Environmental exposure to asbestos fibres before and after removing asbestos cement roofs from two townships in Gauteng

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ABSTRACT

Background: Despite the banning of asbestos in 2008, South Africa has a legacy of asbestos-containing materials (ACMs) extant in the environment. The number of asbestos cement (AC) roofs in the residential and industrial sectors is unknown but, in the low-cost housing sector alone, it is estimated that there are over one million. Eventually, these roofs will need to be replaced, using non-asbestos materials. Removal of AC roofs is regulated in terms of the Asbestos Regulations, 2001. However, there is no documented evidence that adherence to these regulations is protective for the community when large numbers of roofs are removed.

Objective: The objective of this study was to measure asbestos fibres in the air before and after a large-scale removal of AC roofs, and to estimate levels to which members of the community might be exposed.

Methods: Asbestos fibres in the air were sampled before and immediately after the removal of AC roofs, using air-sampling pumps. A total of 16 mixed cellulose ester (MCE) air filters were analysed using phase-contrast microscopy (PCM) and another 18 polycarbonate, gold-coated filters were analysed with scanning electron microscopy-energy dispersive spectrometry (SEM-EDS). The results were compared to the South African occupational exposure limit (OEL) of 0.2 f/ml and the UK clearance indicator for site reoccupation of 0.01 f/ml. Four bulk samples were obtained from the AC roofing material prior to removal to confirm the presence of asbestos, and to identify the types of asbestos fibres in the AC matrix, using SEM-EDS. The contractor work practices were observed during the removal process.

Results: No asbestos fibres were detected in air samples taken before, and immediately after, the removal of asbestos roofs, using the SEM-EDS. Several regulated fibres were counted using the phase-contrast microscopy (PCM) methodology before and after the removal. The corresponding fibre concentrations were all below the clearance indicator of 0.01 f/ml after the removal of the AC roofs. However, fibre concentrations corresponding to two of the air samples taken before the removal of the AC roofs were equal to the clearance indicator; and one was higher, at 0.02 f/ml. All four bulk samples taken from the roof material contained asbestos. Three of the four samples were found to contain a mixture of all three fibre types, i.e. chrysotile, crocidolite and amosite. The fourth sample contained chrysotile and crocidolite.

Conclusion: The removal of AC roofs did not result in elevated fibre concentrations in the households sampled. This suggests that pre-wetting of the AC and careful removal reduces the risk of fibre exposure.

Keywords: asbestos cement, phase-contrast microscopy, scanning electron microscopy, regulated fibre

INTRODUCTION

South Africa, once the world's third-largest producer of asbestos, banned asbestos in 2008. Prior to 2003, large quantities of asbestos were used locally to manufacture asbestos cement (AC) products. Because asbestos confers strength and durability to products, many of these products, including asbestos cement sheets, remain in the environment.[1] Asbestos cement sheets were used extensively as roofs, especially in townships that were built from the 1950s onwards. Analysis of roofs in Soweto, in the Gauteng province, shows that three types of asbestos were used in their manufacture.[2] In addition to chrysotile asbestos, the amphiboles, amosite and crocidolite asbestos, were used, individually or in mixtures. The majority of these roofs contained amphibole asbestos fibres, which are considered to have a greater potential than serpentine asbestos to cause malignant mesothelioma of the pleura, an invariably fatal tumour of the lung pleura.[2,3] It is estimated that there are over a million houses with AC roofs within the government-subsidised, low-cost housing sector in South Africa, many of which do not have ceilings.[4] The total number of building structures with AC roofs, within the other residential and

Figure 1. Asbestos contractors, wearing PPE, collect the removed AC roof sheeting before it is transported to a designated disposal site

Photograph: Tebogo Nthoke

Figure 2. Bolts are loosened manually and AC roof sheeting is wetted before removal

Photograph: Tebogo Nthoke

industrial sectors, is unknown. However, we know that several million people are living and/or working under AC roofs which might contain amphibole asbestos.

