MASS (FM)	FINAL MASS AVG. (FMA)	MASS VARIATION [ΔM]		
69	**M69.302**	28	38	2.5	B69	0.0050 0.0052 0.0051	0.0051	0.0053 0.0050 0.0050	0.0051	0.000		
70	**M70.101**	29	59	1.5	B70	0.0053 0.0054 0.0053	0.005303	0.0052 0.0053 0.0053	0.00527	0.033		

APPENDICES III

ON-FIELD SAMPLING RECORDING SHEET

SAMPLE NO.	ON-FIELD SAMPLING RECORDING SHEET								
	PUMP NO.	BEFORE SAMPLING VOLUME (L/MIN)	SAMPLING TIME (MINUTE)	AFTER SAMPLING VOLUME (L/MIN)	SAMPLING VOLUME VARIATION (VAF-VBE)	VOL. CORRECTION FACTOR (ΔV)	TOTAL SAMPLED VOLUME (L)	TOTAL SAMPLED VOLUME (m^3)	REMARKS
01	1	2.2	179	2.190	0.010	0.0045	392.03	**0.39203**	
02	3	2.2	276	2.180	0.020	0.0090	602.2	0.6022	
03	3	2.2	240	2.190	0.010	0.0045	525.62	0.52562	
04	4	2.2	196	2.200	0.000	0.000	431.2	0.4312	
05	1	2.2	320	2.190	0.010	0.0045	700.83	0.70083	
06	1	2.2	340	2.180	0.020	0.0090	741.2	0.7412	
07	3	2.2	260	2.200	0.000	0.000	572	0.572	
08	2	2.2	196	2.180	0.020	0.0090	429	0.4290	
09	3	2.2	320	2.190	0.010	0.0045	700.83	0.70083	
10	1	2.2	295	2.190	0.010	0.0045	643.16	0.64316	
11	2	2.2	294	2.190	0.010	0.0045	6518	0.6518	
12	3	2.2	390	2.190	0.010	0.0045	849.42	0.84942	
13	1	2.2	280	2.180	0.020	0.0090	610.456	0.61046	
14	3	2.2	350	2.190	0.010	0.0045	766.535	0.76654	
15	2	2.2	350	2.180	0.020	0.0090	763.07	0.76307	
16	3	2.2	360	2.180	0.020	0.0090	784.872	0.78487	
17	3	2.2	319	2.180	0.020	0.0090	695.484	0.69548	
18	3	2.2	350	2.190	0.010	0.0045	766.535	0.76654	
19	1	2.2	195	2.200	0.000	0.000	429	0.4290	
20	2	2.2	400	2.190	0.010	0.0045	876.04	0.8760	
21	3	2.2	400	2.180	0.020	0.0090	872.09	0.8721	
22	3	2.2	300	2.190	0.010	0.0045	657.03	0.6570	
23	3	2.2	315	2.190	0.010	0.0045	689.88	0.6899	
24	2	2.2	320	2.200	0.000	0.000	704	0.704	
25	4	2.2	265	2.200	0.000	0.000	583	0.583	
26	4	2.2	287	2.200	0.000	0.000	631.4	0.6314	
27	2	2.2	290	2.190	0.010	0.0045	635.1	0.6351	
28	3	2.2	380	2.190	0.010	0.0045	832.24	0.8322	
29	2	2.2	490	2.180	0.020	0.0090	1068.3	1.0683	
30	1	2.2	355	2.180	0.020	0.0090	773.97	0.7740	
31	3	2.2	500	2.170	0.030	0.0136	1085.0	1.0850	
32	1	2.2	330	2.190	0.010	0.0045	722.7	0.7227	
33	2	2.2	401	2.190	0.010	0.0045	878.23	0.8782	
34	1	2.2	220	2.200	0.000	0.000	484	0.4840	
35	3	2.2	210	2.200	0.000	0.000	418	0.4180	
36	4	2.2	290	2.190	0.010	0.0045	635.1	0.6351	
37	1	2.2	310	2.180	0.020	0.0090	675.9	0.6759	
38	2	2.2	312	2.100	0.100	0.0450	655.5	0.6555	
39	4	2.2	303	2.100	0.100	0.0450	636.6	0.6366	
40	1	2.2	349	2.190	0.010	0.0045	764.3	0.7643	
41	3	2.2	390	2.190	0.010	0.0045	854.1	0.8541	
42	2	2.2	309	2.180	0.020	0.0090	676.7	0.6767	
43	4	2.2	411	2.100	0.100	0.0450	863.5	0.8635	
44	1	2.2	423	2.190	0.010	0.0045	926.4	0.9264	
45	3	2.2	237	2.190	0.010	0.0045	519	0.519	
46	4	2.2	398	2.190	0.010	0.0045	871.7	0.8717	
47	1	2.2	231	2.200	0.000	0.000	508.2	0.5082	
48	2	2.2	342	2.190	0.010	0.0045	749.0	0.7490	
49	2	2.2	435	2.190	0.010	0.0045	952.7	0.9527	
50	1	2.2	342	2.170	0.030	0.0136	742.2	0.7422	
51	3	2.2	451	2.170	0.030	0.0136	978.7	0.9787	
52	4	2.2	321	2.190	0.010	0.0045	703.0	0.7030	
53	4	2.2	197	2.200	0.000	0.000	433.4	0.4334	
54	4	2.2	444	2.100	0.100	0.045	932.8	0.9328	

APPENDICES III

ON-FIELD SAMPLING RECORDING SHEET

SAMPLE NO.	ON-FIELD SAMPLING RECORDING SHEET								
	PUMP NO.	BEFORE SAMPLING VOLUME (L/MIN)	SAMPLING TIME (MINUTE)	AFTER SAMPLING VOLUME (L/MIN)	SAMPLING VOLUME VARIATION (VAF-VBE)	VOL. CORRECTION FACTOR (ΔV)	TOTAL SAMPLED VOLUME (L)	TOTAL SAMPLED VOLUME (m^3)	REMARKS
55	2	2.2	215	2.2	0.0000	0.000	473	0.4730	
56	1	2.2	301	2.190	0.010	0.0045	659.2	0.6592	
57	3	2.2	299	2.180	0.020	0.0090	651.8	0.6518	
58	4	2.2	380	2.180	0.020	0.0090	828.4	0.8284	
59	1	2.2	209	2.2	0.000	0.000	459.8	0.4598	
60	3	2.2	375	2.190	0.010	0.0045	821.3	0.8213	
61	2	2.2	230	2.2	0.000	0.000	506	0.506	
62	4	2.2	305	2.190	0.010	0.0045	668	0.668	
63	3	2.2	225	2.190	0.010	0.0045	492.8	0.4928	
64	1	2.2	218	2.195	0.005	0.0022	479	0.479	
65	1	2.2	300	2.180	0.020	0.0090	654	0.654	
66	3	2.2	250	2.200	0.000	0.000	550	0.550	
67	4	2.2	260	2.180	0.020	0.0090	568	0.568	
68	2	2.2	267	2.190	0.010	0.0045	584.7	0.5847	
69	3	2.2	230	2.200	0.000	0.000	506	0.506	
70	1	2.2	298	2.200	0.000	0.000	655.6	0.6556	

