Determining the extent of exposure to silica dust of the workers in the non-mining sectors in South Africa: An exploratory study

Final Report

Authors: NN Khoza and T Grove

Document Reference Number:	DMS 19886
Project Number:	MHC 0040
Research Agency:	Centre for Mining Innovation: Human Factors Research Group
Author Contact Details:	tgrove@csir.co.za
Date:	November 2010

Table of Contents

List of Tables

List of Figures

Executive Summary

In 2009 the Human Factors Group of the CSIR's Centre for Mining Innovation (CMI) was awarded a research project to determine the level of exposure of workers to silica dust in the non-mining sectors in South Africa. Phase 1 of the project entailed a literature study from which it was concluded that comprehensive and recent information in the area of silica exposure and silicosis cases to workers in the non-mining sectors is lacking in South Africa. The Phase 1 report concluded that there is a need for personal dust measurements to determine the worker exposure levels to respirable dust and silica dust in these non-mining industries.

The main enabling outputs for the second phase of the research project were to:

- Use the information obtained in Phase 1 of the project and the guidelines in the Occupational Exposure Sampling Strategy Manual (OESSM), taking into account the restrictions of the study, to establish a sampling strategy for conducting a limited survey of worker exposures;
- Conduct sampling (300 samples) at six selected non-mining industries in Gauteng Province;
- Assess the applicability of the audit tool developed by the MHSC for use by the Department of Labour (DOL) Inspectorate; and
- Collate findings/results of enabling outputs 1, 2 and 3 into the final project report.

Methodology

The seven industries that were identified during Phase 1 to have the potential to expose workers to silica dust were foundries, sandstone, sandblasting, construction, ceramics/potteries, refractories and agriculture (crop and grains produce). The study was conducted in six of the seven industries; agriculture was excluded from this study owing to the study constraints and because research is currently being conducted on agriculture workers' exposure to silica dust by another party. Sampling was conducted at 12 companies in total (two companies per industry), most of which were situated in Gauteng Province.

No statistical determination of the sampling or sample size was made, but the study aimed to collect 50 samples of the "maximum risk employees" in each industry, i.e. approximately 25 samples at each company. The number of samples depended on the number of workers in each company, which varied from one company to the next.

Personal sampling was conducted by issuing each worker with a gravimetric dust sampling pump connected to a sampling head by a length of flexible tubing. The sampling head consisted of a 25 mm mixed cellulose ester (MCE) filter that had a generic Higgins-Dewell type sampler attached to it. The pump was positioned on the worker's belt and the sampling head in the worker's breathing zone on the collar of his or her overall or work clothes in order for the sample to represent the dust inhaled by the worker during the shift. These instruments were worn throughout the shift period, during work and rest.

Filters used for sampling were weighed according to the international standard MDHS 14/3: "General methods for sampling and gravimetric analysis of respirable and inhalable dust" and the gravimetric weighing was done with a 6 decimal balance. The alpha quartz content of each filter was determined by direct-on filter analysis using X-Ray Powder Diffraction (XRD). For the alpha quartz data analysis the International Standard on Alpha Quartz Analysis, MDHS 101: "Direct-on filter analysis by infrared spectroscopy and X-ray diffraction" was used.

The CMI Laboratory has SANAS accreditation (ISO 17025) for both these methods and is currently the only laboratory in South Africa accredited for the XRD method.

Results and discussion

Foundries

The samples were collected from two foundry companies, of which one was a complete ferrous foundry and the other was 90% ferrous and 10% non-ferrous. The sections of the foundries that were sampled were mixing, moulding, shot blasting, shake-out, casting, fettling and melting. Out of all the occupations sampled only the grinder had exposures to both respirable dust (4.664 mg/m^3) and respirable silica dust (0.309 mg/m^3) above the respective OELs. Maximum exposures above the OEL for respirable dust occurred for sand mixing operators (4.571 mg/m^3), shake-out operators (2.220 mg/m^3), furnace operators (2.448 mg/m^3), moulders (2.803 mg/m^3), grinders (9.294 mg/m^3) and closers (3.014 mg/m^3).

Respirable silica dust exposures for the foundry workers were all above the OEL for respirable silica dust (0.1 mg/m^3) except for the loco sand filler and remover (at 0.025 mg/m^3). The moulder and sand mixing operators had the highest maximum exposures of 0.836 mg/m^3 and 0.662 mg/m^3, respectively, and the furnace operator also had a maximum exposure of almost four times the OEL (0.392 mg/m^3).

There is a concern with regard to the respirable silica dust exposures of the foundry workers, which were above the OEL for all the occupations except for the loco sand filler and remover. From the sampling observations it was noted that the loco sand fillers and removers did not work in the same area as the rest of the activities and they were therefore not exposed to the same airborne particle concentrations.

Sandstone

The basic operations at the two identified sandstone companies entailed the cutting of sandstone blocks, supplied from a sandstone quarry, into smaller and more useable slabs or products by making use of a saw machine (diamond wire cutting or circular saw cutting). Finer details were then added to some of the cut blocks by chiselling, polishing or grinding them into their desired shapes and sizes. The respirable dust exposures of the sandstone workers were above the OEL (2 mg/m^3) only for the stone carver (9.527 mg/m^3), but with regard to the respirable silica dust exposures the saw operator (0.482 mg/m^3), general labourer (0.159 mg/m^3), polisher (0.328 mg/m^3), forklift operator (0.130 mg/m^3), packer (0.122 mg/m^3) and plant manager (0.232 mg/m^3) were all exposed to levels of above the OEL. The only occupation that had respirable dust and respirable silica dust exposures of above both the respective OELs was the stone carvers, who had alarmingly high exposures for both measurements; the respirable silica dust exposure for the stone carvers was 3.638 mg/m^3 on average.

Sandblasting

One of the sandblasting companies removed rust from steel products and then painted them. The other company removed paint and rust from a wide variety of products, such as old cars, trucks, mining equipment, farming equipment and other steel objects.

Personal respirable dust concentrations for the sandblasting workers mostly averaged below the OEL for respirable dust, with a maximum exposure of the pots worker above the OEL (2.099 mg/m^3). The blaster was the highest exposed individual, with an average and maximum exposure above the OEL of 2.433 mg/m^3 and 10.835 mg/m^3, respectively.

Respirable silica dust exposures for the sandblasting workers were all less than half of the OEL. Only one maximum exposure was seen above the OEL and that was for the blaster (0.119 mg/m^3), but the average exposure was well below the limit.

Construction

Sampling for the construction industry was conducted at two separate sites of the same company, both located outdoors and each in a different phase of the construction process. One site already had concrete slabs in place as well as a few concrete columns, whereas the other site had some of these structures erected, but was in an earlier stage of the construction process.

All the occupations in the construction industry had respirable dust and respirable silica dust exposures well below the respective OELs. The highest average respirable dust exposure was that of the bobcat operator at 0.280 mg/m^3 and for respirable silica dust the highest exposed individual was the general labourer at 0.062 mg/m^3.

Ceramics/potteries

In both the ceramics companies that were sampled the processes consisted of milling, batching, mixing (dry and wet), drying, weighing and blending of ceramics materials and also blending and smelting of frit on a quarterly basis for about three weeks at a time. The blending and smelting of frit were not performed during the sampling period and the results are thus not included in this report. Final products included clay, glaze and bisque, which were supplied to clients either in bulk or on a small scale. Ceramic pigments were also weighed and blended on site.

Both the OELs for respirable dust and respirable silica dust were exceeded by the clay worker (2.181 mg/m^3 and 0.409 mg/m^3) and dispatch clerk (2.720 mg/m^3 and 0.589 mg/m^3). The glaze worker had a maximum exposure to respirable dust that exceeded 2 mg/m^3 (3.188 mg/m^3), but minimum and average exposures below the OEL. The average respirable silica dust exposures for occupations in the ceramics industry did not exceed the OEL for two of the sampled occupations: the general labourer (0.054 mg/m^3) and the supervisor (0.098 mg/m^3). The casting- and glaze workers had average exposures of 0.186 mg/m^3 for the casting worker and 0.253 mg/m^3 for the glaze worker.

Refractories

Sampling was conducted in a firebrick and sliding gate section of one refractory and an alumino-silicate section of another. In the company where the firebrick and sliding sections were sampled, the basic process entailed the receiving and mixing of raw materials that were then poured into moulds, mixed, pressed, dried and then hardened in kilns. After the bricks came out of the kiln, they were inspected for quality and then dispatched. In the alumino-silicate section raw materials were dried and crushed in bulk and then weighed, mixed and packed in a wide range of combinations to be sent off to the clients or other departments.

The workers in the alumino-silicate section all had exposures above the OELs of both respirable dust and silica dust, apart from the forklift driver, who did not have an exposure to respirable silica dust that exceeded 0.1 mg/m^3. The controller was the only occupation in the firebrick and sliding gate section that had exposures that exceeded both OELs.

Dust audit tool

A silica dust audit tool was developed using national and international standards and guidelines governing occupational health and safety. Approximately 16 national and international standards and guidelines relevant to dust exposures in non-mining industries were identified for inclusion in the silica dust audit tool. The dust audit protocol was structured mainly by grouping the 200 relevant issues into 11 main areas of concern, which were sub-divided into indicator areas. The dust audit protocol covers the policy/programme, risk assessment and monitoring, dust laboratory and XRD analysis, instrumentation, transport, qualification, calculation, statistical analysis, sampling strategy, reporting and respiratory protective equipment. The standards and dust audit tool are attached as Appendix B and Appendix C of this report, respectively.

Conclusion and recommendations

Based on the findings of this limited study it can be concluded that there is a problem with regard to the silica dust exposures in the following non-mining industries in South Africa:

- Sandstone;
- Ceramics;
- Refractory; and
- Foundry

These four industries are of particular concern and some exposures in these industries are alarmingly high. It is suggested that further research be conducted on the sandblasting and construction industries, where the results did not provide a reason for concern with regard to silica dust exposures. The reason further research is required is because the companies that were sampled for these two industries do not represent the industries as a whole and therefore this conclusion cannot be extrapolated to represent the exposures in all the sandblasting and construction industries in South Africa.

It should be kept in mind that because it focused on only six industries this study's results represent a portion of the non-mining industry in South Africa. Thus, this study's results cannot be extrapolated to all non-mining industries in South Africa and only reflect the findings from the companies sampled. Also, project constraints meant that certain occupations and phases within the industries sampled could not be included in the study. Other differences between the various industries which require further research include work practices, the occupational health and safety culture, and varying degrees of expertise on airborne dust.

It is strongly recommended that a more in-depth nationwide study (baseline) be conducted to determine the true extent of silica dust exposures in the non-mining industry in South Africa.

With regard to the dust audit tool, it is recommended that a dust audit tool be developed for specific use in the non-mining industries, using the example of the Mine Health and Safety Council Dust Audit Tool (Appendix B) as a guideline.

Abbreviations, acronyms and symbols

AIA	-	Approved Inspection Authority
ANSI	-	American National Standards Institute
AQI	-	Air Quality Index
CMI	-	Centre for Mining Innovation
COIDA	-	Compensation for Occupational Injuries and Diseases Act
CSIR	-	Council for Scientific and Industrial Research
DOL	-	Department of Labour
DMR	-	Department of Mineral Resources
FTIR	-	Fourier-Transformed Infrared
HCS	-	Hazardous Chemical Substance Regulation
HEPA	-	High Efficiency Particulate Air filters
ILO	-	International Labour Organization
ISO	-	International Organization for Standardisation
OEL	-	Occupational Exposure Limit
OESSM	-	Occupational Exposure Sampling Strategy Manual
OSHA	-	Occupational Safety and Health Administration
MCE	-	Mixed Cellulose Ester
MDHS	-	Method for the Determination of Hazardous Substances
MHSC	-	Mine Health and Safety Council
MSDS	-	Material Safety Data Sheet
mg/m^3	-	milligram per cubic metre
NIOSH	-	National Institute for Occupational Safety and Health
NPES	-	National Programme for the Elimination of Silicosis
PAT	-	Proficiency Testing Scheme
PC	-	Pollutant Concentration
RCS	-	Respirable Crystalline Silica
REL	-	Recommended Exposure Limit
RPD	-	Respiratory Protective Device
RPE	-	Respirable Protective Equipment
SANAS -		South African National Accreditation System
SHE	-	Safety, Health and Environment
SRM	-	Standard Reference Method
TLV	-	Threshold Limit Value
TWA	-	Time-weighted Average
WHO	-	World Health Organization
XRD	-	X-Ray Powder Diffraction

Definitions of terms

Abrasive blasting

Abrasive blasting is an industrial process used to polish or clean various types of objects by using high-powered equipment to spray abrasively

Bisque

Hard fired unglazed white ceramic ware

Frit

Fused or partially fused ceramics composition that is quenched in a special fusing oven to form glass, glazes and enamels for potteries

Glass beads

Glass bead is the material used during the process of removing surface deposits by applying fine glass beads at a high pressure without damaging the surface

Inhalable dust

The particulate mass fraction of dust in the work environment that can be inhaled and deposited anywhere in the respiratory tract (particles smaller than 50 µm in aerodynamic diameter)

LAEIS Press

Press used in refractory for moulds

Non-mining industry

The non-mining industry is a broad sector that encompasses many industries, apart from industries that include mining and quarrying

Pneumoconiosis

An occupational and restrictive lung disease caused by the inhalation of dust and characterised by the formation of nodular fibrotic changes in the lungs

Respirable dust concentration

Respirable dust concentrations as measured by gravimetric dust monitoring instrumentation

Respirable silica dust concentration

Respirable silica dust concentrations as measured by alpha quartz analysis of respirable dust

Respirable crystalline silica (RCS)

That portion of airborne crystalline silica that is capable of entering the gas-exchange region of the lungs when inhaled (less than 10 microns)

Silicosis

Silicosis is a form of pneumoconiosis and an occupational disabling, non-reversible and sometimes fatal respirable disease caused by the inhalation of dust that contains free crystalline silica (RCS)

Silica sand

Silica sand is sand that is commonly used in industrial processing, to make glass and to create moulds and castings

1. Introduction

In 2009 the Human Factors Group of the CSIR's Centre for Mining Innovation (CMI) was awarded a project to determine the level of exposure of workers to silica dust in the non-mining sectors in South Africa. This project was initiated to act as a baseline study for the National Programme for the Elimination of Silicosis (NPES) that was established in 2004. Phase 1 of the current research project entailed a literature study from which it was concluded that comprehensive and recent information in the area of silica exposure and silicosis cases of workers in the non-mining sectors in South Africa is lacking. The report provided some insight into the magnitude of the situation in the non-mining industries in South Africa. Owing to under diagnosis, under reporting and inadequate processing of the data collected in the research studies that were reviewed, no reliable statistics exist regarding the exact status of the situation. This revealed a need to determine the personal dust exposure levels of workers to respirable dust and silica dust in the non-mining industries.

The primary objective of Phase 2 of the project was to assess the personal exposures of workers in the non-mining industries to silica dust in order to estimate the extent of the problem. Seven industries that have the potential to expose workers to silica dust were identified during Phase 1, i.e. foundries, sandstone, sandblasting, construction, ceramics/potteries, refractories and agriculture (crop and grains produce). Six of the above-mentioned industries were identified for this study: foundries, sandstone, sandblasting, construction, ceramics/potteries and refractories. Agriculture was excluded from this study owing to the study constraints and because research is currently being conducted on agriculture workers' exposure to silica dust by another party. Sampling was conducted at 12 companies in total (two companies per industry), most of which were situated in the Gauteng Province.

The main enabling outputs for the second phase of the research project were to:

- Use the information obtained in Phase 1 of the project and the guidelines in the Occupational Exposure Sampling Strategy Manual (OESSM), taking into account the restrictions of the study, to establish a sampling strategy to conduct a limited survey of the worker exposures;
- Conduct sampling (300 samples) at six selected non-mining industries in Gauteng Province;
- Assess the applicability of the audit tool developed by the MHSC for use by the Department of Labour (DOL) Inspectorate; and
- Collate findings/results of enabling outputs 1, 2 and 3 into the final project report.

2. Methodology

2.1 Sampling selection

The study was conducted in six non-mining industries in South Africa that were identified in Phase 1, i.e. foundries, sandstone operations, sandblasting, construction, ceramics/potteries and refractories.

Various companies in each of the six non-mining industries were contacted telephonically regarding participation in the study. Appointments were scheduled with the two companies in each industry that agreed to participate in the study and a site visit was arranged where the full details and extent of the study and their participation was explained.

No statistical determination of the sampling or sample size was made owing to the limitations of the study, but the study aimed to collect 50 samples in each industry, i.e. approximately 25 samples at each company. The number of samples depended greatly on the number of workers in each company, which varied from one company to the next. It was decided that the "maximum risk employees" would be sampled, who were then identified after discussion with the supervisor or owner of the various companies.

The following factors were closely observed during sampling and discussed with the companies' occupational health and safety practitioners, managers or supervisors (NIOSH, 1977):

- Distance from the dust-generating source;
- Employee mobility;
- Air movement patterns within a workroom; and
- Differences in work habits of individual workers (as these can significantly affect levels of exposure).

2.2 Sampling method

Personal sampling was performed in the workplace for the "maximum risk employees", who were identified through a detailed labour discussion with the supervisor, manager or owner of the company.

Each worker was issued with a gravimetric dust sampling pump connected to a sampling head by a length of flexible tubing. The sampling head consisted of a 25 mm mixed cellulose ester (MCE) filter that had a generic Higgins-Dewell type sampler attached to it. The pump was positioned on the worker's belt and the sampling head in the breathing zone of the worker on the collar of his or her overall or work clothes in order for the sample to represent the dust inhaled by the worker during the shift. These instruments were worn throughout the shift period, during work and rest.

Each sampling pump was calibrated at a flow rate of 2.2 litres per minute before and after sampling.

2.3 Analytical procedures

Filters used for sampling were weighed according to the international standard MDHS 14/3: “General methods for sampling and gravimetric analysis of respirable and inhalable dust” and the gravimetric weighing was done with a 6 decimal balance. The alpha quartz content of each filter was determined by direct-on filter analysis using X-Ray Powder Diffraction (XRD). For the alpha quartz data analysis the International Standard on Alpha Quartz Analysis, MDHS 101: “Direct-on filter analysis by infrared spectroscopy and X-ray diffraction” was used.

The CMI Laboratory has SANAS accreditation (ISO 17025) for both these methods and is currently the only laboratory in South Africa accredited for the XRD method.