There is no consensus on how to address the legacy of asbestos extant in the South African environment. The AC roofs are ageing and there is evidence that the amount of asbestos fibres released from weathered and corroded AC roofs is sufficiently large to pose a health risk.[5-7] There is, however, paucity of information regarding the levels of fibres released during removal of AC roofs. In a study conducted by the Asbestos Safety and Eradication Agency in Australia, air sampling was conducted during simulation of common tasks undertaken during renovation and maintenance of AC sheeting. Asbestos fibre concentrations during the removal of AC corrugated roof sheeting in dry conditions were 0.21 fibres/millilitre (f/ml) for a personal sample (sampling equipment placed on worker) and 0.01 f/ml for a static sample located within 2 m of the worker.[8] Fibre concentrations during drilling and screwing into AC sheets were 0.062 f/ml and 0.055 f/ml for a personal and static sample, respectively. For a task of removing a small outdoor shed constructed of flat and corrugated AC sheeting, the fibre concentrations were 0.124 f/ml and 0.028 f/ml, for personal and static samples, respectively. Both chrysotile and amphibole asbestos fibres were present in the first two tasks, while only chrysotile was detected on the third task. In another study from Australia, a series of trials was conducted during field operations involving AC cleaning, painting, roof replacement and building demolition.[9] Asbestos concentrations measured near workers during replacement of weathered AC roofing, which included unfastening, removal and disposal of old sheets, ranged from 0.03 f/ml to 0.27 f/ml with an average of 0.10 f/ml. Asbestos fibre concentrations were also measured during stacking of AC sheets, with and without wetting. Without wetting, asbestos concentrations from 0.07 f/ml to 0.32 f/ml were recorded; measurements were 0.03 f/ml for trials where sheets were wetted when stacked.

The suggested best practice from the UK is to keep AC roofs in good states of repair and to encapsulate them to prevent the release of asbestos fibres.[10] Eventually, these roofs will have to be replaced, raising concerns about their safe removal and disposal. Demolition and removal work that might expose any person to asbestos dust must be performed in compliance with the Department of Labour's (DoL) Asbestos Regulations.[11] The purpose of these regulations is to protect workers and the public from exposure to asbestos dust, and to ensure that any asbestos waste material is handled safely and disposed of at a designated site.

While the Asbestos Regulations require air sampling to be conducted during asbestos abatement projects, there is little or no South African literature describing the exposure levels of communities while undertaking demolition and removal work in terms of these regulations. Given the magnitude of the legacy of AC roofs in South Africa, information concerning the levels of asbestos exposure for residents before and after the removal of AC roofs on a large scale is important.

Following a hailstorm in Gauteng province in November 2013, more than 44 000 houses were damaged. The Gauteng Provincial Department of Human Settlement and the City of Tshwane appointed asbestos contractors to remove the damaged asbestos cement roofs from 5 000 of the houses in two areas, and replace them with an asbestos-free roofing material. The Occupational Hygiene Section of the National Institute for Occupational Health (NIOH), was requested to conduct surveys to measure the asbestos concentrations in the air before and after removal of the roofs.

The objective of this study was to measure asbestos fibres in the air before and after a large-scale removal of AC roofs and to estimate levels to which members of the community might be exposed.

MATERIALS AND METHODS

A DoL-registered asbestos contractor (RAC) performed the removal and replacement of the AC roofs. The contractor's employees received training on asbestos work and were equipped with proper personal protective equipment (PPE), including disposable overalls and respirators (Figure 1). An attempt was made to minimise dust generation during the removal of roof sheeting: no high-impact tools were used and AC roofs were wetted before

Figures 3 and 4. Typical asbestos sampling positions inside and outside the household
Photographs: Tebogo Nthoke

removal (Figure 2). The AC roofs sheets were collected at a centralised location and cordoned off, before being transported to an approved asbestos disposal site.