APPENDICES IV

SAMPLING DATA AND GRAVIMETRIC DETERMINATION

SAMPLE NO.	FILTER REFERENCE NO.	INITIAL MASS (MI)	AVERAGE MASS (MI)	FINAL MASS (M2)	AVERAGE MASS (M2)	DUST ON FLITER M =(M2-M1) (mg)	BLANK FIELD MASS VARIATION (∆M)	CORRECTED SAMPLED DUST (MC)	SAMPLED CORRECTED VOLUME (m^3)	DUST CONCENTRATION (mg/m^3)	8 HOUR/TWA CONCENTRATION (mg/m^3)
		0.0058		0.0059							
01	M01.101	0.0057	0.00573	0.0057	0.00577	0.04	0.0000	0.04	0.39203	0.102	0.0380
		0.0057		0.0057							
		0.0062		0.0074					0.6022		
02	M02.302	0.0063	0.0063	0.0075	0.00747	1.17	-0.03	1.2		1.992	1.141
		0.0064		0.0075							
		0.0059		0.0069							
03	M03.203	0.0059	0.0059	0.0068	0.00687	0.97	- 0.04	1.01	0.52562	1.92	0.96
		0.0059		0.0069							
		0.0056		0.0062							
04	M04.402	0.0055	0.0055	0.0062	0.0062	0.7	0.03	0.67	0.4312	1.55	0.63
		0.0054		0.0062							
		0.0062		0.0076							
05	M05.101	0.0062	0.00617	0.0075	0.00757	1.4	-0.07	1.407	0.7008	2.00	1.33
		0.0061		0.0076							
		0.0055		0.0070							
06	M06.101	0.0053	0.00537	0.0070	0.00697	1.6	0.00	1.6	0.7412	2.158	1.52
		0.0053		0.0069							
		0.0062		0.0064					0.572		
07	M07.302	0.0063	0.00627	0.0065	0.00647	0.2	0.000	0.2		0.3496	0.189
		0.0063		0.0065							
		0.0051		0.0061							
08	R08.204	0.0052	0.0051	0.0060	0.00603	0.93	0.0	0.93	0.4290	2.16	0.880
		0.0050		0.0060							
		0.0056		0.0057					0.70083		
09	R09.304	0.0056	0.0056	0.0056	0.00563	0.03	0.03	0.011		0.0156	0.0104
		0.0056		0.0056							
		0.0057		0.0063					0.64316		
10	M10.101	0.0057	0.00573	0.0062	0.00623	0.5	0.0	0.5		0.777	0.478
		0.0058		0.0062							
		0.0061		0.0061							
11	M11.203	0.0061	0.00607	0.0062	0.00613	0.06	-0.03	0.09	0.6518	0.138	0.086
		0.0061		0.0061							
		0.0060		0.0065					0.84942		
12	M12.302	0.0061	0.00603	0.0065	0.00647	0.44	-0.03	0.47		0.553	0.449
		0.0060		0.0064							
		0.0059		0.0063					0.61046		
13	R13.104	0.0059	0.00583	0.0060	0.00617	0.34	0.00	0.34		0.557	0.325
		0.0057		0.0062							
		0.0056		0.0067							
14	M14.301	0.0054	0.0055	0.0067	0.0067	1.2	0.000	1.2	0.76654	1.565	1.141
		0.0055		0.0067							
		0.0058		0.0062							
15	M15.202	0.0059	0.00583	0.0062	0.00623	0.4	0.03	0.37	0.76307	0.484	0.353
		0.0058		0.0063							
		0.0057		0.0066							
16	M16.301	0.0057	0.0057	0.0065	0.00657	0.87	0.03	0.84	0.78487	1.07	0.802
		0.0057		0.0066							

APPENDICES IV

SAMPLING DATA AND GRAVIMETRIC DETERMINATION

SAMPLE NO.	FILTER REFERENCE NO.	INITIAL MASS (MI)	AVERAGE MASS (MI)	FINAL MASS (M2)	AVERAGE MASS (M2)	DUST ON FLITER M =(M2-M1) (mg)	BLANK FIELD MASS VARIATION (∆M)	CORRECTED SAMPLED DUST (MC)	SAMPLED CORRECTED VOLUME (m^3)	DUST CONCENTRATION (mg/m^3)	8 HOUR/TWA CONCENTRATION (mg/m^3)	
		0.0066		0.0070								
17	M17.302	0.0065	0.00653	0.0070	0.0070	0.47	0.000	0.47	0.69548	0.676	0.449	
		0.0065		0.0070								
		0.0055		0.0086								
18	M18.302	0.0056	0.00547	0.0084	0.00843	2.96	-0.07	3.03	0.76654	3.95	2.882	
		0.0053		0.0083								
		0.0060		0.0064								
19	M19.101	0.0060	0.00597	0.0063	0.00637	0.4	0.030	0.37	0.4290	0.862	0.350	R
		0.0059		0.0064								
		0.0057		0.0065								
20	R20.204	0/0058	0.0057	0.0065	0.0065	0.8	-0.04	0.804	0.8760	0.917	0.764	
		0.0056		0.0065								
		0.0055		0.0064								
21	M21.301	0.0053	0.00537	0.0062	0.0063	0.93	0.07	0.86	0.8721	0.986	0.821	
		0.0053		0.0063								
		0.0055		0.0066								
22	M22.301	0.0056	0.00553	0.0067	0.0066	1.07	-0.03	1.073	0.6570	1.63	1.02	
		0.0055		0.0065								
		0.0055		0.0056								
23	R23.304	0.0056	0.00553	0.0056	0.00563	0.1	0.03	0.07	0.6899	0.101	0.0665	
		0.0055		0.0057								
		0.0056		0.0072								
24	R24.204	0.0056	0.0056	0.0070	0.0071	1.5	-0.03	1.53	0.704	2.17	1.45	
		0.0055		0.0071								
		0.0056		0.0058								
25	M25.402	0.0054	0.0055	0.0058	0.0058	0.3	-0.04	0.304	0.583	0.521	0.288	
		0.0055		0.0058								
		0.0061		0.0063								
26	R26.404	0.0061	0.00597	0.0063	0.00627	0.3	0.03	0.27	0.6314	0.427	0.256	
		0.0059		0.0062								
		0.0055		0.0062					0.6351			
27	R27.204	0.0056	0.00557	0.0060	0.0061	0.53	0.000	0.53		0.834	0.504	
		0.0056		0.0061								
		0.0055		0.0055								
28	M28.301	0.0054	0.00547	0.0056	0.00553	0.06	0.00	0.06	0.8322	0.072	0.057	
		0.0055		0.0055								
		0.0051		0.0052								
29	R29.204	0.0051	0.0051	0.0052	0.00517	0.07	-0.07	0.14	1.0850	0.129	0.131	
		0.0051		0.0051								
		0.0060		0.0065								
30	M30.103	0.0060	0.00597	0.0063	0.0064	0.43	-0.03	0.46	0.774	0.594	0.439	R
		0.0059		0.0064								
		0.0056		0.0064								
31	R31.304	0.0055	0.00557	0.0064	0.0064	0.83	0.000	0.83	1.0850	0.765	0.797	
		0.0056		0.0064								
		0.0063		0.0068								
32	R32.104	0.0064	0.00633	0.0067	0.00677	0.44	-0.04	0.48	0.7227	0.664	0.457	
		0.0063		0.0068								