3. Results

After analysis of the sampled filters the results were processed as minimum, average and maximum values to indicate the range of the exposures to respirable dust and silica dust. Statistical analysis was not performed because no statistical determination of the sample size had been made. The results therefore only provide a limited indication of the silica dust exposures in the South African non-mining industry and further research is recommended for statistical purposes.

The results are presented graphically as minimum, average and maximum exposures for each of the sampled occupations in the different industries and they reflect the eight-hour time-weighted average (TWA) exposure of each occupation, representing the workers' average exposures over an eight-hour shift. The exposures are then discussed against the commonly used occupational exposure limits (OELs) for respirable dust and respirable silica dust of 2 mg/m^3 and 0.1 mg/m^3, respectively. An indication (red line) in each graph provides information on whether the exposures exceed the occupational exposure limit for respirable dust or respirable silica dust or not.

3.1 Foundries

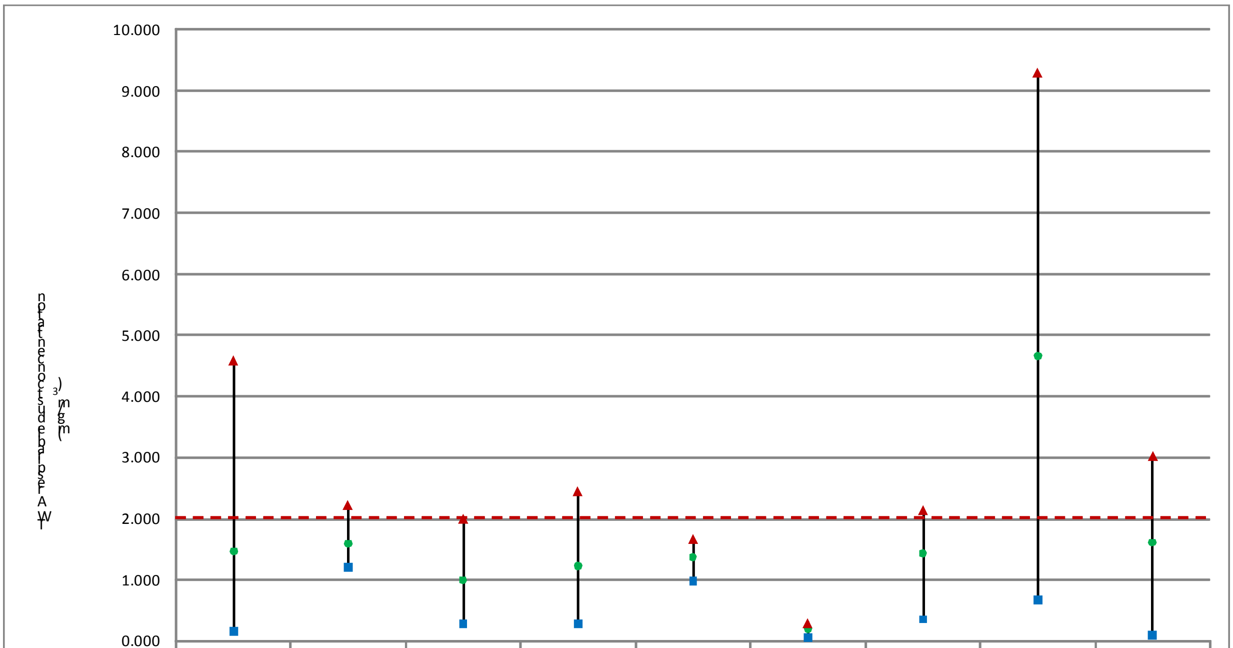
3.1.1 Overview and occupations

The samples were collected from two foundry companies, of which one was a complete ferrous foundry and the other was 90% ferrous and 10% non-ferrous. The sections of the foundries that were sampled were mixing, moulding, shot-blasting, shake-out, casting, fettling and melting.

Table 1: Foundry industry occupations and their descriptions

Occupation	Description
Sand mixing operator	Operates the machines that mix sand in the plant
Shake-out operator	Operates the crane and machine that removes the cast from the mould
Shot-blast operator	Operates the compressed air pipe to remove rust or paint from objects
Furnace operator	Manages the furnace and operates the crane that is used to put the metals into the furnace
Casting operator	Operates the crane used to transport molten metals into the mould and also repair melting pots
Loco sand filler and remover (technician)	Removes sand from the trains while the locomotives are serviced and refills the trains afterwards
Moulder	Makes the moulds or casts
Grinder	Operates the grinder in the fettling section to remove scale and access materials from the products
Closer	Closes the moulds

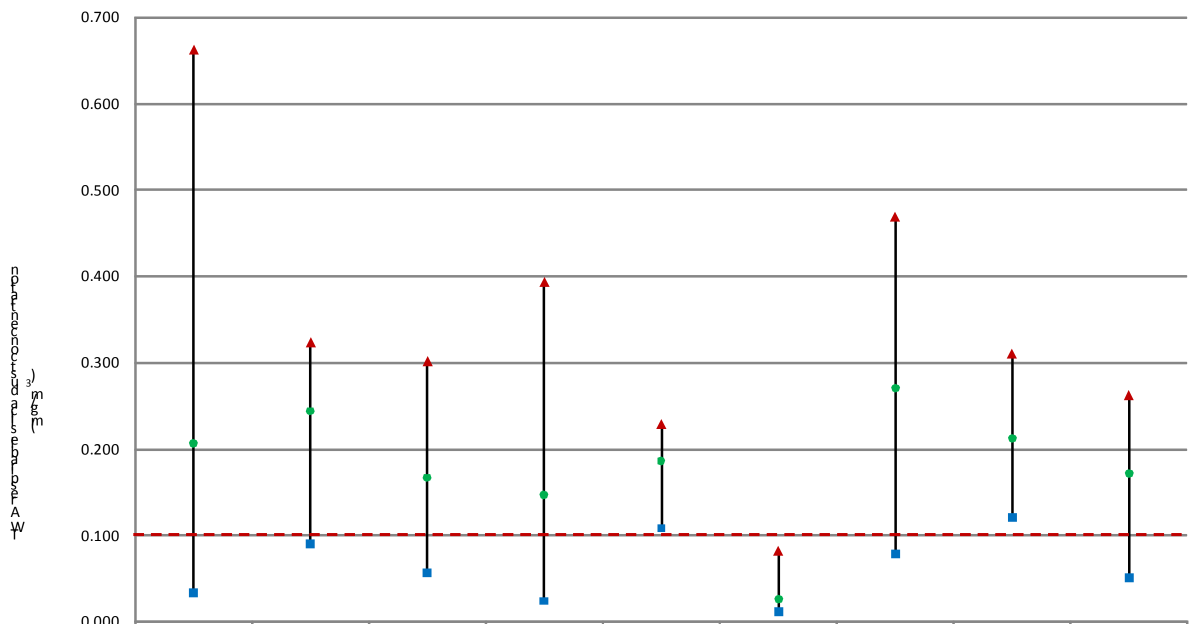
3.1.2 Results and discussion



	Sand mixing operator (n=12)	Shake-out operator (n=4)	Shot-blast operator (n=8)	Furnace operator (n=6)	Casting operator (n=3)	Loco sand filler and remover (n=8)	Moulder (n=4)	Grinder (n=4)	Closer (n=5)
Minimum	0.157	1.207	0.291	0.282	0.976	0.058	0.358	0.668	0.104
Average	1.455	1.582	0.979	1.214	1.365	0.184	1.420	4.664	1.597
Maximum	4.571	2.220	1.994	2.448	1.656	0.297	2.134	9.294	3.014

Figure 1: Personal respirable dust concentrations per occupation for foundry workers

Average personal respirable dust exposures for foundry workers were found to be above the OEL for respirable dust only for the grinder (4.664 mg/m^3). Maximum exposures above the OEL did occur for sand mixing operators (4.571 mg/m^3), shake-out operators (2.220 mg/m^3), furnace operators (2.448 mg/m^3), moulders (2.803 mg/m^3), grinders (9.294 mg/m^3) and closers (3.014 mg/m^3). The shot-blast operator, casting operator and loco sand filler and remover had exposures below the OEL; however, the maximum exposure of the shot-blast operator was just below the limit, with a value of 1.994 mg/m^3.



	Sand mixing operator (n=12)	Shake-out operator (n=4)	Shot-blast operator (n=8)	Furnace operator (n=6)	Casting operator (n=3)	Loco sand filler and remover (n=8)	Moulder (n=4)	Grinder (n=4)	Closer (n=5)
Minimum	0.032	0.089	0.056	0.023	0.107	0.010	0.077	0.120	0.050
Average	0.206	0.244	0.166	0.147	0.186	0.025	0.271	0.212	0.171
Maximum	0.662	0.322	0.301	0.392	0.228	0.082	0.468	0.309	0.261

Figure 2: Personal respirable silica dust concentrations per occupation for foundry workers

Respirable silica dust exposures for the foundry workers were all above the OEL for respirable silica dust (0.1 mg/m^3) except for the loco sand filler and remover (at 0.025 mg/m^3). The moulder and sand mixing operators had the highest maximum exposures of 0.836 mg/m^3 and 0.662 mg/m^3, respectively, and the furnace operator also had a maximum exposure of almost four times the OEL (0.392 mg/m^3).

Out of all the occupations sampled only the grinder had exposures to both respirable dust (4.664 mg/m^3) and respirable silica dust (0.309 mg/m^3) above the respective OELs. The grinder was working in an enclosed workstation in the fettling department, which was in close proximity to the shot-blast operator and his activities mostly involved working with dry sand and further crushing the sand into smaller particles. The grinder's workstation did not have dust control measures in place and, in conjunction with the dust released from the shot-blast activities, the exposures were excessive.

There is a concern with regard to the respirable silica dust exposures of the foundry workers, which were above the OEL for all the occupations except for the loco sand filler and remover. From the sampling observations it was noted that the loco sand fillers and removers did not work in the same area as the rest of the activities and they were therefore not exposed to the same airborne particle concentrations.

3.2 Sandstone operations

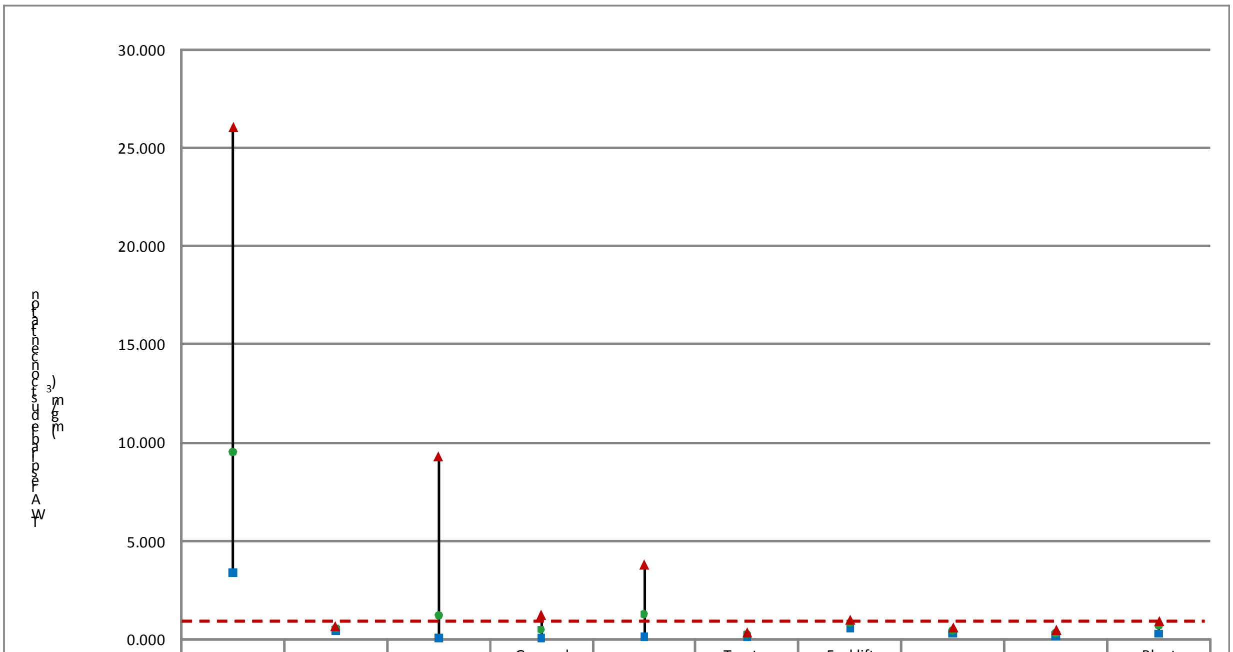
3.2.1 Overview and occupations

The basic operations at the two identified sandstone companies entailed the cutting of sandstone blocks, supplied from a sandstone quarry, into smaller and more useable slabs or products by making use of a saw machine (diamond wire cutting or circular saw cutting). Finer details were then added to some of the cut blocks by chiselling, polishing or grinding them into their desired shapes and sizes. The occupations that were sampled are summarised and described in Table 2.

Table 2: Sandstone occupations and their descriptions

Occupation	Description
Plant manager	Has a supervisory role and assists and instructs workers
Saw operator	Operates the diamond blade and diamond wire saws
Forklift operator	Transports products to and from the sawing machines and to the store areas
Stone mason	Splits rocks by using a handheld chisel and hammer to make cladding bricks
Stone carver	Carves the stone with a chisel and sometimes the angle grinder
General labourer	Moves around all over work area cleaning, controlling the water recycling process, and packaging, and also helps with the finishing of products
Technician	Repairs and fixes the mobile equipment on site and also works as an electrician
Tractor operator	Sprays water onto the roadway in the morning for dust suppression and collects and drops off the sandstone blocks from the quarry
Polisher	Polishes stone with an angle grinder
Packer	Packs and moves final products

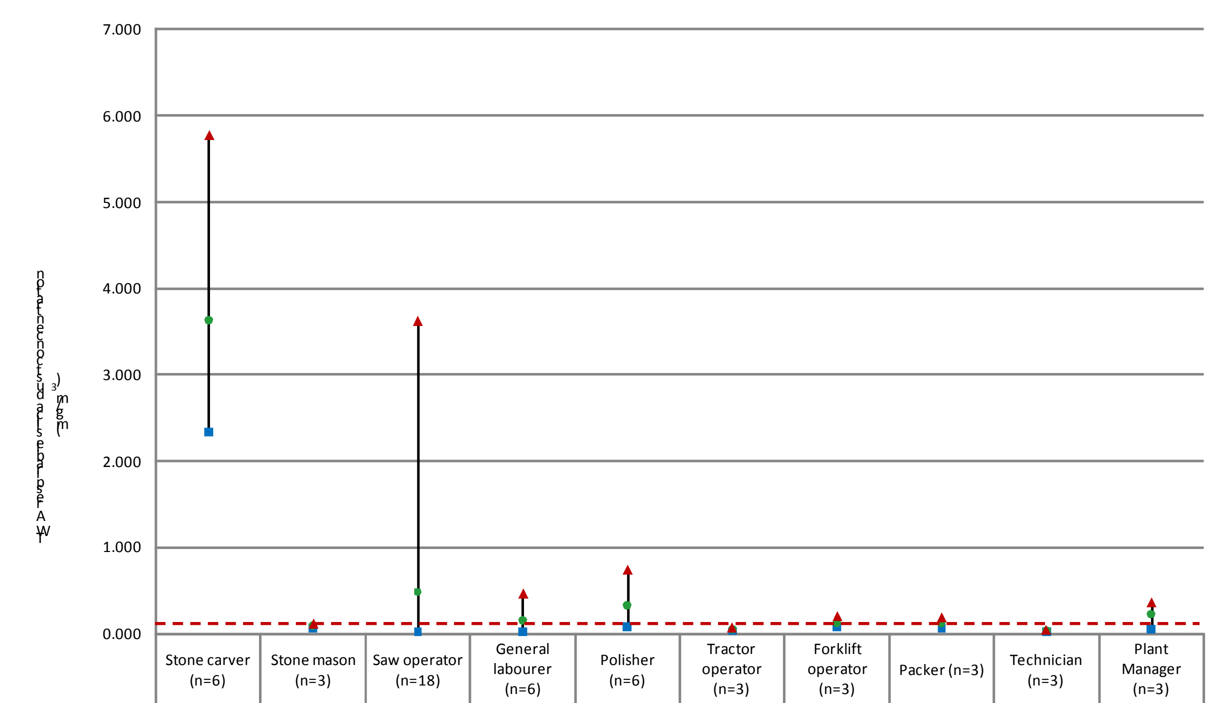
3.2.2 Results and discussion



	Stone carver (n=6)	Stone mason (n=3)	Saw operator (n=18)	General labourer (n=6)	Polisher (n=6)	Tractor operator (n=3)	Forklift operator (n=3)	Packer (n=3)	Technician (n=3)	Plant Manager (n=3)
Minimum	3.419	0.473	0.100	0.110	0.161	0.179	0.590	0.331	0.247	0.340
Average	9.527	0.569	1.255	0.503	1.292	0.276	0.840	0.496	0.343	0.707
Maximum	26.080	0.648	9.265	1.219	3.768	0.341	0.982	0.583	0.414	0.909

Figure 3: Personal respirable dust concentrations per occupation for sandstone workers

The stone carver was the highest exposed individual to respirable dust in the sandstone industry, with a maximum exposure of 26.080 mg/m^3, an exposure well above the OEL, and an average exposure of approximately five times the OEL. The saw operator and polisher had average exposures below, but maximum concentrations above the OEL of 9.265 mg/m^3 and 3.768 mg/m^3, respectively. All the other occupations in the sandstone industry had minimum, maximum and average exposures that were well below the respirable dust OEL.



	Stone carver (n=6)	Stone mason (n=3)	Saw operator (n=18)	General labourer (n=6)	Polisher (n=6)	Tractor operator (n=3)	Forklift operator (n=3)	Packer (n=3)	Technician (n=3)	Plant Manager (n=3)
Minimum	2.337	0.070	0.024	0.023	0.077	0.031	0.082	0.061	0.020	0.056
Average	3.638	0.095	0.482	0.159	0.328	0.050	0.130	0.122	0.036	0.232
Maximum	5.772	0.113	3.607	0.464	0.735	0.066	0.204	0.191	0.046	0.355

Figure 4: Personal respirable silica dust concentrations per occupation for sandstone workers

The stone mason, tractor operator and technician were the only occupations with exposures of below the OEL for respirable silica dust. The other seven occupations were found to have maximum and average respirable silica dust exposures that were above the OEL. The stone carver had respirable silica dust exposures that ranged from approximately twenty (2.337 mg/m^3) to almost sixty (5.772 mg/m^3) times the OEL and the saw operator also had a maximum exposure of almost forty times the OEL (3.607 mg/m^3).