Eight households in two townships in Tshwane, Gauteng that were affected by the hailstorm were selected by NIOH occupational hygienists, in conjunction with the RAC, using convenience sampling. A total of 17 air samples were taken inside and outside eight houses in the two townships before removal. Samples were taken approximately four months prior to the first roof removal. A total of 15 samples were taken in the two townships within 1-2 hours of the removal and replacement of the roofs. Two samples were taken during the removal process. These were unplanned, opportunistic samples. Air sampling pumps were placed in fixed (static) positions inside and outside each of selected households. The sampling pumps were placed as close as possible to the roof outside the home, and at strategic locations inside the home (Figures 3 and 4). Measurements were taken before removal of the roofs during July 2014; and within 1-2 hours after removal of the AC roofs in November 2014 and February 2015. The sampling was conducted during dry (relative humidity 18.0%-55.5%) and warm-to-hot (280 ^{o}C – 330 ^{o}C) weather conditions. Wind direction varied and wind speed ranged from 0.1 metres/second to 1.88 metres/second.

Airborne concentrations of asbestos fibre were measured using Gillian GilAir air sampling pumps calibrated at a nominal flow rate of 1 litre /minute.[13] Two types of collection filter media were used, namely 25 mm mixed cellulose ester (MCE) membrane filters, pore size 0.8-1.2 µm, and 25 mm polycarbonate gold-coated filters. The filter media was placed in an asbestos sampling cassette with a cowl and positioned 1.5-2 metres above ground level. Sampling pumps were run for approximately four hours. Asbestos fibres were analysed

Table 1. Phase-contrast microscopy results

Sample No.	Date	No. regulated asbestos fibres in 100 fields	Asbestos air concentrations (f/ml)*
Pre-roof removal			
PCM1	18/07/14	2.0	< 0.01
PCM2	18/07/14	1.5	< 0.01
PCM3	19/07/14	3.0	< 0.01
PCM4	19/07/14	1.0	< 0.01
PCM5	21/07/14	5.0	0.01
PCM6	21/07/14	4.5	0.01
PCM7	22/07/14	2.5	< 0.01
PCM8	22/07/14	7.0	0.02
Post-roof removal			
PCM9	06/11/14	0.0	< 0.01
PCM10	06/11/14	0.0	< 0.01
PCM11	06/11/14	0.0	< 0.01
PCM12	11/02/15	0.5	< 0.01
PCM13	11/02/15	8.0	< 0.01
PCM14	11/02/15	2.0	< 0.01
PCM15	11/02/15	0.0	< 0.01
PCM16	11/02/15	0.0	< 0.01

* The limit of quantification (LOQ) for the PCM method = 0.01 f/ml[13]

As AC roofs age and deteriorate, they will need to be replaced, raising concerns about their safe removal and disposal *Photograph: Bill Bradley*

(counted) on the MCE filters, using phase-contrast microscopy (PCM)[14] and the polycarbonate gold-coated filters were analysed using scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS).[15] With the PCM method only regulated fibres are counted. A regulated fibre is defined as any particle with a length > 5 µm, a width < 3 µm and a length:width ratio (aspect ratio) > 3:1.[14] Any particle adhering to the above definition is presumed to be an asbestos fibre. The SEM-EDS allows for positive identification of particular types of asbestos fibres, based on their unique chemical compositions (distinct 'peaks' displayed on the instrument screen). Although the SEM-EDS method is more accurate and reliable in identifying asbestos fibres, it requires expensive equipment and expertise, which very few laboratories in South Africa can afford. The PCM method therefore remains the most cost-effective method currently available; it is also the prescribed method in terms of the Asbestos Regulations.

The measured asbestos air concentrations were compared with the South African occupational exposure limit (OEL) for asbestos of 0.2 f/ml of air sampled[11] and, in the absence of a South African environmental limit for asbestos, with the UK clearance indicator for site reoccupation of 0.01 f/ml.[13]

In order to verify the presence of asbestos in the roofing intended for replacement, and to identify the types of fibre present in the cement matrix, bulk samples were taken from the roof sheeting of four of the houses for laboratory analysis. Bulk material preparations were examined by SEM-EDS, using the NIOH standard operating procedure for the preparation, analysis and reporting of bulk samples.