APPENDICES IV

SAMPLING DATA AND GRAVIMETRIC DETERMINATION

SAMPLE NO.	FILTER REFERENCE NO.	INITIAL MASS (MI)	AVERAGE MASS (MI)	FINAL MASS (M2)	AVERAGE MASS (M2)	DUST ON FLITER M =(M2-M1) (mg)	BLANK FIELD MASS VARIATION (∆M)	CORRECTED SAMPLED DUST (MC)	SAMPLED CORRECTED VOLUME (m^3)	DUST CONCENTRATION (mg/m^3)	8 HOUR/TWA CONCENTRATION (mg/m^3)
		0.0057		0.0063							
33	M33.203	0.0057	0.00573	0.0064	0.00633	0.6	-0.27	0.87	0.8782	0.99	0.828
		0.0058		0.0063							
		0.0051		0.0056							
34	R34.104	0.0050	0.00503	0.0055	0.00553	0.5	0.07	0.43	0.4840	0.888	0.407
		0.0050		0.0055							
		0.0059		0.0066							
35	M35.301	0.0057	0.00573	0.0067	0.00667	0.94	-0.04	0.98	0.4180	2.344	1.025
		0.0056		0.0067							
		0.0059		0.0069							
36	R36.404	0.0060	0.0059	0.0068	0.0068	0.9	0.07	0.83	0.6351	1.307	0.8
		0.0058		0.0067							
		0.0055		0.0071							
37	M37.103	0.0056	0.00553	0.0071	0.0071	1.57	0.000	1.57	0.6759	2.322	1.5
		0.0055		0.0071							
		0.0055		0.0060							
38	R38.204	0.0055	0.0055	0.0060	0.00597	0.47	0.00	0.47	0.6555	0.717	0.466
		0.0055		0.0059							
		0.0058		0.0061							
39	R39.404	0.0057	0.00573	0.0060	0.0060	0.27	0.0	0.27	0.6366	0.424	0.268
		0.0057		0.0059							
		0.0058		0.0066							
40	R40.104	0.0058	0.00583	0.0065	0.00657	0.74	0.000	0.74	0.7643	0.968	0.704
		0.0059		0.0066							
		0.0057		0.0059							
41	R41.304	0.0057	0.00567	0.0057	0.0058	0.13	-0.03	0.16	0.8541	0.187	0.152
		0.0056		0.0058							
		0.0059		0.0064							
42	M42.202	0.0058	0.00587	0.0064	0.0064	0.53	0.000	0.53	0.6767	0.783	0.504
		0.0059		0.0064							
		0.0055		0.0070							
43	M43.401	0.0056	0.0055	0.0069	0.00693	1.43	0.0	1.43	0.8635	1.656	1.418
		0.0054		0.0069							
		0.0062		0.0065							
44	R44.104	0.0062	0.00613	0.0065	0.00647	0.34	0.0	0.34	0.9264	0.367	0.323
		0.0060		0.0064							
		0.0060		0.0078							
45	M45.303	0.0060	0.0060	0.0078	0.0078	1.8	0.03	1.77	0.519	3.41	1.68
		0.0060		0.0078							
		0.0059		0.0062							
46	M46.402	0.0059	0.00583	0.0062	0.0062	0.37	-0.04	0.41	0.8717	0.470	0.400
		0.0057		0.0062							
		0.0054		0.0062							
47	R47.104	0.0056	0.0055	0.0063	0.0063	0.8	-0.03	0.803	0.5082	1.58	0.760
		0.0055		0.0064							
		0.0058		0.0072							
48	R48.204	0.0059	0.0058	0.0072	0.00723	1.43	0.000	1.43	0.7490	1.909	1.360
		0.0057		0.0073							