The respirable dust exposures of the sandstone workers were above the OEL (2 mg/m^3) only for the stone carver, but with regard to the respirable silica dust exposures the saw operator, general labourer, polisher, forklift operator, packer and plant manager were all exposed to levels of above the OEL. The only occupation that had both respirable dust and respirable silica dust exposures of above the respective OELs was the stone carver, which had alarmingly high exposures for both measurements.

During the sampling it was observed that the stone carvers performed their cutting functions mostly with a hand-held angle grinder that released large amounts of visible dust. An extractor fan was positioned over the work area, but the observation and results indicate that this dust control method was not effective with regard to controlling the liberation of visible or respirable dust and respirable silica dust. No visible dust was seen at the saw-operating areas, which could be because the saws were operated with water. The saw operators and general labourers could have been exposed to the dust liberated by the other cutting activities in their surroundings, such as the activities of the stone carvers. The polishers carry out the final finishing of the cut products with a hand-held angle grinder, which could have contributed to their exposure to respirable silica dust.

3.3 Sandblasting

3.3.1 Overview and occupations

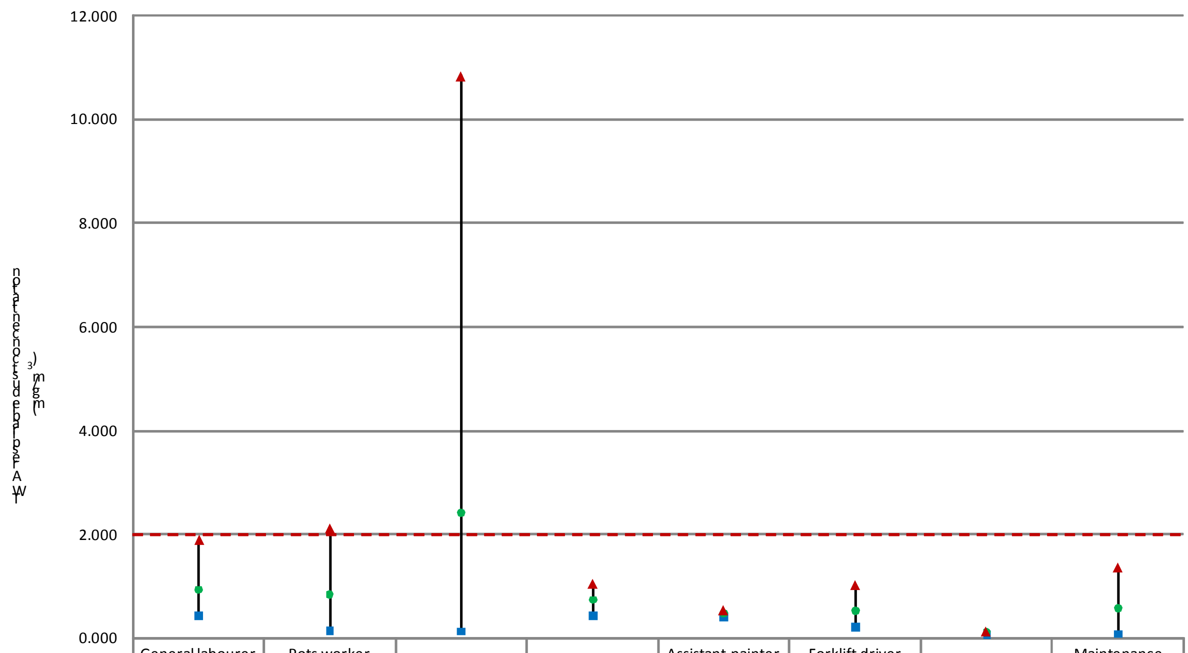
Abrasive- or sandblasting is the process of blowing a stream of abrasive blasting particles (silica sand, steel grit and glass/beads grit) onto a surface by means of compressed air, mainly aimed at removing rust, smoothening surfaces, engraving artistic endeavours and finishing products. Sandblasting activities also include removing paint from stone buildings and metals, finishing tombstones, and cleaning sand and irregularities from casting.

One of the sandblasting companies selected for the study was located in an industrial area and the work performed at this company mostly involved removing rust from steel products and then painting them. The other company was located on a plot where the workers removed paint and rust from a wide variety of products, such as old cars, trucks, mining equipment, farming equipment and other steel objects. The occupations for sandblasting that were sampled are described in Table 3.

Table 3: Sandblasting industry occupations and their descriptions

Occupation	Description
Blaster	Blasts objects by using a high-pressure air-supplied (compressed air) hose and silica sand/steel grit to remove rust and/or paints from objects
Forklift operator	Transports all the objects to be sandblasted to and from the blasting area
Pots worker	Cleans and fills sandblasting pots with the blasting particles used
General labourer	Performs general maintenance and other duties on site
Painter	Paints the blasted materials
Assistant painter	Assists painters during painting of blasted materials
Maintenance officer	Performs repair and maintenance work
Supervisor	Has a supervisory role and assists in loading the forklifts and dealing with clients in the dispatch area

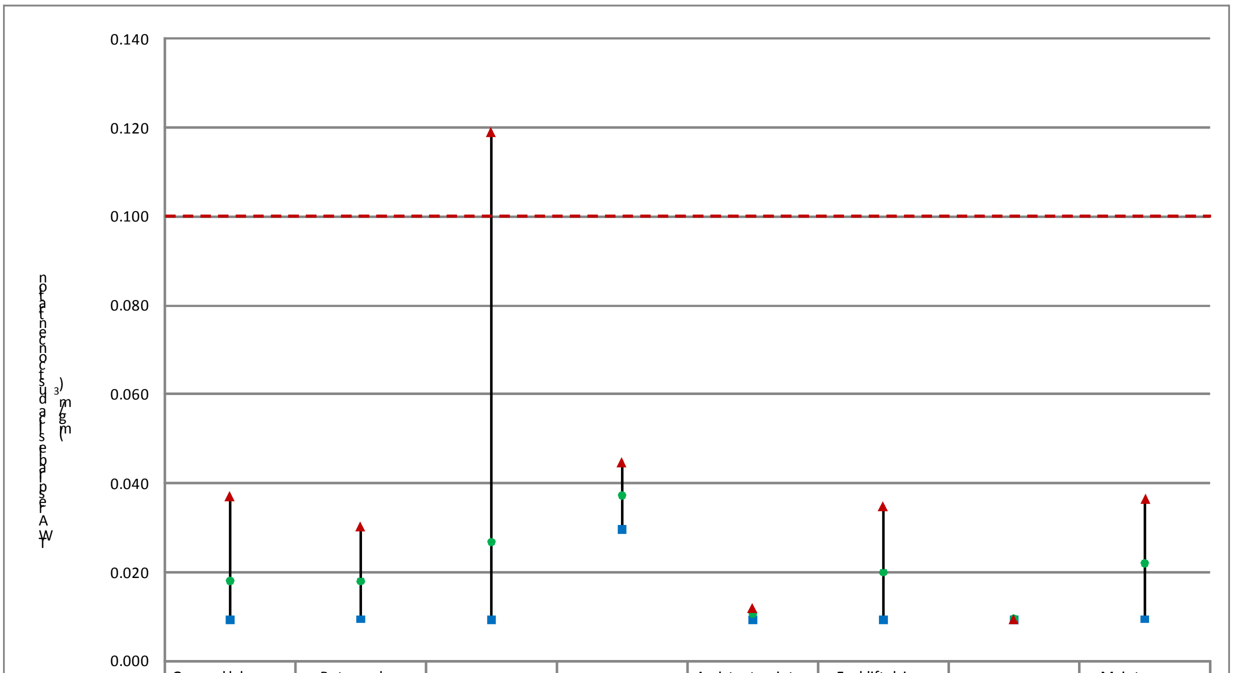
3.3.2 Results and discussion



	General labourer (n=5)	Pots worker (n=4)	Blaster (n=19)	Painter (n=2)	Assistant painter (n=2)	Forklift driver (n=3)	Supervisor (n=3)	Maintenance officer (n=3)
Minimum	0.428	0.145	0.128	0.435	0.410	0.216	0.060	0.073
Average	0.929	0.846	2.433	0.736	0.470	0.530	0.107	0.574
Maximum	1.888	2.099	10.835	1.037	0.530	1.017	0.132	1.362

Figure 5: Personal respirable dust concentrations per occupation for sandblasting workers

Personal respirable dust concentrations for the sandblasting workers mostly averaged below the OEL for respirable dust, with a maximum exposure of the pots worker above the OEL (2.099 mg/m^3). The blaster was the highest exposed individual with an average and maximum exposure above the OEL of 2.433 mg/m^3 and 10.835 mg/m^3, respectively.



	General labourer (n=5)	Pots worker (n=4)	Blaster (n=19)	Painter (n=2)	Assistant painter (n=2)	Forklift driver (n=3)	Supervisor (n=3)	Maintenance officer (n=3)
Minimum	0.009	0.009	0.009	0.030	0.009	0.009	0.009	0.009
Average	0.018	0.018	0.027	0.037	0.011	0.020	0.009	0.022
Maximum	0.037	0.030	0.119	0.045	0.012	0.035	0.010	0.036

Figure 6: Personal respirable silica dust concentrations per occupation for sandblasting workers

Respirable silica dust exposures for the sandblasting workers were all less than half of the OEL. Only one maximum exposure is seen above the OEL and that was for the blaster (0.119 mg/m^3), but the average exposure was well below the limit.

According to the results the respirable dust and respirable silica dust exposures for the sandblasting industry were below the limits for both the measured pollutants, with only the pots worker having a maximum respirable dust exposure above the limit and the blaster having a maximum exposure to respirable silica dust and an average exposure to respirable dust of above the respective OELs. The blaster's exposure levels may be the result of this worker doing the actual blasting activity and therefore being directly exposed to the abrasive particles that were blasted onto the surface of the object with compressed air. The other workers were not exposed in the same direct manner, but had a more general exposure to the airborne particles of concern, which meant that their exposures were lower.

3.4 Construction

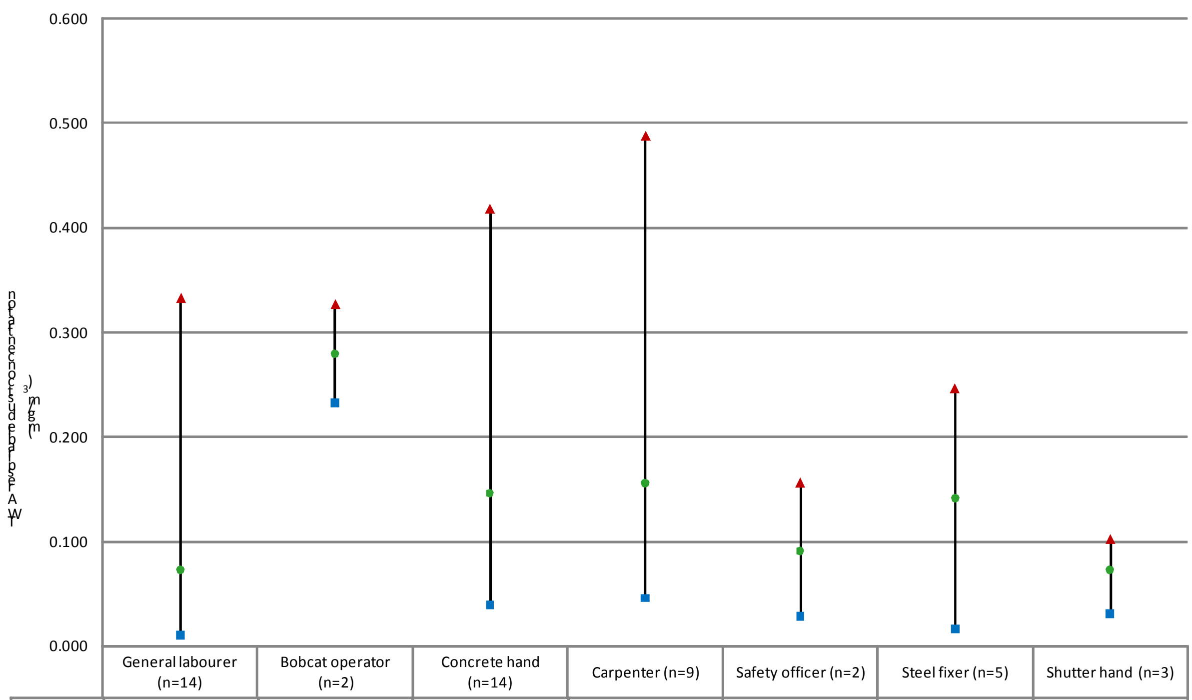
3.4.1 Overview and occupations

Sampling for the construction industry was conducted at two separate sites of the same company, both located outdoors and each in a different phase of the construction process. One site already had concrete slabs in place as well as a few concrete columns, whereas the other site had some of these structures erected, but was in a more initial stage of the construction process. The occupations that were sampled on both sites are described in Table 4.

Table 4: Construction industry occupations and their descriptions

Occupation	**Description**
General labourer	Performs general duties on site, including the passing and cleaning of tools, pick and shovel work, digging of holes, cleaning and housekeeping of the site and basic carrying of equipment
Bobcat operator	Performs backfilling (filling an area with sand) and earthmoving activities by means of a Bobcat machine
Concrete hand	Performs concrete pouring, levelling, floating and aeration
Carpenter	Constructs the shutters for the concrete columns, which can be made of wood boards and/or steel
Steel fixer	Prepares the steel rods used to re-enforce the concrete
Shutter hand	Provides assistance during the production and fixing of shutters into which the concrete is poured
Safety officer	Moves about the site and carries out safety inspections and checks

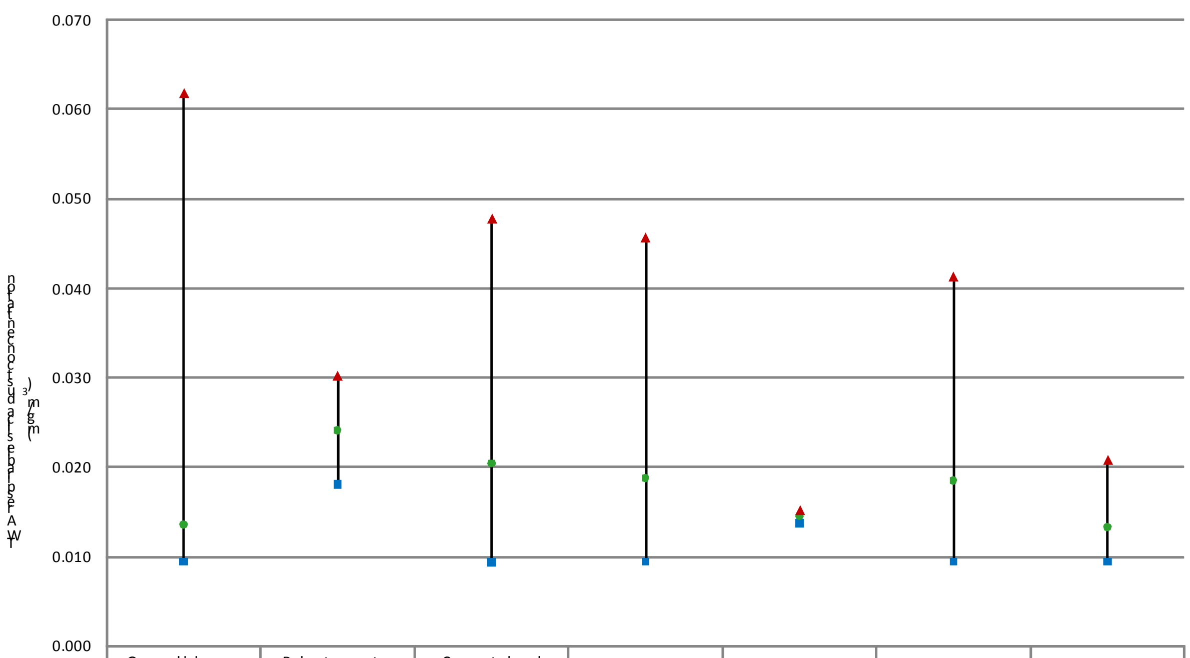
3.4.2 Results and discussion



	General labourer (n=14)	Bobcat operator (n=2)	Concrete hand (n=14)	Carpenter (n=9)	Safety officer (n=2)	Steel fixer (n=5)	Shutter hand (n=3)
Minimum	0.010	0.233	0.039	0.046	0.028	0.016	0.031
Average	0.073	0.280	0.146	0.156	0.092	0.142	0.073
Maximum	0.333	0.326	0.418	0.488	0.155	0.246	0.102

Figure 7: Personal respirable dust concentrations per occupation for construction workers

All the occupations in the construction industry had respirable dust exposures well below the OEL for respirable dust, the average exposure of the bobcat operator being the highest at 0.280 mg/m^3.



	General labourer (n=14)	Bobcat operator (n=2)	Concrete hand (n=14)	Carpenter (n=9)	Safety officer (n=2)	Steel fixer (n=5)	Shutter hand (n=3)
Minimum	0.009	0.018	0.009	0.009	0.014	0.009	0.009
Average	0.014	0.024	0.020	0.019	0.014	0.018	0.013
Maximum	0.062	0.030	0.048	0.046	0.015	0.041	0.021

Figure 8: Personal respirable silica dust concentrations per occupation for construction workers

All respirable silica dust exposures for workers in the construction industry were below the OEL. The highest exposed individual was the general labourer, with a maximum exposure of 0.062 mg/m^3.

None of the occupations in the construction industry had exposures to respirable dust or respirable silica dust that were above the respective OELs. Possible reasons may include the location of the two sites that were sampled, the phase that the construction process was in and/or the activities performed at the sites. Both sites were located on an open piece of land and were subject to the wind (natural ventilation) that could have effectively carried away the dust that was released. Both sites were constructing warehouses at an initial stage and the activities performed did not include road, tunnel, rail, or bridge constructions, which would have included earthmoving, grinding, renovation, modifying and demolition construction processes. It is, however, not clear whether the same activities performed in a different environment would result in a different outcome. In addition, piling was carried out by a subcontractor and these workers were also not sampled, and dry concrete mixing was also not performed on site, as the concrete was prepared elsewhere and then delivered to the site.