RESULTS

Scanning electron microscopy

No asbestos fibres were detected in 16 air samples taken either before (n = 9) or after (n = 7) the removal of asbestos roofs when analysed using the SEM-EDS methodology. Three chrysotile asbestos fibres were found on one of the two air samples taken during the process of roof removal. The fibre concentration for this sample was, however, below the UK clearance indicator of 0.01 f/ml.

Phase-contrast microscopy

The air concentrations of fibres measured on eight samples taken after the removal of the AC roofs were all below the UK clearance indicator of 0.01 f/ml. The fibre concentrations of two of the eight samples taken before the removal of the AC roofs were equal to the UK clearance indicator; another was 0.02 f/ml, which is above the UK clearance indicator (Table 1).

Bulk samples

All four bulk samples that were analysed using the SEM-EDS methodology contained asbestos. Three of the four samples were found to contain a mixture of all three fibre types, i.e. chrysotile (serpentine asbestos), crocidolite and amosite (amphibole asbestos). The fourth sample contained chrysotile and crocidolite.

DISCUSSION

Only one of the samples (taken during the removal process), analysed using SEM-EDS, had asbestos fibres. Regulated fibres were counted using the PCM method on all samples taken pre-roof removal, one of which exceeded the clearance indicator, and on three post-removal samples. Asbestos levels in all air samples were below the South African OEL.

It is important to note that the PCM method cannot distinguish between asbestos and other particles (or non-asbestos fibres) that have a similar geometry to asbestos. This means that any particle with the dimensions of a 'regulated fibre' is presumed to be asbestos. This could explain why three samples contained levels of 'fibres' equal to, or exceeding, the clearance indicator. This limitation is more pronounced when a very small number of regulated fibres are counted; the analytical method states that, if fewer than 20 fibres are counted, the calculated result will have increased imprecision.[13]

All three commercial types of asbestos (chrysotile, crocidolite and amosite) were found in the bulk materials taken from roof sheeting. This might have implications in terms of public health as there is strong evidence that all three types are toxic; crocidolite is the most toxic, particularly with regard to the mesothelioma risk.[3]

Asbestos fibre concentrations measured during this study were lower than those reported in the two Australian studies on AC material.[8,9] However, only static (fixed position) sampling was performed in our study as the focus was on exposure to the community, while the Australian study deployed both static and personal sampling. It is very possible that personal samples, taken on the contractor employees while removing the AC sheeting in our study, could have yielded higher concentrations due to the proximity to the sources of fibre release. It might also be that the wetting of AC roofs before removal of the sheets and careful removal (using no impact tools) might have contributed to the reduction of dust and fibres released into the air during the removal of the roofs in our study.

LIMITATIONS

Dry or wet weather conditions, as well as wind direction and speed, influence localised fibre concentrations. The impacts of these parameters were not assessed in this study. In addition, the accuracy of the PCM method is reduced when fibre concentrations are very low, as in this study. The results cannot be generalised to the community where the study was done, due to the small number of samples analysed.

CONCLUSION

Asbestos fibre concentrations, measured inside or outside the affected houses immediately after the removal of AC roof sheeting, indicated that the removal process did not result in elevated fibre concentrations, and complied with the SA OEL and the UK clearance indicator. Correct work procedures, proper training of contractors, supervision and good hygiene practices, as stipulated in the DoL Asbestos Regulations, might be contributing factors in suppressing the release of this toxic dust during AC replacement processes. However, more measurements, taken during varying weather conditions, should be taken to confirm this hypothesis.

LESSONS LEARNED

- The wetting of AC roofs and careful removal might reduce the release of asbestos fibres into the environment.
- Methods that are more sophisticated than PCM should be used when few regulated fibres are suspected in a sample, to improve accuracy of results.
- All three commercial types of asbestos (chrysotile, crocidolite and amosite) are present in cement products in South Africa, which has implications for public health.

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DECLARATION

The authors declare no conflicts of interest.

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