APPENDICES IV

SAMPLING DATA AND GRAVIMETRIC DETERMINATION

SAMPLE NO.	FILTER REFERENCE NO.	INITIAL MASS (MI)	AVERAGE MASS (MI)	FINAL MASS (M2)	AVERAGE MASS (M2)	DUST ON FLITER M =(M2-M1) (mg)	BLANK FIELD MASS VARIATION (∆M)	CORRECTED SAMPLED DUST (MC)	SAMPLED CORRECTED VOLUME (m^3)	DUST CONCENTRATION (mg/m^3)	8 HOUR/TWA CONCENTRATION (mg/m^3)
49	M49.203	0.0061 0.0059 0.0059	0.00597	0.0071 0.0069 0.0069	0.00697	1.0	0.000	1	0.9527	1.04	0.951
50	R50.104	0.0050 0.0049 0.0049	0.00493	0.0055 0.0055 0.0055	0.0055	0.57	0.07	0.5	0.7422	0.6736	0.4800
51	M51.303	0.0052 0.0052 0.0051	0.00517	0.0075 0.0074 0.0074	0.00743	2.26	0.000	2.26	0.9787	2.309	2.17
52	M52.401	0.0059 0.0059 0.0059	0.0059	0.0066 0.0064 0.0067	0.00657	0.67	0.000	0.67	0.7030	0.953	0.637
53	M53.402	0.0058 0.0057 0.0059	0.0058	0.0059 0.0060 0.0059	0.00593	0.13	0.03	0.1	0.4334	0.230	0.095
54	R54.404	0.0060 0.0060 0.0059	0.00597	0.0066 0.0067 0.0067	0.00667	0.7	0.17	0.53	0.9328	0.568	0.525
55	R55.204	0.0057 0.0056 0.0056	0.00563	0.0073 0.0072 0.0071	0.0072	1.57	-0.03	1.6	0.4730	3.38	1.515
56	M56.101	0.0063 0.0061 0.0061	0.00617	0.0066 0.0065 0.0065	0.00653	0.36	-0.03	0.39	0.6592	0.591	0.468
57	R57.304	0.0056 0.0054 0.0054	0.00547	0.0069 0.0068 0.0069	0.00687	1.4	-0.03	1.43	0.6518	2.19	1.37
58	M58.401	0.0057 0.0058 0.0057	0.00573	0.0062 0.0060 0.0061	0.0061	0.37	0.07	0.3	0.8284	0.362	0.286
59	R59.104	0.0056 0.0055 0.0054	0.0055	0.0057 0.0056 0.0057	0.00567	0.17	-0.07	0.24	0.4598	0.522	0.227
60	M60.303	0.0054 0.0052 0.0052	0.00533	0.0077 0.0076 0.0077	0.00767	2.34	0.000	2.34	0.8213	2.849	2.22
61	M61.202	0.0057 0.0059 0.0059	0.00597	0.0062 0.0061 0.0062	0.00617	0.2	0.000	0.2	0.506	0.395	0.189
62	R62.404	0.0050 0.0049 0.0050	0.00497	0.0058 0.0057 0.0058	0.00577	0.8	0.03	0.77	0.668	1.152	0.732
63	R63.304	0.0057 0.0055 0.0055	0.00557	0.0061 0.0062 0.0062	0.00617	0.6	-0.04	0.64	0.4928	1.298	0.608
64	R64.104	0.0056 0.0057 0.0057	0.00567	0.0062 0.0061 0.0060	0.0061	0.43	0.0000	0.43	0.479	0.897	0.407