3.5 Ceramics/Potteries

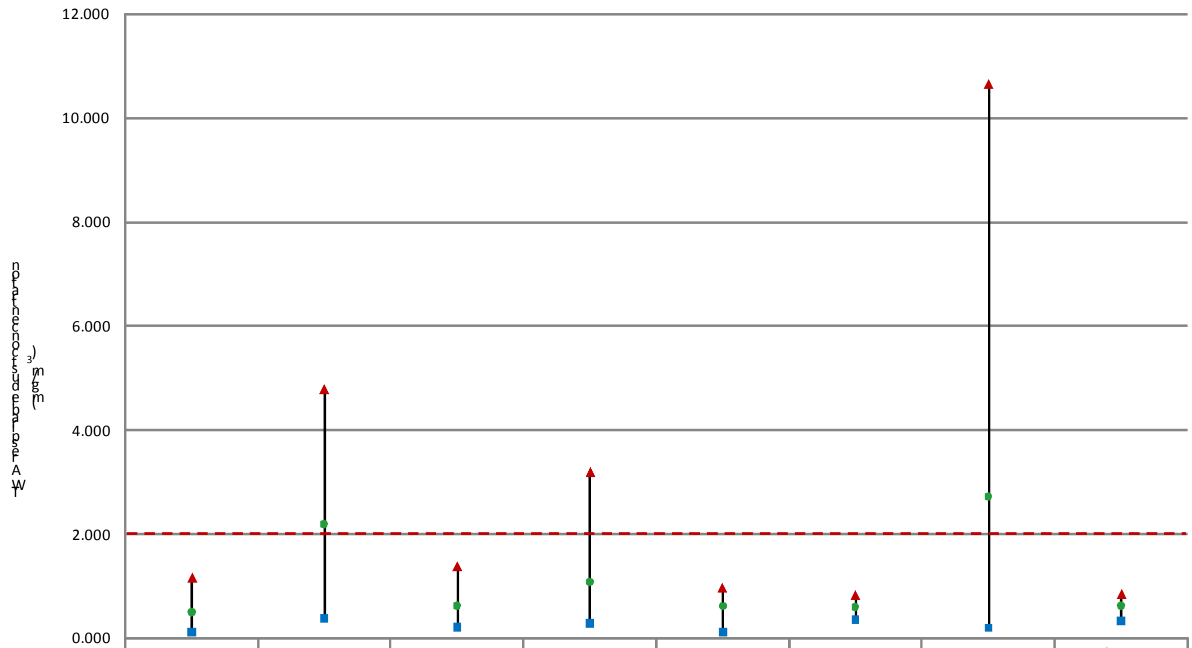
3.5.1 Overview and occupations

In both the ceramics companies that were sampled the processes consisted of milling, batching, mixing (dry and wet), drying, weighing and blending of ceramics materials and also blending and smelting of frit on a quarterly basis for about three weeks at a time. The blending and smelting of frit were not performed during the sampling period and the results are thus not included in this report. Final products included clay, glaze and bisque, which were supplied to clients either in bulk or on a small scale. Ceramic pigments were also weighed and blended on site. The occupations are described individually in Table 5.

Table 5: Ceramics industry occupations and their descriptions

Occupation	Description
Clay worker	Weighs and blends clay mixes and extrudes and packages clay
Casting worker	Makes the final product of the clay
Dispatch clerk	Weighs and blends orders and materials for stock and dispatching
Glaze worker	Weighs the batches of glaze and frit mixes; charges the mills; mixes orders and empties dryers; and blends and smelts frit on a quarterly basis for about three weeks at a time
Mould worker	Makes the green wares
Forklift operator	Transports final products (moulds, clay and other materials) in the workshop and may also assist the clay worker
Supervisor	Has a supervisory role and also assists the workers in the various departments
General labourer	Cleans offices, makes tea, weighs and blends small orders and assists in the dispatching department

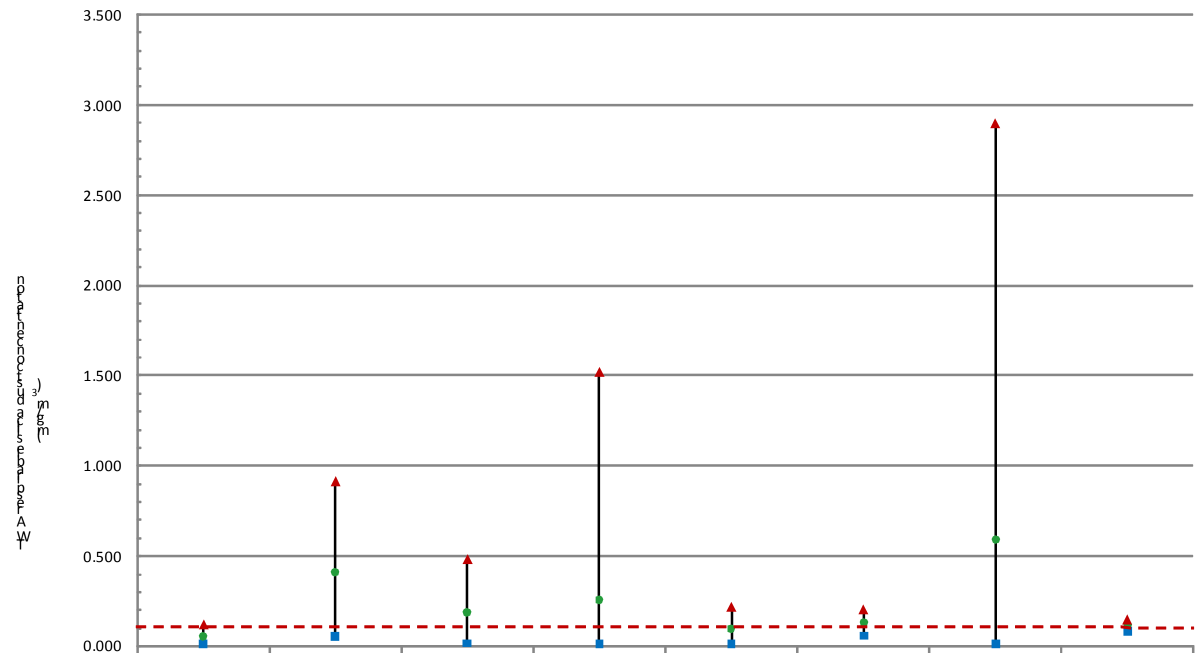
3.5.2 Results and discussion



	General labourer (n=6)	Clay worker (n=12)	Casting worker (n=3)	Glaze worker (n=12)	Supervisor (n=6)	Mould worker (n=3)	Dispatch clerk (n=6)	Forklift operator (n=3)
Minimum	0.107	0.377	0.199	0.280	0.103	0.353	0.193	0.320
Average	0.495	2.181	0.616	1.083	0.609	0.590	2.720	0.627
Maximum	1.161	4.789	1.389	3.188	0.972	0.832	10.664	0.838

Figure 9: Personal respirable dust concentrations per occupation for ceramics workers

Average respirable dust exposures for the ceramics workers were below the OEL for respirable dust, with the exception of the clay worker and dispatch clerk, which had average exposures of 2.181 mg/m^3 and 2.720 mg/m^3 and maximum exposures of 4.789 mg/m^3 and 10.664 mg/m^3, respectively. The glaze worker had a maximum exposure that exceeded 2 mg/m^3 (3.188 mg/m^3), but minimum and average exposures of below the OEL.



	General labourer (n=6)	Clay worker (n=12)	Casting worker (n=3)	Glaze worker (n=12)	Supervisor (n=6)	Mould worker (n=3)	Dispatch clerk (n=6)	Forklift operator (n=3)
■ Minimum	0.010	0.054	0.013	0.009	0.009	0.057	0.009	0.083
● Average	0.054	0.409	0.186	0.253	0.098	0.131	0.589	0.119
▲ Maximum	0.118	0.913	0.479	1.513	0.209	0.201	2.900	0.144

Figure 10: Personal respirable silica dust concentrations per occupation for ceramics workers

The average respirable silica dust exposures for occupations in the ceramics industry did not exceed the OEL for two of the sampled occupations: the general labourer (0.054 mg/m^3) and the supervisor (0.098 mg/m^3). The clay-, casting- and glaze workers together with the dispatch clerk had average exposures ranging from 0.186 mg/m^3 for the casting worker to 0.589 mg/m^3 for the dispatch clerk. These four occupations also had maximum respirable silica dust exposures of 0.913 mg/m^3, 0.479 mg/m^3, 1.513 mg/m^3 and 2.900 mg/m^3, respectively.

Both the OELs for respirable dust and respirable silica dust were exceeded by the clay worker and dispatch clerk. The workers in these two occupations mainly work with dry materials (measuring, weighing, mixing) to produce the desired product. Silica sand is one of these dry products that are used and it can be a contributing factor to these workers having excessive respirable silica dust exposures. The casting worker has a close working relationship with the clay worker in that their functions are performed in the same room or area. The casting worker is therefore also exposed to the dry products that the clay worker uses to prepare the final clay product, causing his respirable silica dust exposure to be above the OEL. The glaze worker had an average respirable silica dust exposure and a maximum exposure to respirable dust of above the respective OELs, mainly due to the cleaning of the mills, which causes dust liberation. The mould worker works with wet and dry products and generally mixes the products with his hands, which can cause dust liberation when dry products are used, contributing to the exposures of this occupation. The supervisor had an average exposure to respirable silica dust of 0.098 mg/m^3 and although it is below the OEL for respirable silica dust it provides reason for concern with regard to his exposure, especially because he had an maximum exposure that did exceed the OEL. The exposure of the supervisor and forklift operator (both having exposures that exceed the OEL) is of concern because their exposures represent an overall exposure of the workplace. In this case the exposures of the supervisor and forklift driver indicate an overall exposure in the workplace that is close to and above the OEL, meaning that all the workers are exposed to levels of respirable silica dust that are harmful to their health.

3.6 Refractories

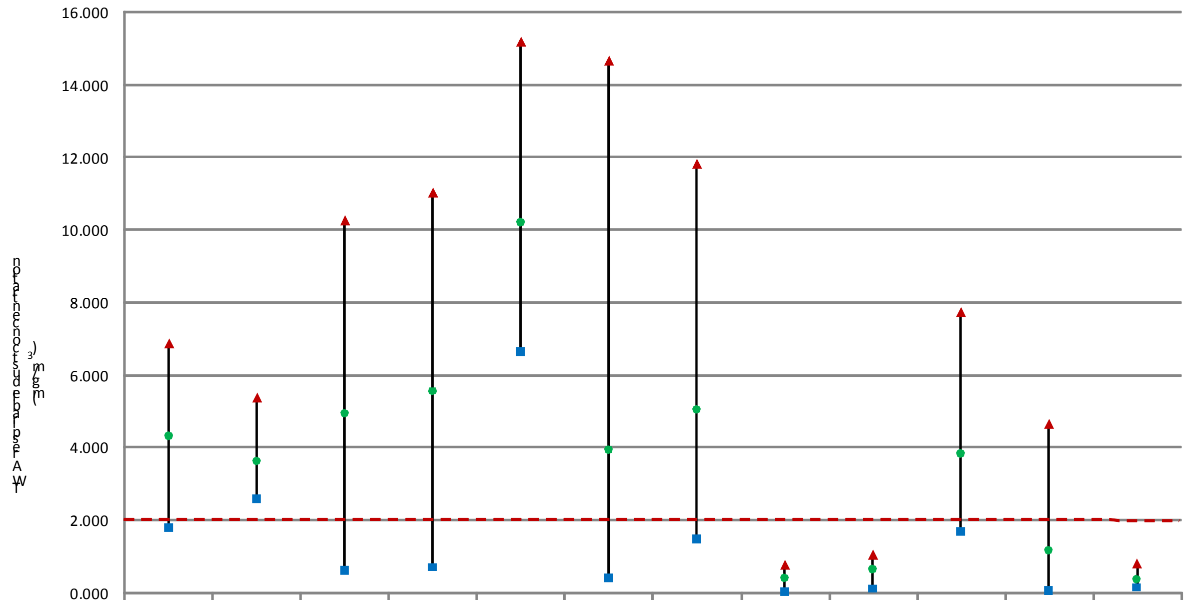
3.6.1 Overview and occupations

Sampling was conducted in a firebrick and sliding gate section of one refractory and an alumino-silicate section of another. In the company where the firebrick and sliding sections were sampled, the basic process entailed the receiving and mixing of raw materials that were then poured into moulds, mixed, pressed, dried and then hardened in kilns. After the bricks came out of the kiln, they were inspected for quality and then dispatched. In the alumino-silicate section raw materials were dried and crushed in bulk and then weighed, mixed and packed in a wide range of combinations to be sent off to the clients or other departments.

Table 6: Refractory industry occupations and descriptions

Occupation	Description
Chemical batcher	Pre-weighs various chemical additives, using a shovel
Packer	Packs final product bags from conveyor onto pallets and wraps the pallets
Chemical additioner	Cuts bagged material into mixer hopper or pneumatic pots
Forklift operator	Moves packed material all over plant
Bagger operator	Operates the bagging unit by inserting bags into clamps/spouts for filling
Operator of the shuttle at the conveyor	Positions conveyor over bin for pouring and cleans the general area
Weigh larry operator	Transfers bagged materials into weigh larry and weighs off required materials from the bins; a weigh larry is a travelling hopper for receiving, weighing or measuring and distributing bulk materials
Berry press operator	Weighs the mixed clay material and pours it into the mould in the berry press machine for the making of green bricks
LAEIS press operator	Operates the LAEIS press machines during the manufacturing of green bricks
Crusher operator	Crushes the waste or green bricks that do not pass the quality control inspections and recycles them back into the mixing machine
Mixer operator	Operates all the mixing machines and mixes different raw materials, depending on the final product desired
Controller	Controls temperatures of the kiln for different brick products

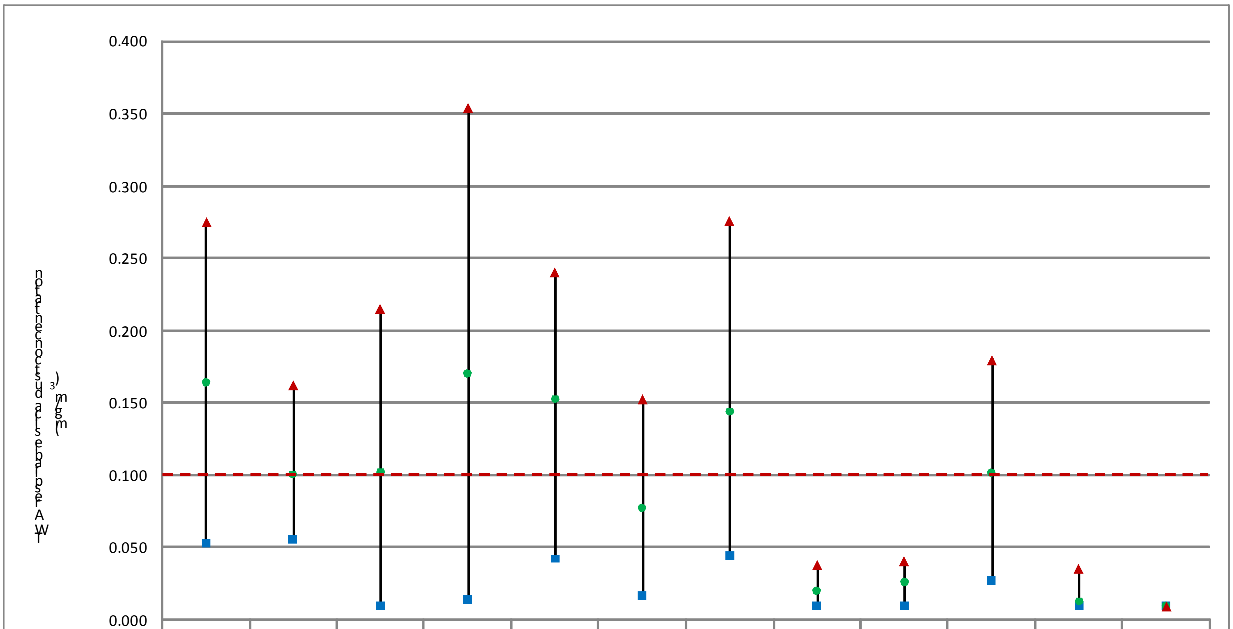
3.6.2 Results and discussion



	Chemical batcher (n=2)	Operator shuttle conveyor (n=3)	Packer (n=4)	Operator bagger (n=6)	Operator weigh larry (n=3)	Forklift driver (n=6)	Chemical additioner (n=6)	Boyd press operator (n=3)	LAEIS press operator (n=6)	Controller (n=6)	Berry press operator (n=9)	Crusher operator (n=3)
Minimum	1.802	2.617	0.619	0.712	6.680	0.429	1.488	0.031	0.122	1.700	0.081	0.160
Average	4.339	3.664	4.981	5.575	10.251	3.969	5.085	0.435	0.669	3.858	1.197	0.390
Maximum	6.876	5.378	10.270	11.028	15.210	14.668	11.825	0.787	1.063	7.734	4.663	0.791

Figure 11: Personal respirable dust concentrations per occupation for refractory workers

Three occupations in the refractory industry indicated minimum, average and maximum exposures below the OEL for respirable dust. These were the Boyd press operator, LAEIS press operator and crusher operator. The berry press operator had an average exposure below the OEL (1.197 mg/m^3), but a maximum exposure of 4.663 mg/m^3. The chemical batcher, operator of the shuttle at the conveyor, packer, operator bagger, operator at the weigh larry, forklift driver, chemical additioner and controller all had maximum and average exposures of above 2 mg/m^3.



	Chemical batcher (n=2)	Operator shuttle conveyor (n=3)	Packer (n=4)	Operator bagger (n=6)	Operator weigh larry (n=3)	Forklift driver (n=6)	Chemical additioner (n=6)	Boyd press operator (n=3)	LAEIS press operator (n=6)	Controller (n=6)	Berry press operator (n=9)	Crusher operator (n=3)
Minimum	0.053	0.056	0.009	0.014	0.042	0.016	0.044	0.010	0.009	0.027	0.009	0.009
Average	0.164	0.100	0.102	0.171	0.153	0.077	0.144	0.020	0.026	0.102	0.012	0.009
Maximum	0.275	0.162	0.215	0.355	0.240	0.152	0.276	0.038	0.040	0.180	0.035	0.009

Figure 12: Personal respirable silica dust concentrations per occupation for refractory workers

Respirable silica dust exposures for the Boyd press operator, LAEIS press operator, berry press operator and crusher operator were all below the OEL. The operator of the shuttle at the conveyor had an average exposure of 0.1 mg/m^3, equal to the OEL and a maximum exposure that was above the OEL (0.162 mg/m^3). The packer and controller both had average exposures of 0.102 mg/m^3 and the maximum and average exposures of the chemical batcher, operator bagger, operator of the weigh larry and the chemical additioner were all above 0.1 mg/m^3. The operator bagger had the highest maximum exposure of 0.355 mg/m^3, more than three times the OEL for respirable silica dust.