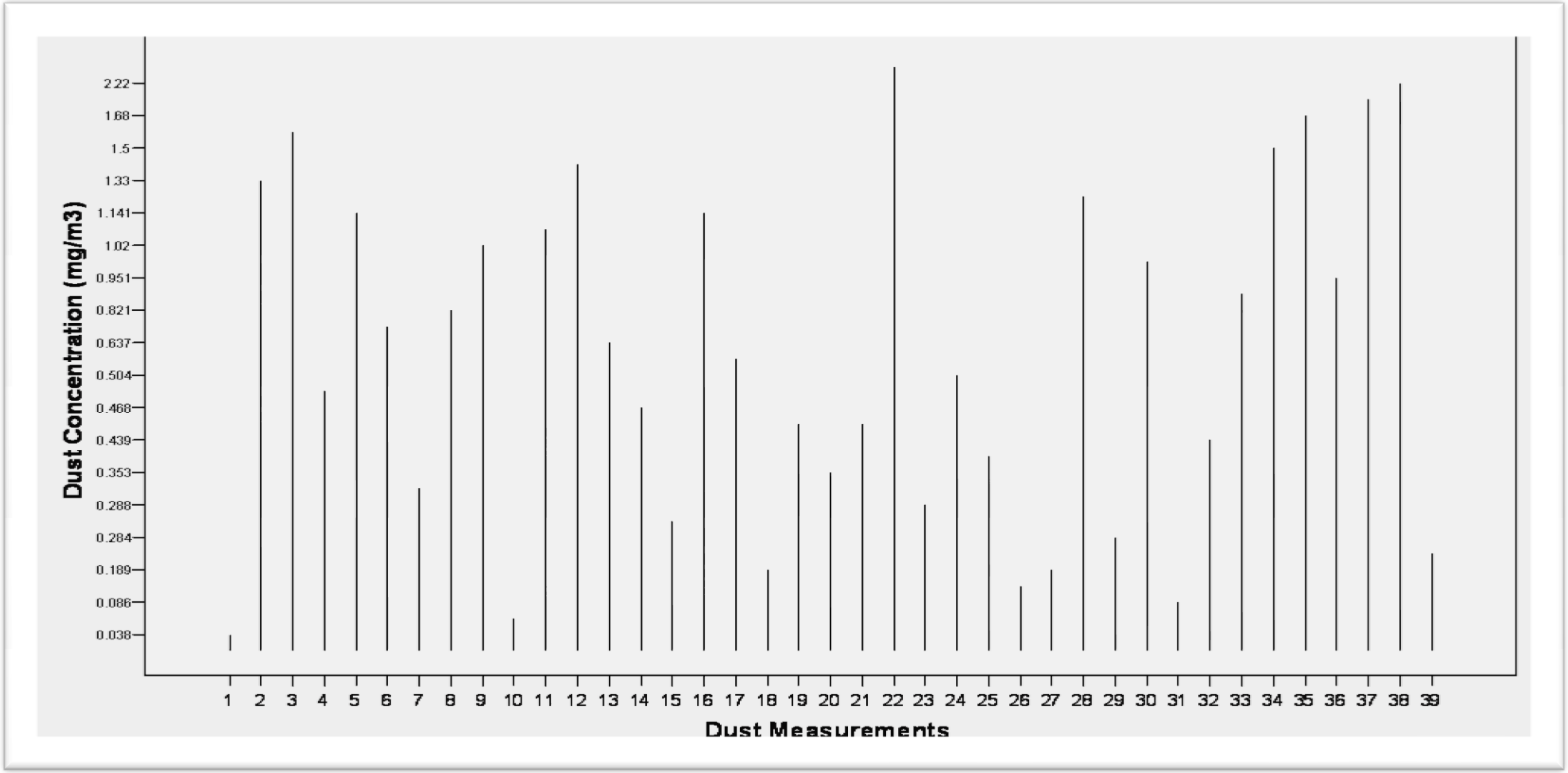
APPENDICES IV

SAMPLING DATA AND GRAVIMETRIC DETERMINATION

SAMPLE NO.	FILTER REFERENCE NO.	INITIAL MASS (MI)	AVERAGE MASS (MI)	FINAL MASS (M2)	AVERAGE MASS (M2)	DUST ON FLITER M =(M2-M1) (mg)	BLANK FIELD MASS VARIATION (∆M)	CORRECTED SAMPLED DUST (MC)	SAMPLED CORRECTED VOLUME (m^3)	DUST CONCENTRATION (mg/m^3)	8 HOUR/TWA CONCENTRATION (mg/m^3)
65	M65.103	0.0056 0.0055 0.0056	0.00557	0.0058 0.0059 0.0059	0.00587	0.3	0.03	0.27	0.654	0.413	0.258
66	R66.304	0.0055 0.0056 0.0056	0.00557	0.0058 0.0059 0.0059	0.00587	0.3	-0.03	0.303	0.550	0.551	0.287
67	M67.402	0.0059 0.0057 0.0058	0.0058	0.0072 0.0071 0.0071	0.00713	1.33	0.03	1.3	0.568	2.29	1.24
68	R68.204	0.0054 0.0055 0.0053	0.0054	0.0056 0.0056 0.0056	0.0056	0.2	0.03	0.17	0.5847	0.290	0.161
69	M69.302	0.0056 0.0056 0.0056	0.0056	0.0060 0.0060 0.0058	0.00593	0.33	0.03	0.3	0.506	0.593	0.284
70	R70.104	0.0058 0.0056 0.0057	0.0057	0.0061 0.0061 0.0061	0.0061	0.4	0.000	0.4	0.6556	0.610	0.378

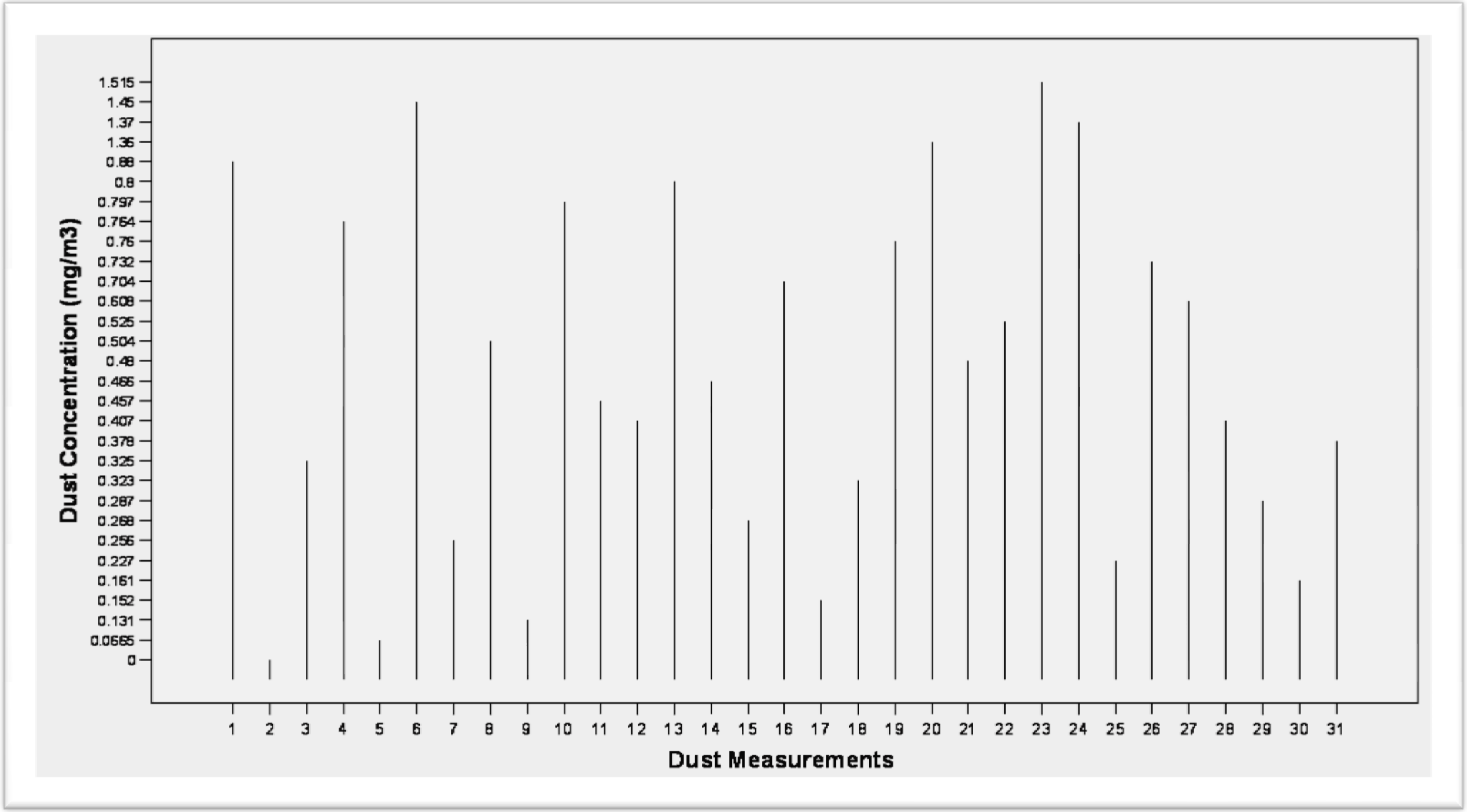
APPENDICE V

GRAPHICAL DISTRIBUTION OF THE MAIZE CROP AND CULTIVATION

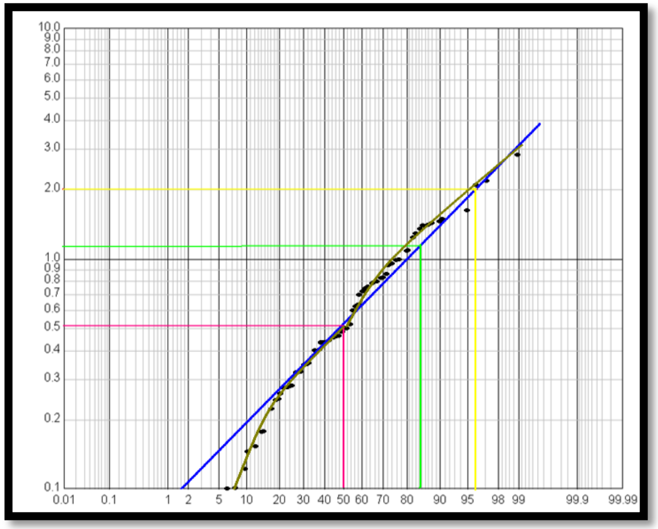


APPENDICES VI

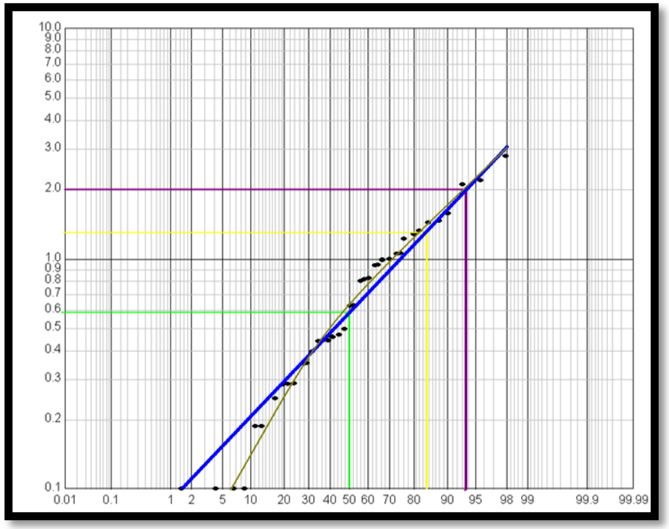
ROOT PLANT CULTIVATION EXPOSURE MEASUREMENTS DISTRIBUTION FOR SINGLE FULL TIME EMPLOYED TRACTOR OPERATOR