Different processes were performed in the two refractory factory sections, resulting in the results indicating the exposures that can be expected at different stages and sections of the refractory industry. At the alumino-silicate section the operations performed mainly entail the mixing, weighing, measuring and bagging of dry materials, in contrast with the firebrick and sliding gate section where bricks are the final product and the mixing of dry products is only carried out in the initial stages of the process. The Boyd press operator, LAEIS press operator, control room operator, berry press operator and crusher operator were the occupations in the firebrick and sliding gate section and the chemical batcher, operator of the shuttle at the conveyor, packer, bagger operator, weigh larry operator and forklift operator were the occupations at the alumino-silicate section.

A clear difference can be seen in the results when comparing one section to the other. In the firebrick and sliding gate section only one occupation, the controller, was exposed to concentrations exceeding both the respirable dust and respirable silica dust OELs. The other occupations were well below both the limits, with the exception of the berry press operator, who had a maximum respirable dust exposure of above the OEL. The controller operates the crane and sand mixing equipment and his workstation is located above the general workstation. Observation revealed that the controller was the only worker that worked with dry materials, causing his excessive exposure. The results in the alumino-silicate section indicated that almost all the occupations had exposures above the OEL for both respirable dust and respirable silica dust, except the forklift operator whose exposure only exceeded the OEL for respirable dust. The exposures of the workers in the alumino-silicate section were mainly due to their handling of dry products for production purposes.

The results clearly indicate that different processes in one industry can have different exposures, depending on the process, phase and materials used.

4. Dust Audit Tool

4.1 Background

The silica dust audit tool was developed using national and international standards and guidelines governing occupational health and safety in South Africa. The majority of the questions were developed using these guidelines and some of the questions were modified or taken directly from the dust audit tool developed by the Mine Health and Safety Council (MHSC). The dust audit tool was developed to cater for six industries of the non-mining industries, i.e. foundries, sandstone, sandblasting, construction, ceramic/potteries and refractories. It is envisaged that this tool will be used to evaluate compliance with the relevant standards in non-mining industries. The standards are attached as Appendix A.

4.2 Dust audit protocol

The silica dust audit protocol was developed to facilitate the evaluation of the current status of silica dust management (compared against minimum legal and best practice requirements) utilised by the non-mining industries, Approved Inspection Authorities (AIAs) and the occupational hygiene and health practitioners.

4.3 Legal standards and guidelines identified

Approximately 16 national and international standards and guidelines relevant to dust exposures in non-mining industries were identified for inclusion in the silica dust audit tool. The DOL has developed a strategy called "Strategic Plan 2010-2015", in which it has committed the department to reducing 20% of employees' exposures to silica dust through establishing provincial silicosis working groups, running awareness-raising road shows on the dangers of silica dust, assisting companies to develop programmes that aim to control employees' exposure to silica dust, and conducting regular inspections to assess and enforce compliance.

4.4 Structure and content of the dust audit protocol

The dust audit protocol was structured mainly by grouping the 200 relevant issues into 11 main areas of concern, and these were sub-divided into indicator areas. The content of the dust audit protocol covers the policy/programme, risk assessment and monitoring, dust laboratory and silica analysis, instrumentation, transport, qualification, calculation, statistical analysis, sampling strategy, reporting and respiratory protective equipment. Table 7 summarises the structure and content of the dust audit protocol and questions are attached as Appendix C. These questions, however, were not piloted, although the modified questions and those that were directly taken from the MHSC had been piloted and found to be highly effective in measuring compliance with legal standards and best practices in the mining industry.

Development of a silica dust audit tool that will assist the DOL in its endeavour to eliminate silicosis requires a multi-disciplinary approach and teams. For this reason areas of concern are structured in this context. For proper and effective compliance evaluation of the silicosis elimination programme, the DOL needs to evaluate the AIAs who will be collecting samples, the industries, and the laboratories analysing the samples as to whether they meet the required national and international standards and guidelines.

Table 7: Overview of dust audit protocol structure and content

NO	AREA OF CONCERN	ISSUES COVERED	POTENTIAL SCORE
1	**Policy or programme**	Committee Compliance Policy/programme Access to documents Company details and registration Implementation Medical requirements Commitment to NPES	33
2	Risk assessment, monitoring, medical surveillance and control	Risk assessment Monitoring Medical surveillance Control measures	40
3	Instrumentation	Cyclones, pumps and train and cassettes with regard to quality control	21
4	Transport	Quality assurance during sample transportation	6
5	Qualification	Competency and qualifications of personnel	6
6	Calculation	Calculations	7
7	Statistical analysis	Analysis methodology	6
8	Sampling strategy	Sampling schedule Strategies used Discard procedures Sampling procedures	23
9	Reporting	Record keeping and access Internal and external reporting	10
10	PPE	Appropriate and approved RPE RPE training RPE zones	8
11	Dust lab and XRD analysis	Analytical procedures Calculations and calibrations Quantification of Quartz Direct-on Filter: Std Redeposition: Sample Preparation Quantification	40
	Total Score		**200**

5. Effective Dust Control Management

Best management practices are required for the effective and successful control of dust in any industry. Management should ensure that its industry or activities are designed, operated and maintained in an adequate manner in terms of occupational health and safety. Industries and their management should be able to prove beyond any reasonable doubts that they have put in place a planned systematic approach for the improvement of health and safety in their workplace.

A need exists for the establishment of a dust hazard prevention and control programme. Management should realise that to have the benefit of a healthier and happier workforce and a subsequent increase in productivity it should provide a health and safety programme with the necessary resources and administrative support. Dust control measures should be integrated into a comprehensive and well-managed prevention and control programme, rather than implemented in an *ad hoc* manner. The integrated hazard prevention and control programme requires good political will and decision making; commitment from top management; sufficient human and financial resources; required technical knowledge and experience; and competent management of the programme (WHO, 1999).

Management and implementation policy and tools should be developed to assist in the implementation of the dust hazard prevention and control programme. The system elements required include organisational responsibilities and line of communications; clear working procedures; evaluation programmes; monitoring programmes; internal standards; and internal processes.

For continuous improvement the dust control management strategy cannot be static but should be designed to meet the needs of the workplace in terms of changes in process, technology and socio-economics. It is important to assess the system to evaluate its relevance and whether it is still up to date.

Performance of the programme should be constantly monitored and evaluated to ensure efficiency and continuous improvement. Indicators that can be utilised to monitor the performance of the programme are workplace and health surveillance, based on data which is general, scientific and user relevant (WHO, 1999).

5.1 Methods of dust control

This study provided a snapshot survey, with limited applicability to other non-mining industries; for this reason, generic dust control methods are discussed here to offer guidelines as to what can be undertaken to control dust in non-mining industries in the absence of more specific strategies. It was not practical to develop a comprehensive dust prevention and control strategy which would represent all the non-mining industries in South Africa, considering that this snapshot study was undertaken in the Gauteng Province. Other factors such as the geographic area, types of companies representing non-mining industries, the diverse number of occupations in one non-mining industry, different types of processes and operations and non-classifications of these industries into large, medium and small non-mining industries (primary, secondary and tertiary non-mining industries) make it difficult to develop a comprehensive dust prevention and control strategy for all the non-mining industries.

The generic dust control measures are elimination, substitution, isolation/enclosure, dust suppression/wet methods, engineering control, administration, and respiratory protective equipment. These generic dust control measures are not applicable across all non-mining industries; for example, the wet method cannot be implemented in shot blasting because water will make the product rust quickly. The methods are described briefly below.

Elimination simply means changing technology or altering the process by completely removing hazardous substances and replacing them with non-hazardous substances, where workers will no longer be exposed to dust.

Substitution is applied when elimination is impossible; it involves substituting the hazardous substance with a less hazardous substance, for example using steel grit, glass beads and olivine sands instead of silica sands. Care must be taken not to substitute one problem with another problem.

Isolation involves enclosing the process into a cab or booth that is supplied with fresh, clean and filtered air. This will protect both workers and the general environment and workplace from the release of and exposure to harmful dust.

Mechanical Control:

a.) Local exhaust ventilation captures dust from the sources and removes it before it can spread throughout the workplace and reach the breathing zones of the workers.

b.) General ventilation refers to supply and exhaust of a large volume of air to a place with a number of scattered dust sources for diluting and displacing airborne particles.

Wet Method:

a.) Wet dust suppression system uses liquids (water) to wet materials so that they generate low dust volumes.

b.) Water sprays produce fine water droplets that capture fine dust and prevent it from spreading by forming agglomerates (NIOSH, 2010; WHO, 1999; Riala, 2002).

Administrative control involves good housekeeping and cleaning using a wet method or vacuum cleaners with high efficiency particulate air filters (HEPA). Rotating workers to reduce exposure time; restricting unauthorised personnel entry to these areas and jobs; properly selecting workers; and providing information, instructions and training regarding the silica dust health effects, prevention and control are involved in administrative control.

Respiratory Protective Equipment should be implemented as a last resort, according to the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993) as amended. RPE does not protect the work environment and the worker completely. These devices should be SABS approved and should be appropriate and recommended for controlling exposure to respirable crystalline silica dust (Mody & Jakhete, 1988; WHO, 1999; Riala, 2002).

6. Conclusions and Recommendations

Based on the findings of this limited study it can be concluded that there is a problem with regard to the silica dust exposures in the following non-mining industries in South Africa:

- Sandstone;
- Ceramics;
- Refractory; and
- Foundry.

These four industries are of particular concern and some exposures in these industries are alarmingly high. It is suggested that further research be conducted on the sandblasting and construction industries, where the results did not provide a reason for concern with regard to silica dust exposures. The reason further research is required is because the companies that were sampled for these two industries do not represent the industries as a whole and therefore this conclusion cannot be extrapolated to represent the exposures in all the sandblasting and construction industries in South Africa.

It should be kept in mind that because it focused on only six industries this study's results represent a portion of the non-mining industry in South Africa. Thus, this study's results cannot be extrapolated to all non-mining industries in South Africa and only reflect the findings from the companies sampled. Also, project constraints meant that certain occupations and phases within the industries sampled could not be included in the study. Other differences between the various industries which require further research include work practices, the occupational health and safety culture, and varying degrees of expertise on airborne dust.

It is strongly recommended that a more in-depth nationwide study (baseline) be conducted to determine the true extent of silica dust exposures in the non-mining industry in South Africa.

It is also recommended that a dust audit tool be developed for specific use in the non-mining industries, using the example of the Mine Health and Safety Dust Audit Tool (Appendix C) as a guideline.

7. Bibliography

CROTEAU, G.A., FLANAGAN, M.E., CAMP, J.E. AND SEIXAS, N.S. 2004. The Efficacy of Local Exhaust Ventilation for Controlling Dust Exposures during Concrete Surface Grinding. *Ann Occup Hyg 48(6):509 – 518*.

INTERNATIONAL LABOUR ORGANIZATION. 2002. Guidelines for the use of the ILO classification of Pneumoconiosis. Occupational Safety and Health Series No. 22. International Labour Office: Geneva. ISBN 92-2-110832-5. P 1-39.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. 2005. General requirements for the competence of testing and calibration laboratories. ISO/IEC 17025:2005.

MODY, V. AND JAKHETE, R. 1988. *Dust Control Handbook: Pollution Technology Review No. 161*. Noyes publication. ISBN 0-8155-1182-5. New Jersey. P 1-6.

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH). 2010. Best Practice for Dust Control in Coal Mining. Information Circular 9517. DHHS (NIOSH) Publication No. 2010 – 110. January 2010. Available online at www.cdc.gov/niosh. Accessed on 01 November 2010.

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH). 1977. Occupational Exposure Sampling Strategy Manual. NIOSH Publication No. 77-173: Available online at **http://www.cdc.gov/niosh/docs/77-173/**. Accessed on 20 May 2010.

RIALA, R. 2002. Good practices in controlling quartz exposure. In: Elgstrand, K. and Lundkvist, I. (eds.) 2002. *OSH & Development*. Published in cooperation with UFA, Sida, ICOH and NIWL. Chap 3. Available online: http://www.ufa.se/publikationer/OSHD4.html. Accessed on 6 October 2009.

WORLD HEALTH ORGANISATION (WHO). 1999. Prevention and Control Exchange (PACE) – Hazard Prevention and Control in the Work Environment: Airborne Dust. WHO Geneva WHO/SDE/OEH/99.14. P 74-128.

8. Appendices

Appendix A: Respirable dust and respirable silica dust results

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
24/08/2010	Foundry	Sand mixing operator	108670	2.200	405	0.891	2.215	2.487	2.098	0.307	0.345	0.291
25/08/2010	Foundry	Sand mixing operator	108684	2.185	439	0.959	1.514	1.579	1.444	0.286	0.298	0.273
26/08/2010	Foundry	Sand mixing operator	108692	2.169	470	1.019	4.758	4.669	4.571	0.689	0.676	0.662
01/09/2010	Foundry	Sand mixing operator	107586	2.257	493	1.113	1.220	1.096	1.126	0.224	0.201	0.207
31/08/2010	Foundry	Sand mixing operator	108625	2.226	519	1.155	0.167	0.145	0.157	0.034	0.030	0.032
31/08/2010	Foundry	Sand mixing operator	108630	2.229	512	1.141	1.643	1.440	1.536	0.244	0.214	0.228
31/08/2010	Foundry	Sand mixing operator	108701	2.223	485	1.078	0.638	0.592	0.598	0.084	0.078	0.079
01/09/2010	Foundry	Sand mixing operator	108703	2.235	476	1.064	0.422	0.396	0.393	0.042	0.040	0.039
01/09/2010	Foundry	Sand mixing operator	108704	2.234	478	1.068	1.234	1.156	1.151	0.088	0.082	0.082
02/09/2010	Foundry	Sand mixing operator	108708	2.211	486	1.074	2.120	1.973	1.998	0.303	0.282	0.286
02/09/2010	Foundry	Sand mixing operator	108710	2.212	483	1.068	1.422	1.331	1.339	0.082	0.077	0.077
02/09/2010	Foundry	Sand mixing operator	108714	2.214	510	1.129	1.114	0.987	1.048	0.233	0.206	0.219
24/08/2010	Foundry	Shake-out operator	108671	2.192	409	0.896	1.354	1.510	1.287	0.255	0.284	0.242
25/08/2010	Foundry	Shake-out operator	108686	2.198	446	0.980	2.342	2.390	2.220	0.340	0.347	0.322
26/08/2010	Foundry	Shake-out operator	108690	2.168	467	1.012	1.680	1.660	1.615	0.333	0.329	0.320
02/09/2010	Foundry	Shake-out operator	108707	2.197	486	1.068	1.273	1.192	1.207	0.094	0.088	0.089
24/08/2010	Foundry	Shot-blast operator	108672	2.228	920	2.049	0.498	0.243	0.466	0.132	0.064	0.123
25/08/2010	Foundry	Shot-blast operator	108681	2.208	438	0.967	1.770	1.830	1.670	0.287	0.297	0.271
26/08/2010	Foundry	Shot-blast operator	108695	2.178	471	1.026	0.304	0.297	0.291	0.058	0.057	0.056
01/09/2010	Foundry	Shot-blast operator	107581	2.238	483	1.081	0.957	0.885	0.891	0.119	0.110	0.111

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
01/09/2010	Foundry	Shot-blast operator	108706	2.225	479	1.066	1.176	1.103	1.101	0.203	0.190	0.190
02/09/2010	Foundry	Shot-blast operator	108713	2.227	501	1.115	0.740	0.664	0.693	0.118	0.106	0.110
02/09/2010	Foundry	Shot-blast operator	108716	2.233	492	1.099	0.777	0.707	0.725	0.180	0.164	0.168
31/08/2010	Foundry	Shot-blast operator	1088632	2.211	505	1.116	2.116	1.896	1.994	0.319	0.286	0.301
24/08/2010	Foundry	Furnace operator	108674	2.186	427	0.933	2.568	2.751	2.448	0.146	0.156	0.139
25/08/2010	Foundry	Furnace operator	108683	2.217	476	1.055	1.308	1.240	1.229	0.185	0.175	0.174
26/08/2010	Foundry	Furnace operator	108691	2.207	479	1.057	0.298	0.282	0.282	0.040	0.037	0.037
31/08/2010	Foundry	Furnace operator	108631	2.217	486	1.077	0.364	0.338	0.342	0.024	0.023	0.023
01/09/2010	Foundry	Furnace operator	108705	2.195	496	1.089	2.393	2.198	2.272	0.413	0.379	0.392
02/09/2010	Foundry	Furnace operator	108711	2.201	504	1.109	0.752	0.678	0.712	0.122	0.110	0.116
24/08/2010	Foundry	Casting operator	108675	2.188	422	0.923	1.740	1.884	1.656	0.234	0.253	0.223
25/08/2010	Foundry	Casting operator	108687	2.179	464	1.011	1.528	1.512	1.461	0.238	0.235	0.228
26/08/2010	Foundry	Casting operator	108679	2.192	475	1.041	1.027	0.987	0.976	0.113	0.109	0.107
24/08/2010	Foundry	Loco sand filler and remover	108676	2.202	451	0.993	0.134	0.135	0.127	0.013	0.013	0.012
24/08/2010	Foundry	Loco sand filler and remover	108677	2.204	452	0.996	0.189	0.190	0.179	0.014	0.014	0.013
24/08/2010	Foundry	Loco sand filler and remover	108678	2.192	463	1.015	0.312	0.308	0.297	0.086	0.085	0.082
25/08/2010	Foundry	Loco sand filler and remover	108673	2.216	477	1.057	0.136	0.128	0.127	0.024	0.023	0.023
25/08/2010	Foundry	Loco sand filler and remover	108680	2.188	472	1.033	0.061	0.059	0.058	0.012	0.012	0.012
25/08/2010	Foundry	Loco sand filler and remover	108682	2.174	476	1.035	0.233	0.225	0.224	0.018	0.017	0.017
26/08/2010	Foundry	Loco sand filler and remover	108688	2.187	492	1.076	0.301	0.280	0.287	0.029	0.027	0.028
26/08/2010	Foundry	Loco sand filler and remover	108693	2.202	499	1.099	0.181	0.165	0.171	0.011	0.010	0.010
24/08/2010	Foundry	Moulder	108669	2.191	428	0.938	2.244	2.393	2.134	0.391	0.417	0.372
26/08/2010	Foundry	Moulder	108689	2.218	464	1.029	1.615	1.569	1.517	0.177	0.172	0.166
01/09/2010	Foundry	Moulder	107585	2.236	503	1.125	0.384	0.341	0.358	0.083	0.074	0.077
02/09/2010	Foundry	Moulder	108712	2.230	506	1.128	1.787	1.584	1.670	0.501	0.444	0.468
01/09/2010	Foundry	Grinder	107583	2.183	496	1.083	9.738	8.994	9.294	0.201	0.186	0.192