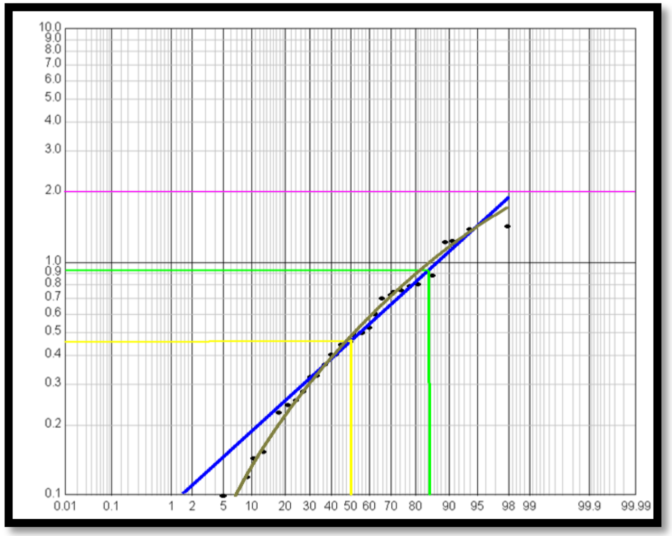
APPENDICE VII
MAIZE AND ROOT PLANT CROP CULTIVATION MEASUREMENTS



APPENDICES VIII
MAIZE EXPOSURE MEASUREMENTS

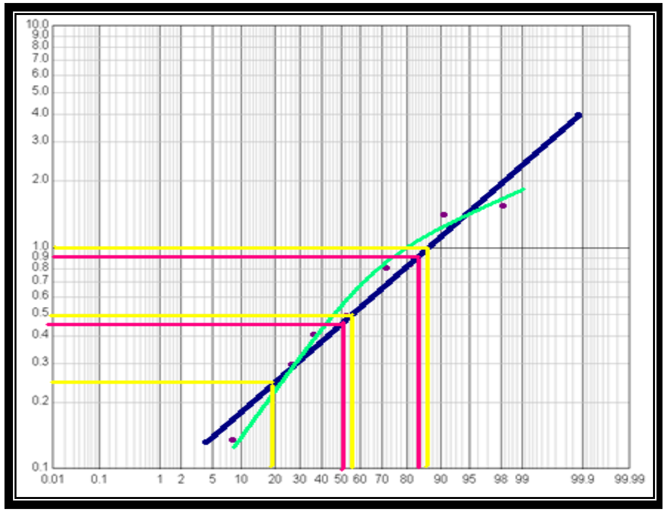


APPENDICES IX
ROOT PLANT EXPOSURE MEASUREMENTS

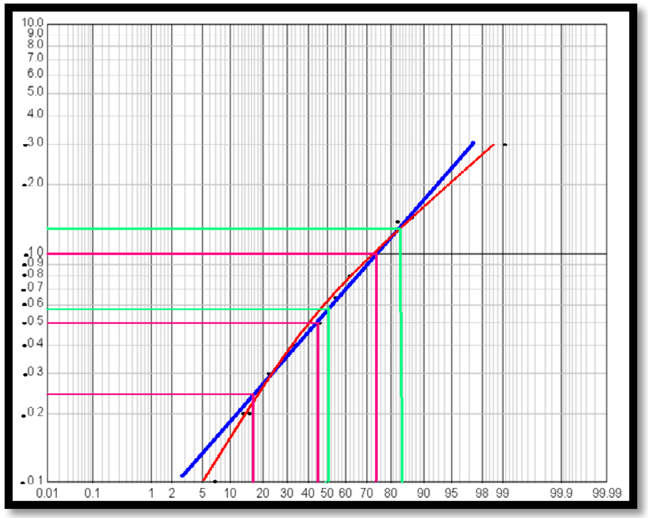


APPENDIX XI
RESPIRABLE QUARTZ DISTRIBUTION MAIZE

APPENDIX XII
RESPIRABLE QUARTZ DISTRIBUTION ROOT PLANT



APPENDIX XIII
RESPIRABLE QUARTZ DISTRIBUTION MEDIUM SIZED

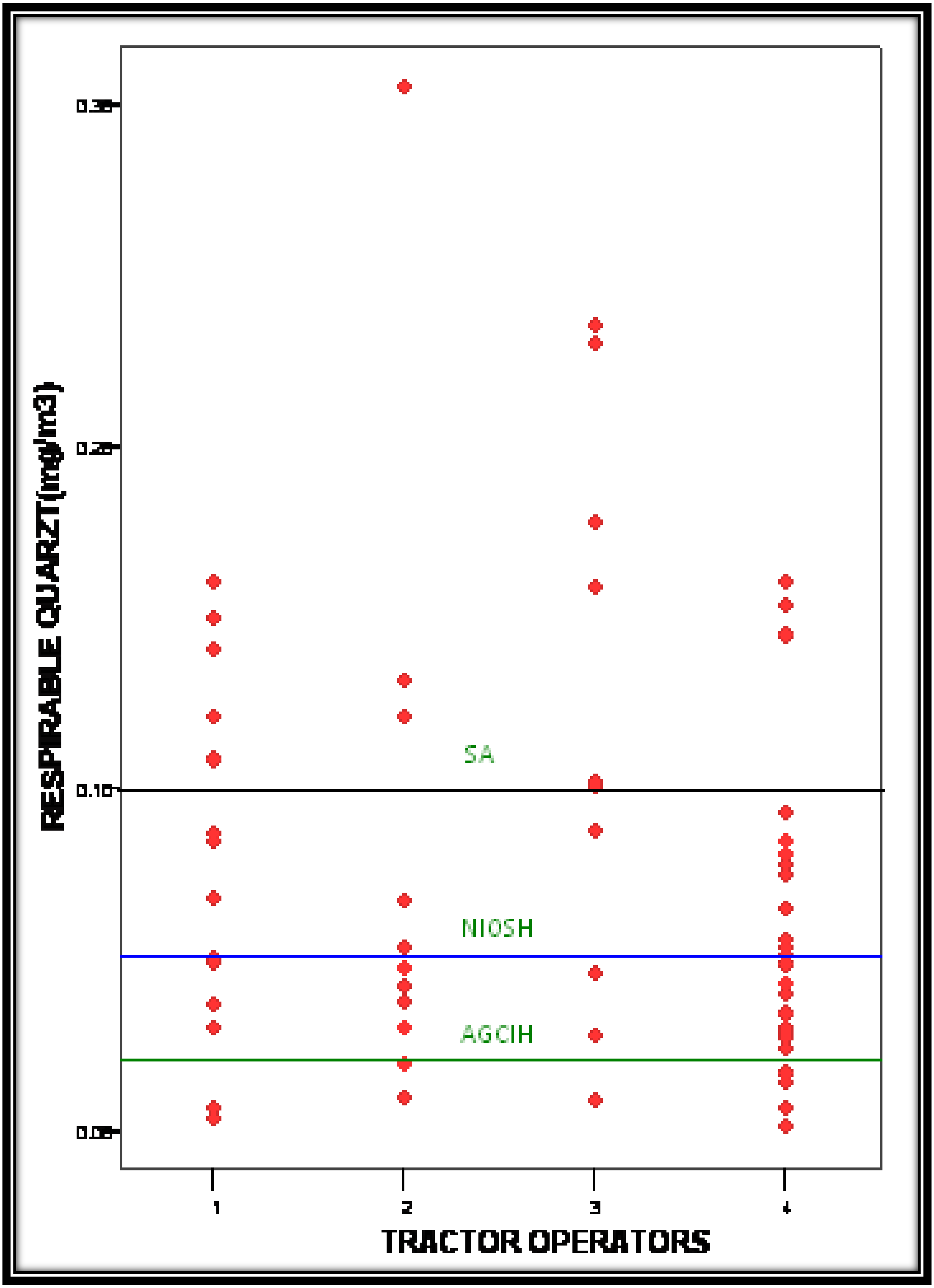


APPENDIX X:

RESPIRABLE DUST CONCENTRATION 8-HOUR TIME AVERAGE (TWA) [mg/m^3]

No.	TRACTOR OPERATOR 1		TRACTOR OPERATOR 2		TRACTOR OPERATOR 3		TRACTOR OPERATOR 4	
	DUST	QUARTZ	DUST	QUARTZ	DUST	QUARTZ	DUST	QUARTZ
01	0.038	0.004028	1.141	0.120946	0.96	0.10176	0.880	0.09328
02	1.33	0.14098	0.63	0.06678	0.086	0.009116	0.0104	0.001102
03	1.52	0.16112	0.189	0.020034	0.439	0.046534	0.325	0.03445
04	0.478	0.050668	0.449	0.047594	0.828	0.087768	0.764	0.080984
05	1.141	0.120946	0.353	0.037418	1.5	0.159	0.0665	0.007049
06	0.802	0.085012	0.449	0.047594	1.68	0.17808	1.45	0.1537
07	0.350	0.0371	2.88	0.30528	0.951	0.100806	0.256	0.027136
08	0.821	0.087026	0.288	0.030528	2.17	0.23002	0.504	0.053424
09	1.02	0.10812	0.504	0.053424	2.22	0.23532	0.131	0.013886
10	0.057	0.006042	0.4	0.0424	0.258	0.027348	0.797	0.084482
11	1.025	0.10865	0.095	0.01007			0.457	0.048442
12	1.418	0.150308	0.189	0.020034			0.407	0.043142
13	0.637	0.067522	1.24	0.13144			0.8	0.0848
14	0.468	0.049608	0.284	0.030104			0.466	0.049396
15	0.286	0.030316					0.268	0.028408
16							0.704	0.074624
17							0.152	0.016112
18							0.323	0.034238
19							0.760	0.08056
20							1.360	0.14416
21							0.480	0.05088
22							0.525	0.05565
23							1.515	0.16059
24							1.37	0.14522
25							0.227	0.024062
26							0.732	0.077592
27							0.608	0.064448
28							0.407	0.043142
29							0.287	0.030422
30							0.161	0.017066
31							0.378	0.040068

APPENDIX XIV



ANNEX I

EXPOSURE SAMPLING TIME DISTRIBUTION

SAMPLING TIME DISTRIBUTION

STEM & LEAF AND BOX PLOT OF DATA DISPLAYING THE EXTREME AND OUTLIER VALUES OF THE EXPOSURE SAMPLING TIME

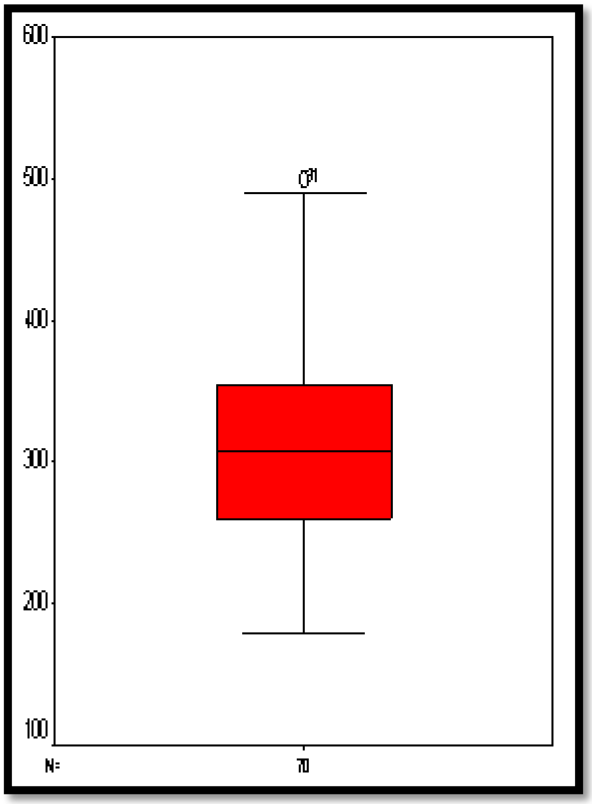
STEM & LEAF PLOT

```
Frequency    Stem &  Leaf

     5.00        1 .  79999
    11.00        2 .  01112233334
    14.00        2 .  56666788999999
    19.00        3 .
0000001111222234444
    11.00        3 .  55556788999
     7.00        4 .  0001234
     2.00        4 .  59
     1.00 Extremes    (>=500)

 Stem width:       100
 Each leaf:       1 case(s)
```

BOX PLOT



Nr.	GENERAL COMMENTS	STUDENT'S COMMENT	POSITION REFERENCE IN THE REPORT
01	The examiners refer to the need of including a section on the occupational exposure limits (national and international) at the end of the introduction/literature review section.	I agree with this comment and a section on occupational exposure limit is considered. Due to many reasons, at national level there is no occupational exposure limit for dust or quartz officially established or adopted.	Page 13, Subsection 1.1.5
02	The examiners suggest a change of one of the objectives in Page 6, considering that the first two objectives are identical	The student perception is that the first two objectives are not identical. The terms "Respirable Dust" in the first objective and "Respirable Quartz" in the second objective makes a huge difference between the both objectives. In fact in analyzing occupational exposure to dust in the agriculture setting, quartz is the most critical element due to its carcinogenicity. To determine respirable quartz inhaled by someone, the first step is to sample and measure respirable dust.	Not applicable
03	Over the methodology section, Page 14, the examiners suggest that the indication on how long is the overall farming production cycle need to be pointed out	Because of changeable character of farming works and, in particularly because medium sized farms are associated with low level of planning is difficult to estimate precisely how long the overall farming production cycle of tractor operators is. We were also concerned about it. We monitored for period of one month, prior to the commencement of sampling and measurement, the production cycle (see subsection 2.2.3. II. Duration and timing) and we found out that 47 percent of eight hour effective time is achieved by tractor permanently employed and 35 percent for seasonal tractor operator.	Subsection 2.2.3. II.
04	Over the methodology section Page 16 and Page 17 the NIOH, Occupational Hygiene Unit is referred as Unit and Section respectively. The examiners suggest that this need to checked if it's a unit or a section	I agree with this comment. The correct designation is Occupational Hygiene Unit	Page 17

Nr.	GENERAL COMMENTS	STUDENT'S COMMENT	POSITION REFERENCE IN THE REPORT
05	Over the results section, Page 21 the report refers to a stem and leaf plot without showing it. Examiners suggest that the stem and leaf plot should be included in the report	I agree with the examiners comments. The student though not relevant at the view point of overall worker exposure assessment and no need to present this because it was a simple exercise aiming to understand working time vs. the percentage in excess to the obligatory working time. Agreeing with the examiners, I have proposed to add an annex and reformulate the sentence to make it sound simple and clear.	Annex I Page 22 first paragraph
06	Over the results section, Page 31, 33 and 35 of the original document the examiners have noted incorrect reference and they recommend that the author's name need to be changed to Swanepoel[15]	I agree with the examiners comment. Change made accordingly	Page 32 Page 34 Page 36
07	Over the result section, Page 32, First paragraph of Section 4.3, there is apparently a reference on Canadian study which is a South African study. The examiners recommend checking it and if necessary chang it.	I agree with the examiners comment. In fact the reference was cited by Swanepoel A., et. Quartz Exposure in Agriculture: Literature Review (2010): Ann. Occup.Hyg, Vol.54. nr.3, pp.281-292. The student had access to the above mentioned SA study and to the original study referenced as "Green FH, Yoshida K, Fick G et al. (1990): Characterization of airborne mineral dust associated with farming activities in rural Albert, Canada. Int.Arch occup. Environ. Health: 62: 423-30. With the permission of the examiners, I want to keep the reference under the SA study.	Page 33

Nr.	GENERAL COMMENTS	STUDENT'S COMMENT	POSITION REFERENCE IN THE REPORT
08	Over the discussion, conclusion and recommendation section, the examiners consider that the recommendations need to go beyond the discussion of the potential research needs. The examiners consider the need to discuss the control measure to reduce exposure	I agree with the examiners comments and the discuss on control measures to reduce exposure was considered	Recommendation section
09	Over the reference section, the examiners consider that Vancouver style need be strictly observed and they recommend that this section need to be re-done	The student agree with the examiners comments and necessary arrangement and adjustment to the Vancouver style was made	Page 42
10	Examiners consider some grammatical errors, crossing referencing and errors in formatting the tables	Crossing referencing was made in many part of the text to tells the reader to look in another part of the report for further information The student understand that the general arrangement and design of the tables are appropriate for the sharp and overall design of the report and that the standard format is used Few grammatical errors were detected by examiners and appropriately corrected by the student	Check made in whole report Not applicable Check made in whole report

Nr.	GENERAL COMMENTS	STUDENT'S COMMENT	POSITION REFERENCE IN THE REPORT
11	Very few consistency in wording were detected by examiners	I agree with the examiners comment and the necessary check was made	Page 2 and Page 5
12	Very few spelling errors and sentences construction were detected by the examiners	The text was sent to the text editor. The student admit that this could happen and agree with the examiners comment	Check made in whole report
13	Incorrect use of punctuation	The student agrees. In fact in the Page 24 the (;) was used in a way that confuse the readers with a full stop over the elevated number ($mg/m^{3.}$) and in page 33 the punctuation was wrongly posted	Page 24 and Page 33
14	GDP/LOD/PBZ not included in nomenclature	I agree with the examiners comment	Terms and Definitions
15	The examiners found table not labeled in Page 27	I agree with the examiners comments and all tables were re-labeled	Page 28 and list of tables
16	Space check recommended by the examiners in Page 40	I agree with examiners comments and check was made	Page 42
17	Examiners addresses general note on the results chapter	The check back to appendices was the easy way the student found to make the main report small, simple with a pleasing sharp and appearance. In general, the student agrees with the examiners comment and the issues presented by examiners were addressed in the exposure compliance analysis.	Page 29