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
31/08/2010	Foundry	Grinder	108626	2.170	512	1.111	6.419	5.777	6.163	0.322	0.290	0.309
31/08/2010	Foundry	Grinder	108628	2.228	516	1.149	2.707	2.355	2.532	0.243	0.211	0.227
31/08/2010	Foundry	Grinder	108709	2.223	436	0.969	0.713	0.735	0.668	0.128	0.132	0.120
31/08/2010	Foundry	Closer	107582	2.252	492	1.108	2.782	2.511	2.573	0.282	0.255	0.261
31/08/2010	Foundry	Closer	107587	2.225	479	1.066	3.219	3.021	3.014	0.246	0.231	0.230
31/08/2010	Foundry	Closer	108627	2.245	515	1.156	0.112	0.097	0.104	0.054	0.046	0.050
31/08/2010	Foundry	Closer	108629	2.221	511	1.135	1.603	1.413	1.504	0.140	0.123	0.131
02/09/2010	Foundry	Closer	108715	2.227	504	1.122	0.843	0.752	0.789	0.197	0.176	0.184
20/07/2010	Sandstone	Stone carver	107466	2.188	517	1.131	7.924	7.007	7.547	4.245	3.754	4.043
20/07/2010	Sandstone	Stone carver	107467	2.208	516	1.139	27.635	24.261	26.080	6.116	5.369	5.772
21/07/2010	Sandstone	Stone carver	107489	2.209	535	1.182	3.625	3.067	3.419	2.981	2.522	2.811
21/07/2010	Sandstone	Stone carver	107490	2.205	533	1.175	4.407	3.750	4.164	2.650	2.255	2.504
22/07/2010	Sandstone	Stone carver	107533	2.183	530	1.157	8.921	7.712	8.515	2.448	2.116	2.337
22/07/2010	Sandstone	Stone carver	107539	2.191	527	1.154	7.821	6.775	7.438	4.586	3.973	4.362
14/07/2010	Sandstone	Stone mason	107503	2.230	564	1.258	0.694	0.552	0.648	0.108	0.086	0.101
15/07/2010	Sandstone	Stone mason	107518	2.231	566	1.262	0.506	0.401	0.473	0.075	0.059	0.070
16/07/2010	Sandstone	Stone mason	107528	2.231	510	1.138	0.627	0.551	0.585	0.121	0.106	0.113
20/07/2010	Sandstone	Saw operator	107468	2.208	513	1.133	1.176	1.038	1.109	0.893	0.788	0.843
20/07/2010	Sandstone	Saw operator	107470	2.187	512	1.120	9.726	8.686	9.265	3.787	3.382	3.607
20/07/2010	Sandstone	Saw operator	107474	2.198	514	1.130	1.908	1.689	1.809	0.988	0.875	0.937
21/07/2010	Sandstone	Saw operator	107485	2.214	537	1.189	0.697	0.586	0.655	0.234	0.197	0.220
21/07/2010	Sandstone	Saw operator	107486	2.232	542	1.209	0.107	0.088	0.100	0.025	0.021	0.024
21/07/2010	Sandstone	Saw operator	107493	2.198	524	1.151	3.130	2.718	2.967	1.511	1.312	1.432
22/07/2010	Sandstone	Saw operator	107531	2.210	528	1.167	0.444	0.381	0.419	0.192	0.165	0.181
22/07/2010	Sandstone	Saw operator	107532	2.212	534	1.181	1.353	1.146	1.275	0.740	0.626	0.697
22/07/2010	Sandstone	Saw operator	107536	2.206	535	1.180	0.771	0.654	0.729	0.215	0.182	0.203

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
14/07/2010	Sandstone	Saw operator	107505	2.224	560	1.245	0.500	0.401	0.468	0.054	0.043	0.050
14/07/2010	Sandstone	Saw operator	107506	2.208	575	1.270	0.531	0.418	0.501	0.072	0.057	0.068
14/07/2010	Sandstone	Saw operator	107508	2.220	562	1.248	0.534	0.428	0.501	0.061	0.049	0.057
15/07/2010	Sandstone	Saw operator	107511	2.208	563	1.243	0.420	0.338	0.396	0.058	0.046	0.054
15/07/2010	Sandstone	Saw operator	107515	2.223	555	1.233	0.613	0.497	0.574	0.035	0.028	0.033
15/07/2010	Sandstone	Saw operator	107516	2.226	554	1.233	0.530	0.430	0.496	0.091	0.074	0.085
16/07/2010	Sandstone	Saw operator	107521	2.218	511	1.133	0.460	0.406	0.432	0.063	0.055	0.059
16/07/2010	Sandstone	Saw operator	107525	2.215	490	1.085	0.284	0.261	0.267	0.033	0.030	0.031
16/07/2010	Sandstone	Saw operator	107526	2.206	511	1.127	0.658	0.584	0.621	0.093	0.082	0.087
20/07/2010	Sandstone	General labourer	107469	2.176	517	1.125	0.115	0.102	0.110	0.024	0.022	0.023
21/07/2010	Sandstone	General labourer	107494	2.211	392	0.867	0.568	0.656	0.536	0.275	0.317	0.259
22/07/2010	Sandstone	General labourer	107537	2.176	542	1.179	1.274	1.080	1.219	0.485	0.411	0.464
14/07/2010	Sandstone	General labourer	107509	2.199	575	1.264	0.609	0.482	0.577	0.113	0.089	0.107
15/07/2010	Sandstone	General labourer	107519	2.220	567	1.259	0.387	0.308	0.363	0.041	0.032	0.038
16/07/2010	Sandstone	General labourer	107529	2.237	506	1.132	0.230	0.203	0.214	0.070	0.062	0.065
20/07/2010	Sandstone	Polisher	107480	2.199	475	1.045	0.800	0.765	0.757	0.452	0.433	0.428
20/07/2010	Sandstone	Polisher	107484	2.165	515	1.115	1.474	1.322	1.419	0.764	0.685	0.735
21/07/2010	Sandstone	Polisher	107488	2.210	541	1.195	0.171	0.143	0.161	0.082	0.069	0.077
21/07/2010	Sandstone	Polisher	107492	2.160	527	1.138	3.906	3.432	3.768	0.329	0.289	0.317
22/07/2010	Sandstone	Polisher	107534	2.215	534	1.183	1.208	1.021	1.136	0.325	0.275	0.306
22/07/2010	Sandstone	Polisher	107535	2.213	532	1.177	0.541	0.459	0.509	0.110	0.093	0.104
14/07/2010	Sandstone	Tractor operator	107501	2.170	591	1.282	0.355	0.277	0.341	0.056	0.043	0.053
15/07/2010	Sandstone	Tractor operator	107512	2.202	562	1.238	0.324	0.262	0.307	0.070	0.056	0.066
16/07/2010	Sandstone	Tractor operator	107522	2.203	516	1.137	0.190	0.167	0.179	0.033	0.029	0.031
14/07/2010	Sandstone	Forklift operator	107502	2.211	570	1.260	1.005	0.798	0.947	0.111	0.088	0.105
16/07/2010	Sandstone	Forklift operator	107520	2.222	567	1.260	0.629	0.500	0.590	0.088	0.070	0.082

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
14/07/2020	Sandstone	Forklift operator	107530	2.227	512	1.140	1.050	0.921	0.982	0.218	0.191	0.204
14/07/2010	Sandstone	Packer	107504	2.220	560	1.243	0.614	0.494	0.576	0.122	0.098	0.115
15/07/2010	Sandstone	Packer	107514	2.230	562	1.253	0.624	0.498	0.583	0.204	0.163	0.191
16/07/2010	Sandstone	Packer	107524	2.240	513	1.149	0.355	0.309	0.331	0.066	0.057	0.061
14/07/2010	Sandstone	Technician	107507	2.194	592	1.299	0.386	0.297	0.367	0.021	0.016	0.020
15/07/2010	Sandstone	Technician	107517	2.205	541	1.193	0.438	0.367	0.414	0.045	0.038	0.043
16/07/2010	Sandstone	Technician	107527	2.216	510	1.130	0.263	0.233	0.247	0.049	0.043	0.046
15/07/2010	Sandstone	Plant Manager	107510	2.166	554	1.200	0.353	0.294	0.340	0.058	0.048	0.056
15/07/2010	Sandstone	Plant Manager	107513	2.174	564	1.226	0.948	0.773	0.909	0.370	0.302	0.355
16/07/2010	Sandstone	Plant Manager	107523	2.208	508	1.122	0.924	0.824	0.872	0.304	0.271	0.287
11/08/2010	Sandblasting	General labourer	104152	2.197	486	1.068	1.992	1.865	1.888	0.039	0.037	0.037
12/08/2010	Sandblasting	General labourer	10623	2.219	498	1.105	0.553	0.500	0.519	0.011	0.010	0.010
16/08/2010	Sandblasting	General labourer	10630	2.214	483	1.069	0.467	0.437	0.439	0.010	0.009	0.009
17/08/2010	Sandblasting	General labourer	10629	2.210	501	1.107	0.454	0.410	0.428	0.011	0.010	0.011
10/08/2010	Sandblasting	General labourer	108608	2.211	443	0.979	1.454	1.485	1.371	0.023	0.024	0.022
11/08/2010	Sandblasting	Pots worker	104153	2.176	487	1.060	2.192	2.069	2.099	0.032	0.030	0.030
12/08/2010	Sandblasting	Pots worker	10622	2.197	495	1.087	0.781	0.718	0.741	0.010	0.009	0.009
16/08/2010	Sandblasting	Pots worker	10624	2.196	484	1.063	0.153	0.144	0.145	0.010	0.009	0.009
17/08/2010	Sandblasting	Pots worker	10631	2.211	499	1.103	0.426	0.386	0.401	0.024	0.021	0.022
11/08/2010	Sandblasting	Blaster	104186	2.228	488	1.087	0.985	0.906	0.921	0.013	0.011	0.012
11/08/2010	Sandblasting	Blaster	10609	2.224	489	1.087	0.552	0.508	0.517	0.010	0.009	0.009
12/08/2010	Sandblasting	Blaster	10620	2.212	496	1.097	0.585	0.533	0.551	0.010	0.009	0.009
12/08/2010	Sandblasting	Blaster	10621	2.241	497	1.114	0.468	0.420	0.435	0.013	0.012	0.012
16/08/2010	Sandblasting	Blaster	10625	2.189	482	1.055	0.493	0.467	0.469	0.023	0.022	0.022
16/08/2010	Sandblasting	Blaster	10626	2.203	481	1.059	0.558	0.526	0.527	0.010	0.009	0.009
17/08/2010	Sandblasting	Blaster	10628	2.225	500	1.112	1.349	1.213	1.264	0.027	0.024	0.025

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
10/08/2010	Sandblasting	Blaster	108636	2.157	509	1.098	2.795	2.547	2.701	0.054	0.049	0.052
10/08/2010	Sandblasting	Blaster	108603	2.183	518	1.131	0.872	0.772	0.833	0.010	0.009	0.010
10/08/2010	Sandblasting	Blaster	108602	2.204	500	1.102	0.693	0.629	0.655	0.023	0.021	0.022
10/08/2010	Sandblasting	Blaster	108606	2.203	503	1.108	6.694	6.042	6.332	0.066	0.060	0.063
11/08/2010	Sandblasting	Blaster	108610	2.237	483	1.080	4.931	4.565	4.594	0.010	0.009	0.009
11/08/2010	Sandblasting	Blaster	108616	2.240	493	1.104	0.138	0.125	0.128	0.013	0.012	0.013
11/08/2010	Sandblasting	Blaster	108609	2.211	480	1.061	3.828	3.608	3.608	0.048	0.046	0.046
11/08/2010	Sandblasting	Blaster	108611	2.242	479	1.074	0.195	0.181	0.181	0.010	0.009	0.009
12/08/2010	Sandblasting	Blaster	108620	2.216	541	1.199	10.325	8.614	9.709	0.034	0.029	0.032
12/08/2010	Sandblasting	Blaster	108617	2.241	539	1.208	0.401	0.332	0.373	0.010	0.008	0.009
12/08/2010	Sandblasting	Blaster	108622	2.204	545	1.201	11.463	9.543	10.835	0.126	0.105	0.119
12/08/2010	Sandblasting	Blaster	108618	2.250	497	1.118	1.716	1.534	1.589	0.028	0.025	0.026
10/08/2010	Sandblasting	Painter	108633	2.166	412	0.892	0.453	0.507	0.435	0.031	0.035	0.030
10/08/2010	Sandblasting	Painter	108605	2.194	458	1.005	1.092	1.087	1.037	0.047	0.047	0.045
11/08/2010	Sandblasting	Assistant painter	108612	2.230	516	1.151	0.568	0.493	0.530	0.013	0.011	0.012
12/08/2010	Sandblasting	Assistant painter	108624	2.212	508	1.123	0.436	0.388	0.410	0.010	0.009	0.009
10/08/2010	Sandblasting	Forklift driver	108604	2.193	472	1.035	0.228	0.220	0.216	0.016	0.015	0.015
11/08/2010	Sandblasting	Forklift driver	108613	2.215	487	1.078	0.380	0.352	0.357	0.010	0.009	0.009
12/08/2010	Sandblasting	Forklift driver	108619	2.185	550	1.201	1.066	0.887	1.017	0.037	0.030	0.035
10/08/2010	Sandblasting	Supervisor	108635	2.188	500	1.094	0.063	0.058	0.060	0.010	0.009	0.010
11/08/2010	Sandblasting	Supervisor	108614	2.218	540	1.197	0.140	0.117	0.132	0.010	0.008	0.009
12/08/2010	Sandblasting	Supervisor	108621	2.222	501	1.113	0.138	0.124	0.129	0.010	0.009	0.009
10/08/2010	Sandblasting	Maintenance officer	108607	2.199	364	0.800	0.077	0.096	0.073	0.010	0.012	0.009
11/08/2010	Sandblasting	Maintenance officer	108615	2.231	496	1.107	0.306	0.276	0.286	0.021	0.019	0.020
12/08/2010	Sandblasting	Maintenance officer	108623	2.194	505	1.108	1.434	1.295	1.362	0.038	0.035	0.036
06/07/2010	Construction	General labourer	107180	2.203	496	1.092	0.069	0.063	0.065	0.010	0.009	0.009

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
06/07/2010	Construction	General labourer	107181	2.210	514	1.136	0.017	0.015	0.017	0.010	0.009	0.009
06/07/2010	Construction	General labourer	107186	2.201	518	1.140	0.075	0.066	0.071	0.010	0.009	0.009
06/07/2010	Construction	General labourer	107197	2.202	501	1.103	0.011	0.010	0.010	0.010	0.009	0.009
07/07/2010	Construction	General labourer	107146	2.218	506	1.122	0.061	0.055	0.058	0.010	0.009	0.009
07/07/2010	Construction	General labourer	107155	2.221	508	1.128	0.074	0.066	0.069	0.013	0.012	0.012
07/07/2010	Construction	General labourer	107160	2.220	490	1.088	0.026	0.024	0.025	0.010	0.009	0.009
07/07/2010	Construction	General labourer	107162	2.208	494	1.091	0.103	0.095	0.098	0.010	0.009	0.009
08/07/2010	Construction	General labourer	107167	2.212	504	1.115	0.084	0.075	0.079	0.010	0.009	0.009
08/07/2010	Construction	General labourer	107169	2.205	502	1.107	0.065	0.059	0.062	0.010	0.009	0.009
08/07/2010	Construction	General labourer	107487	2.204	392	0.864	0.077	0.089	0.073	0.010	0.012	0.009
07/07/2010	Construction	General labourer	107148	2.214	535	1.184	0.035	0.029	0.033	0.011	0.010	0.011
06/07/2010	Construction	General labourer	107182	2.191	455	0.997	0.035	0.035	0.033	0.011	0.011	0.010
08/07/2010	Construction	General labourer	107476	2.209	528	1.166	0.353	0.303	0.333	0.065	0.056	0.062
07/07/2010	Construction	Bobcat operator	107159	2.212	499	1.104	0.247	0.224	0.233	0.019	0.017	0.018
08/07/2010	Construction	Bobcat operator	107477	2.237	500	1.119	0.350	0.313	0.326	0.032	0.029	0.030
06/07/2010	Construction	Concrete hand	107188	2.211	508	1.123	0.064	0.057	0.061	0.010	0.009	0.009
06/07/2010	Construction	Concrete hand	107194	2.212	512	1.133	0.172	0.152	0.162	0.015	0.014	0.014
07/07/2010	Construction	Concrete hand	107150	2.242	500	1.121	0.049	0.044	0.046	0.010	0.009	0.009
07/07/2010	Construction	Concrete hand	107170	2.223	505	1.123	0.041	0.037	0.039	0.010	0.009	0.009
08/07/2010	Construction	Concrete hand	107171	2.218	504	1.118	0.150	0.135	0.141	0.021	0.019	0.020
08/07/2010	Construction	Concrete hand	107177	2.206	505	1.114	0.093	0.083	0.088	0.010	0.009	0.009
07/07/2010	Construction	Concrete hand	107147	2.219	560	1.243	0.203	0.164	0.191	0.041	0.033	0.038
07/07/2010	Construction	Concrete hand	107164	2.202	523	1.151	0.304	0.264	0.288	0.032	0.028	0.031
06/07/2010	Construction	Concrete hand	107190	2.207	444	0.980	0.116	0.119	0.110	0.051	0.052	0.048
06/07/2010	Construction	Concrete hand	107192	2.203	450	0.991	0.071	0.072	0.067	0.010	0.010	0.009
06/07/2010	Construction	Concrete hand	107196	2.213	445	0.985	0.058	0.059	0.054	0.010	0.010	0.009

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
08/07/2010	Construction	Concrete hand	107471	2.188	554	1.212	0.225	0.186	0.215	0.023	0.019	0.022
08/07/2010	Construction	Concrete hand	107473	2.235	555	1.240	0.448	0.361	0.418	0.046	0.037	0.043
08/07/2010	Construction	Concrete hand	107475	2.198	583	1.281	0.179	0.139	0.169	0.014	0.011	0.013
06/07/2010	Construction	Carpenter	107189	2.217	519	1.150	0.068	0.059	0.064	0.010	0.009	0.009
07/07/2010	Construction	Carpenter	107166	2.206	503	1.110	0.251	0.227	0.237	0.021	0.019	0.020
08/07/2010	Construction	Carpenter	107176	2.218	504	1.118	0.070	0.063	0.066	0.010	0.009	0.009
07/07/2010	Construction	Carpenter	107149	2.212	524	1.159	0.054	0.046	0.050	0.024	0.021	0.023
07/07/2010	Construction	Carpenter	107156	2.206	535	1.180	0.517	0.438	0.488	0.048	0.041	0.046
08/07/2010	Construction	Carpenter	107174	2.206	520	1.147	0.062	0.054	0.058	0.014	0.012	0.013
06/07/2010	Construction	Carpenter	107179	2.210	454	1.003	0.359	0.358	0.338	0.010	0.010	0.009
06/07/2010	Construction	Carpenter	107193	2.202	462	1.017	0.048	0.047	0.046	0.010	0.010	0.009
08/07/2010	Construction	Carpenter	107478	2.181	571	1.245	0.059	0.047	0.056	0.032	0.026	0.030
07/07/2010	Construction	Safety officer	107165	2.229	504	1.123	0.166	0.148	0.155	0.016	0.014	0.015
08/07/2010	Construction	Safety officer	107168	2.197	502	1.103	0.030	0.027	0.028	0.014	0.013	0.014
07/07/2010	Construction	Steel fixer	107152	2.212	547	1.210	0.179	0.148	0.169	0.012	0.010	0.011
06/07/2010	Construction	Steel fixer	107154	2.216	439	0.973	0.017	0.018	0.016	0.010	0.010	0.009
06/07/2010	Construction	Steel fixer	107187	2.211	442	0.977	0.098	0.101	0.093	0.011	0.011	0.010
08/07/2010	Construction	Steel fixer	107465	2.215	544	1.205	0.261	0.217	0.246	0.044	0.036	0.041
08/07/2010	Construction	Steel fixer	107481	2.233	551	1.230	0.200	0.163	0.187	0.022	0.018	0.021
08/07/2010	Construction	Shutter hand	107158	2.164	552	1.195	0.106	0.089	0.102	0.010	0.008	0.010
07/07/2010	Construction	Shutter hand	107163	2.201	520	1.145	0.092	0.081	0.088	0.022	0.019	0.021
06/07/2010	Construction	Shutter hand	107185	2.218	449	0.996	0.032	0.033	0.031	0.010	0.010	0.009
27/07/2010	Ceramics	General labourer	104175	2.187	486	1.063	0.323	0.304	0.308	0.027	0.025	0.025
28/07/2010	Ceramics	General labourer	104166	2.172	470	1.021	0.191	0.187	0.183	0.016	0.016	0.016
29/07/2010	Ceramics	General labourer	104161	2.183	498	1.087	0.235	0.216	0.224	0.010	0.009	0.010
31/08/2010	Ceramics	General labourer	108723	2.229	453	1.010	1.053	1.043	0.984	0.126	0.125	0.118

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
01/09/2010	Ceramics	General labourer	108731	2.251	455	1.024	0.115	0.113	0.107	0.061	0.059	0.056
02/09/2010	Ceramics	General labourer	108739	2.227	435	0.969	1.242	1.282	1.161	0.105	0.108	0.098
27/07/2010	Ceramics	Clay worker	104174	2.208	480	1.060	0.400	0.377	0.377	0.057	0.054	0.054
27/07/2010	Ceramics	Clay worker	104172	2.226	477	1.062	3.603	3.393	3.372	0.192	0.181	0.180
28/07/2010	Ceramics	Clay worker	104171	2.192	491	1.076	3.493	3.245	3.320	0.694	0.645	0.660
28/07/2010	Ceramics	Clay worker	104163	2.218	492	1.091	0.750	0.688	0.705	0.115	0.105	0.108
29/07/2010	Ceramics	Clay worker	104160	2.217	498	1.104	0.579	0.525	0.544	0.124	0.112	0.117
29/07/2010	Ceramics	Clay worker	104157	2.226	508	1.131	5.117	4.525	4.789	0.847	0.749	0.793
31/08/2010	Ceramics	Clay worker	108720	2.208	457	1.009	1.851	1.835	1.747	0.673	0.667	0.635
31/08/2010	Ceramics	Clay worker	108721	2.203	460	1.013	4.828	4.764	4.566	0.512	0.505	0.484
01/09/2010	Ceramics	Clay worker	108728	2.234	457	1.021	2.264	2.217	2.111	0.979	0.959	0.913
01/09/2010	Ceramics	Clay worker	108729	2.256	459	1.036	1.825	1.763	1.686	0.194	0.187	0.179
02/09/2010	Ceramics	Clay worker	108736	2.231	442	0.986	1.493	1.514	1.394	0.564	0.572	0.527
02/09/2010	Ceramics	Clay worker	108737	2.233	441	0.985	1.667	1.693	1.556	0.273	0.277	0.255
27/07/2010	Ceramics	Casting worker	104176	2.194	293	0.643	0.209	0.326	0.199	0.014	0.022	0.013
28/07/2010	Ceramics	Casting worker	104164	2.186	443	0.968	0.272	0.281	0.259	0.069	0.071	0.066
29/07/2010	Ceramics	Casting worker	104156	2.232	502	1.120	1.488	1.328	1.389	0.513	0.458	0.479
27/07/2010	Ceramics	Glaze worker	104173	2.184	486	1.061	0.461	0.435	0.440	0.036	0.034	0.034
28/07/2010	Ceramics	Glaze worker	104170	2.193	498	1.092	0.581	0.532	0.552	0.081	0.074	0.077
29/07/2010	Ceramics	Glaze worker	104162	2.218	496	1.100	0.362	0.329	0.340	0.103	0.094	0.097
31/08/2010	Ceramics	Glaze worker	108718	2.199	459	1.009	1.111	1.101	1.053	0.087	0.087	0.083
31/08/2010	Ceramics	Glaze worker	108719	2.205	458	1.010	0.742	0.735	0.701	0.020	0.020	0.019
31/08/2010	Ceramics	Glaze worker	108722	2.216	456	1.010	1.285	1.272	1.208	0.066	0.065	0.062
01/09/2010	Ceramics	Glaze worker	108725	2.193	464	1.018	0.727	0.714	0.691	0.089	0.087	0.084
01/09/2010	Ceramics	Glaze worker	108727	2.214	462	1.023	3.387	3.312	3.188	1.608	1.572	1.513
01/09/2010	Ceramics	Glaze worker	108730	2.233	463	1.034	1.648	1.594	1.537	1.060	1.025	0.989

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
02/09/2010	Ceramics	Glaze worker	108734	2.233	422	0.942	0.436	0.463	0.407	0.045	0.047	0.042
02/09/2010	Ceramics	Glaze worker	108735	2.215	433	0.959	2.769	2.887	2.604	0.010	0.010	0.009
02/09/2010	Ceramics	Glaze worker	108738	2.231	441	0.984	0.300	0.305	0.280	0.032	0.032	0.030
27/07/2010	Ceramics	Supervisor	104180	2.210	486	1.074	0.109	0.102	0.103	0.010	0.009	0.009
28/07/2010	Ceramics	Supervisor	104167	2.220	459	1.019	0.237	0.233	0.223	0.013	0.013	0.012
29/07/2010	Ceramics	Supervisor	104158	2.199	497	1.093	1.026	0.939	0.972	0.221	0.202	0.209
31/08/2010	Ceramics	Supervisor	108726	2.224	452	1.005	0.787	0.782	0.737	0.112	0.111	0.105
01/09/2010	Ceramics	Supervisor	108733	2.230	458	1.021	0.728	0.713	0.680	0.108	0.106	0.101
02/09/2010	Ceramics	Supervisor	108741	2.235	437	0.977	1.005	1.029	0.937	0.162	0.166	0.151
27/07/2010	Ceramics	Mould worker	104177	2.198	486	1.068	0.373	0.349	0.353	0.060	0.056	0.057
28/07/2010	Ceramics	Mould worker	104169	2.190	493	1.080	0.615	0.569	0.585	0.142	0.132	0.135
29/07/2010	Ceramics	Mould worker	104159	2.254	441	0.994	0.900	0.905	0.832	0.217	0.218	0.201
27/07/2010	Ceramics	Dispatch clerk	104178	2.211	483	1.068	0.205	0.192	0.193	0.010	0.009	0.009
28/07/2010	Ceramics	Dispatch clerk	104168	2.179	472	1.028	0.716	0.696	0.685	0.019	0.019	0.018
29/07/2010	Ceramics	Dispatch clerk	104144	2.224	490	1.090	11.382	10.447	10.664	3.095	2.841	2.900
31/08/2010	Ceramics	Dispatch clerk	108724	2.189	455	0.996	2.246	2.255	2.138	0.190	0.191	0.181
01/09/2010	Ceramics	Dispatch clerk	108732	2.202	461	1.015	1.812	1.785	1.714	0.249	0.245	0.236
02/09/2010	Ceramics	Dispatch clerk	108740	2.208	437	0.965	0.982	1.018	0.927	0.202	0.209	0.191
27/07/2010	Ceramics	Forklift operator	104179	2.173	488	1.060	0.753	0.710	0.722	0.150	0.141	0.144
28/07/2010	Ceramics	Forklift operator	104165	2.188	490	1.072	0.880	0.821	0.838	0.135	0.126	0.129
29/07/2010	Ceramics	Forklift operator	104155	2.226	504	1.122	0.342	0.305	0.320	0.089	0.079	0.083
27/07/2010	Refractory	Chemical batcher	107540	2.229	553	1.232	1.928	1.564	1.802	0.057	0.046	0.053
28/07/2010	Refractory	Chemical batcher	107551	2.232	553	1.234	7.367	5.969	6.876	0.295	0.239	0.275
27/07/2010	Refractory	Operator shuttle conveyor	107541	2.235	390	0.871	3.213	3.687	2.996	0.174	0.200	0.162
28/07/2010	Refractory	Operator shuttle conveyor	107556	2.247	390	0.876	2.822	3.221	2.617	0.090	0.102	0.083
29/07/2010	Refractory	Operator shuttle conveyor	107561	2.236	394	0.881	5.771	6.552	5.378	0.060	0.068	0.056

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
27/07/2010	Refractory	Packer	107542	2.202	562	1.237	0.654	0.529	0.619	0.020	0.016	0.019
28/07/2010	Refractory	Packer	107550	2.225	557	1.239	0.773	0.623	0.724	0.010	0.008	0.009
29/07/2010	Refractory	Packer	107560	2.212	574	1.270	10.904	8.588	10.270	0.228	0.180	0.215
29/07/2010	Refractory	Packer	107568	2.214	554	1.227	8.831	7.200	8.310	0.176	0.143	0.166
27/07/2010	Refractory	Operator bagger	107543	2.240	545	1.221	5.823	4.771	5.417	0.187	0.153	0.174
27/07/2010	Refractory	Operator bagger	107549	2.211	545	1.205	0.756	0.627	0.712	0.015	0.012	0.014
28/07/2010	Refractory	Operator bagger	107555	2.215	545	1.207	4.877	4.041	4.588	0.171	0.142	0.161
28/07/2010	Refractory	Operator bagger	107557	2.228	551	1.228	4.690	3.820	4.386	0.117	0.095	0.109
29/07/2010	Refractory	Operator bagger	107562	2.267	567	1.285	7.962	6.195	7.318	0.229	0.178	0.210
29/07/2010	Refractory	Operator bagger	107563	2.215	383	0.848	11.725	13.821	11.028	0.377	0.444	0.355
27/07/2010	Refractory	Operator weigh larry	107544	2.202	555	1.222	16.077	13.155	15.210	0.185	0.151	0.175
28/07/2010	Refractory	Operator weigh larry	107558	2.233	551	1.230	9.498	7.720	8.861	0.045	0.037	0.042
29/07/2010	Refractory	Operator weigh larry	107565	2.235	557	1.245	7.166	5.757	6.680	0.258	0.207	0.240
27/07/2010	Refractory	Forklift driver	107545	2.247	382	0.858	0.463	0.539	0.429	0.028	0.033	0.026
27/07/2010	Refractory	Forklift driver	107547	2.178	538	1.171	4.516	3.855	4.321	0.075	0.064	0.072
28/07/2010	Refractory	Forklift driver	107553	2.236	545	1.219	1.308	1.074	1.219	0.017	0.014	0.016
28/07/2010	Refractory	Forklift driver	107559	2.239	392	0.877	2.071	2.360	1.928	0.131	0.149	0.122
29/07/2010	Refractory	Forklift driver	107564	2.225	403	0.897	1.335	1.489	1.250	0.081	0.090	0.076
29/07/2010	Refractory	Forklift driver	107567	2.241	545	1.221	15.775	12.919	14.668	0.164	0.134	0.152
27/07/2010	Refractory	Chemical additioner	107546	2.197	541	1.189	1.569	1.320	1.488	0.046	0.039	0.044
27/07/2010	Refractory	Chemical additioner	107548	2.234	532	1.188	2.161	1.818	2.015	0.250	0.210	0.233
28/07/2010	Refractory	Chemical additioner	107552	2.224	555	1.234	7.111	5.762	6.663	0.126	0.102	0.118
28/07/2010	Refractory	Chemical additioner	107554	2.217	540	1.197	2.938	2.454	2.761	0.062	0.052	0.058
29/07/2010	Refractory	Chemical additioner	107566	2.213	560	1.239	12.559	10.136	11.825	0.293	0.236	0.276
29/07/2010	Refractory	Chemical additioner	107569	2.202	268	0.590	6.086	10.312	5.758	0.141	0.239	0.133
16/08/2010	Refractory	Boyd press operator	108637	2.226	701	1.560	0.841	0.539	0.787	0.040	0.026	0.038

Date	Commodity	Occupation	Filter	Avg flow	Run time (min)	Volume (m3)	Dust (mg)	Dust (mg/m^3)	Dust TWA (mg/m^3)	Quartz (mg)	Quartz (mg/m^3)	Quartz TWA (mg/m^3)
17/08/2010	Refractory	Boyd press operator	108647	2.202	656	1.444	0.515	0.356	0.487	0.013	0.009	0.012
18/08/2010	Refractory	Boyd press operator	108657	2.193	602	1.320	0.032	0.024	0.031	0.010	0.008	0.010
16/08/2010	Refractory	LAEIS press operator	108638	2.217	705	1.563	0.611	0.391	0.575	0.029	0.018	0.027
17/08/2010	Refractory	LAEIS press operator	108643	2.224	515	1.145	1.135	0.991	1.063	0.043	0.038	0.040
17/08/2010	Refractory	LAEIS press operator	108648	2.223	659	1.465	0.568	0.388	0.533	0.021	0.014	0.019
18/08/2010	Refractory	LAEIS press operator	108653	2.219	583	1.293	0.839	0.649	0.788	0.037	0.028	0.034
18/08/2010	Refractory	LAEIS press operator	108658	2.221	604	1.341	0.130	0.097	0.122	0.010	0.007	0.009
19/08/2010	Refractory	LAEIS press operator	108663	2.234	532	1.188	1.004	0.845	0.936	0.026	0.022	0.024
16/08/2010	Refractory	Control room operator	108639	2.209	692	1.529	1.803	1.179	1.700	0.038	0.025	0.036
17/08/2010	Refractory	Control room operator	108644	2.190	533	1.167	8.130	6.965	7.734	0.189	0.162	0.180
17/08/2010	Refractory	Control room operator	108649	2.199	658	1.447	2.305	1.594	2.185	0.135	0.093	0.128
18/08/2010	Refractory	Control room operator	108654	2.210	585	1.293	2.459	1.902	2.319	0.028	0.022	0.027
18/08/2010	Refractory	Control room operator	108659	2.197	594	1.305	6.920	5.304	6.564	0.168	0.129	0.159
19/08/2010	Refractory	Control room operator	108664	2.228	527	1.174	2.831	2.412	2.648	0.087	0.074	0.081
16/08/2010	Refractory	Berry press operator	108640	2.250	688	1.548	0.087	0.056	0.081	0.010	0.006	0.009
16/08/2010	Refractory	Berry press operator	108641	2.216	702	1.555	2.714	1.745	2.552	0.010	0.006	0.009
17/08/2010	Refractory	Berry press operator	108645	2.212	493	1.090	4.950	4.540	4.663	0.037	0.034	0.035
17/08/2010	Refractory	Berry press operator	108650	2.208	644	1.422	0.250	0.176	0.236	0.010	0.007	0.009
17/08/2010	Refractory	Berry press operator	108651	2.224	640	1.423	2.003	1.407	1.876	0.010	0.007	0.009
18/08/2010	Refractory	Berry press operator	108655	2.242	563	1.262	0.112	0.089	0.104	0.010	0.008	0.009
18/08/2010	Refractory	Berry press operator	108660	2.245	597	1.340	0.214	0.160	0.199	0.010	0.007	0.009
18/08/2010	Refractory	Berry press operator	108661	2.220	593	1.316	1.023	0.777	0.960	0.010	0.008	0.009
19/08/2010	Refractory	Berry press operator	108665	2.210	509	1.125	0.113	0.100	0.106	0.013	0.011	0.012
17/08/2010	Refractory	Crusher operator	108642	2.243	516	1.157	0.852	0.736	0.791	0.010	0.009	0.009
18/08/2010	Refractory	Crusher operator	108652	2.240	578	1.294	0.236	0.182	0.219	0.010	0.008	0.009
19/08/2010	Refractory	Crusher operator	108662	2.257	509	1.149	0.173	0.150	0.160	0.010	0.009	0.009

Appendix B: Some of the standards identified as relevant to the dust audit protocol

National Standards

- DOL Compulsory: Compensation for Occupational Injuries and Diseases Act, 1993 (Act No. 130 of 1993) as amended.
- DOL Compulsory: Circular instructions regarding compensation for pulmonary Tuberculosis associated with silica dust exposure: Circular Instruction number 179, July 2004.
- DOL Compulsory: Hazardous Chemical Substances Regulations under Occupational Health and Safety Act, 1993 (Act No. 85 of 1993) as amended.
- DOL Compulsory: Silica exposure monitoring and compliance tool. Government notice number 66. 5 February 2010.
- DOL Info: National Programme for the Elimination of Silicosis, 2007.

International Standards

- NIOSH OESSM: National Institute for Occupational Safety and Health. United States. Occupational Exposure Sampling Strategy Manual. January 1977.
- ASTM D4532: Standard test method for respirable dust in workplace atmospheres. United States. 2003.
- AS2985: Australian Standards. Workplace atmosphere – method for sampling and gravimetric determination of respirable dust. 2004.
- NOHSC AU: Australian Standards. Exposure standard for atmospheric contaminants in the occupational environment. Guidance note on the interpretation of exposure standard for atmospheric contamination in the occupational environment. 1995.
- OSHA Tech Man: Occupational Safety and Health Administration Technical Manual. United States.
- MSHA CFR 30 Coal: Mine Safety and Health Administration. Code of federal regulation 30. United States. 1978.
- OSHA ID-142: Occupational Safety and Health Administration. Quartz in workplace atmospheres.
- MDHS 101: Crystalline silica in respirable airborne dust. Direct on filter analysis by infrared spectrometry and x-ray diffraction. February 2005.
- NIOSH 7602: National Institute for Occupational Safety and Health. Manual of analytical methods, 4th edition. 15 March 2003.

- MDHS 14/3: Health and Safety Executive. United Kingdom. Method for determination of hazardous substances. General method for sampling and gravimetric analysis of respirable and inhalable dust. February 2000.

Appendix C: Dust audit questions and applicable standards

Question No.	Question
Policy/Programme aimed at Eliminating Silicosis	
1	Are the name and effective and revision dates of the company reflected?
2	Are the titles, purpose, objectives of the programme clearly indicated in the programme or policy?
3	Are the company registration numbers and VAT number included?
4	Does the programme have a table of contents?
5	Is there an indication that the health and safety committee was involved in the preparation, implementation and revision of the silicosis programme or policy?
6	Are all members of the drafting committee indicated (including: full name, designation, affiliations and experience)?
7	Is a description of the company and its location included in the programme?
8	Are the commodities produced by the company indicated in the programme or policy?
9	Are general controls that are in place indicated in the programme or policy (e.g. ventilation)?
10	Are related codes of practices and other management standards indicated in the programme?
11	Are definitions and acronyms indicated in the programme or the policy?
12	Is the programme reviewed after serious major changes as well as at specified intervals and are the reviews approved by the management?
13	Is the risk assessment process described in the programme or the policy?
14	Are silicosis health effects, prevention and control measures described in the programme?
15	Are the routes of entry and health effects of significant airborne pollutants described in the silicosis programme?
16	Are the locations where pollutants may be present described in the programme?
17	Is the airborne nature of pollutants that have been identified described in the programme or policy?
18	Is the nature of key workplace operations and activities that pose greatest potential for exposure described in the programme?
19	Are occupations and the number of employees being exposed to airborne pollutants described in the programme?

Question No.	Question
20	Are existing control measures and planned control measures described, together with their implementation plans?
21	Is the frequency of monitoring to assess effectiveness of controls described?
22	Were relevant material safety data sheets (MSDS) considered?
23	Does the programme or policy indicate that sampling will be carried out randomly (i.e. covering all shifts and all job categories)?
24	Does the programme or policy indicate that the company occupational hygienist or Approved Inspection Authority (AIA) will determine when additional sampling must be conducted?
25	Does the programme indicate that a sampling schedule will be compiled and kept in the office of the company's occupational hygienist or SHE for two years?
26	Does the programme indicate that sampling analysis will be conducted by a South African National Accreditation System (SANAS) accredited laboratory?
27	Does the policy or programme state that all activity area assessment records and reports will be kept for at least five years?
28	Does the programme or policy indicate that reports will be submitted to the Department of Labour (DOL) bi-annually?
29	Is the correct hierarchy of control indicated (i.e. eliminate, isolate or control at source; minimise the risk with a personal protection equipment (PPE) programme to monitor the risk and related controls)?
30	Is the medical surveillance programme described in the policy and programme?
31	Is the programme in line with the National Programme for the Elimination of Silicosis in South Africa?
32	Does the programme or policy describe the management commitment to eliminate silicosis in the workplace?
33	Does the policy indicate that the company manager will ensure that all employees are fully conversant with those sections of the policy/programme relevant to their respective areas of responsibility?
Risk Assessment	
1	Is a baseline airborne pollutants risk assessment report available?
2	Is the revision date of the risk assessment indicated?
3	Is the current risk assessment valid (i.e. within revision period)?

Question No.	Question
4	Is the risk assessment reviewed after significant changes or serious incidents relating to airborne pollutants?
5	Does the risk assessment report include the date of the report?
6	Does the risk assessment report include the identification of the employees at the work operation?
7	Was crystalline silica dust identified in the risk assessment conducted?
8	Is the risk assessment report made available to the health and safety committee for assessment of trends in silica dust exposures?
9	Have actual exposure levels of silica dust been measured and compared to occupational exposure limits (OELs)?
10	Does the concentration of respirable silica dust equal or exceed 50% of the DOL's OEL?
11	What is the total number of employees in the company?
12	How many employees are exposed to crystalline silica dust?
13	What are the employees' minimum, average and maximum exposure levels to silica dust?
14	Does the company comply with the new silica dust DOL OEL of 0.1 mg/m^3?
15	Are there any control measures implemented to comply with the above-mentioned OELs?
16	Is silica exposure monitoring conducted on an annual basis as required by the Hazardous Chemical Substances Regulation?
17	Do employees exposed to respirable silica dust receive suitable and sufficient information instructions and training?
18	Are all silica-containing substances supplied with MSDS in terms of regulation 7 of General Administrative Regulations?
Silica Dust Monitoring	
19	Does the company conduct annual silica dust monitoring?
20	Does the company have an occupational hygiene services on site to conduct silica dust monitoring?
21	Does the company make use of Approved Inspection Authorities (AIAs) for silica dust monitoring?
22	Are sampling areas determined?
23	Are monitoring results presented to the health and safety community?
24	Are monitoring results used to further improve silica dust control measures in

Question No.	Question
	the workplace?
Medical surveillance	
25	Does the workplace have an occupational health services?
26	Are patients that complain of respiratory-related diseases referred to occupational health physicians?
27	Are initial health evaluations carried by an occupational health practitioner immediately before or within 14 days after employment?
28	Is employee periodic and exit medical surveillance conducted?
29	Are annual medical reports of the occupational health practitioner made available to the health and safety committee for assessment of trends in TB and silicosis?
30	Are x-rays read by specialists who are competent in the use of the ILO International Classification of Radiographs of Pneumoconiosis?
31	Are all cases of silicosis and pulmonary Tuberculosis reported to the compensation commissioner and the Chief Inspector at the DOL in terms of Compensation for Occupational Injuries and Diseases Act, 1993 (COIDA) and Occupational Health and Safety Act, 1993 as amended?
32	How many cases of silicosis have you reported to the compensation commissioner in the last financial year?
33	Has any medical information indicating exposures been considered?
34	Is pulmonary Tuberculosis associated with silica dust exposure reported in terms of Circular Instruction 179 of COIDA as amended?
Control	
35	Have all current controls been considered, i.e. ventilation and dust suppression?
36	Are strategies or plans developed to reduce exposure of employees whose x-rays show changes consistent with silicosis?
37	Is silica sand substituted with material less hazardous (steel grit) to employees in abrasive blasting?
38	Is the workplace supplied with vacuum cleaning equipment with High-Efficient Particulate Air (HEPA) filters?
39	Are employees instructed to vacuum, hose down or wet sweep work areas instead of dry sweeping or compressed air?
40	Are employees trained on the health effects of silica dust, engineering controls

Question No.	Question
	and work practices that reduce exposure to dust?
Silica analysis	
1	Is the dust laboratory accredited by SANAS for ISO 17025?
2	Is the analysis performed by an external analytical laboratory or by the internal laboratory?
3	Is the analytical laboratory accredited by any other international accreditation body such as UKAS or ANSI?
4	Does the laboratory participate in any of the following proficiency testing schemes (PTS) for silica analysis: WASP or PAT? If not specify.
5	Does the laboratory participate in either an inter-laboratory or Round Robin programme for silica analysis?
6	Is MDHS 101 Direct-on filter using X-ray Diffraction **(XRD)** used to determine the silica concentration in respirable dust?
7	Is MDHS 101 Direct-on filter using Fourier-Transform Infrared **(FTIR)** used to determine the silica concentration in respirable dust?
8	Is the NIOSH 7602 method used to determine the silica concentration using FTIR with a **KBr** pellet?
9	Are any of the following redeposition methods used to determine the silica concentration in respirable dust using **XRD**? (NIOSH 7500 or OSHA ID-142)
10	Are any of the following redeposition methods used to determine the silica concentration in respirable dust using **FTIR**? (NIOSH 7603 or OSHA P-7)
11	Is an in-house method used for the determination of silica concentration in respirable dust?
12	Is NIST 1878a quartz standard reference material (SRM) used to calibrate the instrumentation?
13	Is Sikron F-600 (A9950) quartz SRM used to calibrate the instrumentation for silica analysis?
14	Are any of the following SRMs used to calibrate instrumentation for silica analysis: Min-U-Sil, QuinB, QuinS, QuinR, DQ12?
Instrumentation	
1	Is the pump leak test performed?
2	Do sampling pumps run for a few minutes for stabilisation before calibration?
3	Do sampling pumps run for 15 minutes for stabilisation before calibration?

Question No.	Question
4	Are sampling pumps calibrated daily before and after sampling and a maximum variance of only five per cent allowed?
5	Is a constant flow maintained by the pump?
6	Is there a calibration mark indicated on the pump's float?
7	Do sampling pumps have automatic flow control? If not, is a tool used to adjust flow rate?
8	Does the sampling pump have a malfunction indicator?
9	Are sampling pumps clean and in proper working condition and is voltage testing of each battery under actual load performed before use?
10	Is a sufficient battery charging rate ensured?
11	Are grit pots tight-fitting, with no cracks or cuts?
12	Is the cyclone kept in an upright position at all times?
13	Are cyclones cleaned and fitted properly and in good condition?
14	Are cyclones and plastic cassettes cleaned with alcohol?
15	Does the sampling train consist of a pump, flexible tubing, cyclone filter support pad, and filter holder, with suitable caps available?
16	When assembling filter cassettes and cyclones, are internal and external leakages prevented?
17	Are plastic cassette segments firmly pressed together and checked for cracks?
18	Are joints wrapped with insulation tape or a shrink seal?
19	Is transparent tubing free of cracks or weak areas?
20	Is an ultra-sonic bath used for cleaning as per the manufacturer’s specifications?
21	Are all instruments cleaned before use (damp cloth submerged in a mild solution of detergent and water)?
Transport	
1	Are samples transported in suitable containers to minimise possible particulate loss resulting from bumping vibration or defying the Law of Gravity?
2	Is the transport case constructed to prevent inadvertent opening during handling or transport?
3	Is the transport case marked “right-side up"?
4	Is the transport case lined with low density sponge?

Question No.	Question
5	Are samples kept right-side up and no public couriers used for transportation unless a specialised service is allowed to transport samples?
6	Are people responsible for transporting the carry case briefed?
Qualification	
1	Is the occupational hygienist an approved inspection authority in terms of the Occupational Health and Safety Act, 1993?
2	In case of usage of a consultant (AIA) has his/her competency been confirmed?
3	Are approved sampling devices maintained and calibrated by a certified person?
4	Are samples analysed by a certified person?
5	Are personnel collecting samples registered with the South African Institute for Occupational Hygiene as occupational hygiene assistants, technologists or hygienists?
6	Does the person conducting sampling have an MSHA qualification?
Calculations	
1	Is the pollutant concentration (PC) correctly calculated?
2	Is the air quality index (AQI) correctly calculated?
3	Is the dust mass calculation performed where “mass before sampling” is deducted from “mass after sampling” and then “dust from blank filter” subtracted?
4	Is the quantity determined by the “mean flow rate” times “sampling time” divided by “1 000”?
5	Is the mass concentration determined by the correction factor for the cyclone to convert to “respirable mass fraction” times “dust mass” divided by “quantity”?
6	Are correction calculations performed according to type of sampling, i.e. full period continuous sampling, full period consecutive sampling?
7	Is the concentration related back to an eight-hour exposure?
Statistical Analysis	
1	Is statistical analysis for HEG determination carried out according to the Occupational Exposure Sampling Strategy Manual (OESSM)?
2	Is the 90th or 95th percentile used for allocation of exposures to group?

Question No.	Question
3	Is quarterly statistically analysis carried out in the company?
4	Are HEGs correct on first test and the maximum and minimum within 95 per cent of two standard deviations (SDs)?
5	Are investigations conducted to determine whether more than one HEG is represented by data?
6	Are HEGs correct on the second test and maximum and minimum greater than five per cent outside two SDs?
Sampling Strategy	
1	Is a sampling protocol developed before sampling begins?
2	Is the sampling strategy carried out in accordance with internationally recognised sampling strategies?
3	Are maximum risk employees sampled?
4	Is a HEG description (plan or list and flow chart for chemicals) available in the office of the occupational hygienist or SHE officer?
5	Are sampling areas sub-divided into HEGs based on work activity?
6	Does the sampling methodology comply with internationally compatible best practice?
7	Does the quality control programme comply with internationally compatible best practice?
8	Is the number of samples enough to ensure a 90 and 95 per cent confidence level?
9	Once identified, are all persons suspected of being exposed to silica dust above action level sampled?
10	Have over-exposed employees being informed that they are over-exposed?
11	Is sample size compliance demonstrated through compliance with Appendix E of the OESSM?
12	Are samples taken as planned?
13	Is re-sampling scheduled and conducted without delay?
14	Is the sampling schedule available in the office of the company occupational hygienist or practitioner (last two years)?
15	Does the sampling schedule cover all shifts (day, afternoon, night)?
16	Are damaged, wet, spoiled or tampered with filters discarded?
17	Are pre-weight filters together with their reference filters used within three months?

Question No.	Question
18	Is full-shift personal monitoring being conducted?
19	Are 16-hour rest periods between exposure shifts maintained; if not are modified exposure standards specified?
20	Is the filter cassette placed as close to the breathing zone as possible (300 mm radius extending in front of face) or as required by process?
21	Is the employee properly briefed before sampling?
22	After sampling, is the filter cassette removed from the holder cyclone; taken off; and the inlet and outlet closed with plugs?
23	Was area sampling carried out to assist with the interpretation of personal sampling?
Dust laboratory	
1	Is the dust laboratory accredited by SANAS for ISO 17025?
2	Is the dust laboratory accredited by any other international accreditation body such as UKAS or ANSI?
3	Does the laboratory participate in any of the following proficiency testing schemes (PTS) for silica analysis: WASP or PAT?
4	Does the laboratory participate in either an inter-laboratory or Round Robin programme for silica analysis?
5	If the laboratory does not participate in a PTS, is another quality assurance procedure in place? Please specify.
6	Is method MDHS 14/3 used to determine the respirable dust concentration?
7	Are the r guidelines used to determine the respirable dust concentration?
8	Is the laboratory a dust- and vibration-free environment?
9	Is the laboratory a draught-free environment?
10	Is the temperature controlled in this laboratory to ensure consistent readings from the electronic balance?
11	Is there a room dedicated to filter weighing?
12	Are steps taken to limit people from going in and out of the weighing room during weighing?
13	Are there either no carpets or carpets complying with SABS specification installed in the weighing room?
14	Is pollution of surroundings avoided, e.g. dust or cigarette smoke?
15	If a weighing cabinet/box is used, is the atmosphere inside regularly checked for temperature and humidity stability?

Question No.	Question
16	Is it ensured that the cabinet is not lifted up or the aperture opened during the acclimatisation period?
17	Are sleeves covering the arms and cotton gloves used when weighing?
18	Is the balance capable of weighing to 0.00001 g or 10 microgram (five decimal)?
19	Is the balance capable of weighing to 0.000001 g or 1 microgram (six decimal)?
20	Is the balance located on a rigid, specially designed balance table with vibration absorbers?
21	Is the balance correctly leveled?
22	Are steps taken to eliminate static electricity such as the use of an ioniser and/or anti-static mats which are properly earthed?
23	Is the balance left uncovered and side doors left slightly open when not in use?
24	Are calibrated check weights available to check the accuracy of the balance at appropriate intervals?
25	Is the balance calibration conducted annually?
26	Is a record of maintenance and calibration of the balance kept?
27	Is a filter stabilisation chamber available where free air circulation is possible?
28	Are flat-tipped, self-retaining forceps available for the handling of filter papers?
29	Are Petri-dish slides available for storing the filters?
30	Are suitable means for recording the weight available (balance linked to computer or paper and pen)?
31	Is a non-static cloth for cleaning purposes available?
32	Is the balance allowed to warm up for at least 30 minutes before being used (not required for balances in "standby" mode)?
33	Do the reference filters remain in the weighing room?
34	Are reference filters selected from each new batch/pack, with a maximum 100 filters per batch/pack?
35	Are references and field blank filters weighed before and after mass determination of field filters?
36	Is the maximum allowable variation of the same filter paper recorded (in three consecutive weights of the same filter paper) less than 0.010 mg?
37	Are reference filters weighed individually for three consecutive times?

Question No.	Question
38	Are reference filters and field filters allowed to acclimatise overnight before being weighed?
39	If a series of filters is weighed, is the accuracy of the balance checked at appropriate intervals?
40	Is the balance zero checked after every weighing and samples re-weighed if not?
Reporting	
1	Are reports forwarded to the DOL bi-annually?
2	Are reports forwarded to the DOL in the required format?
3	Does the report contain updated details of the company, occupational hygienist in the company, or AIAs used by the company?
4	Are employees informed of their exposure levels after receiving an AIA's report?
5	Is the history of each activity area kept for at least five years (including reasons for deviation of sampling results and hierarchy of controls implemented)?
6	Are monthly average TWAs reported to management with an indication of remedial actions, completion dates and responsibilities?
7	Are remedial actions with regard to ventilation districts/sampling areas that indicate increased dust concentration trends defined and reported to appropriate personnel, and completion dates indicated and monitored?
8	Are results from personal sampling compared to historical data or from measured data in a particular activity area to respective OEL values?
9	Is remedial action with regard to HEGs indicating increased dust concentration trends defined and reported to appropriate personnel, and completion dates indicated and monitored?
10	Are dust results reported to appropriate persons and reviewed quarterly?
PPE	
1	Were all control measures in terms of hierarchy of control considered before resorting to respiratory protection equipment (RPE)?
2	Are RPE/RPD provided where an employee's adequate exposure control to silica is not reasonably practicable?
3	Is the selected RPE capable of controlling employees' exposure to silica dust to below OEL?

Question No.	Question
4	Is only SABS-approved RPE used?
5	Is correct disposable RPE available to all other users, including visitors and contractors?
6	Are employees given information, instructions, training and supervision on the proper use of RPE?
7	Are RPEs kept in good working condition and efficient working order?
8	Are employees and tasks/sections with high exposure to silica dust identified and zoned?