A South African database of samples analysed for the presence of asbestos

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ABSTRACT

Background: **Asbestos mining and other activities have left a legacy of environmental contamination. Asbestos was used in a large number of manufactured products but little is documented about the nature and location of these products. Compliance with asbestos regulations depends on accurate identification of the presence of asbestos. The National Institute for Occupational Health (NIOH) has been identifying asbestos for regulatory purposes since 2003.**

Objective: **To analyse a database of samples submitted for asbestos analysis to the NIOH.**

Methods: **Asbestos was identified using scanning electron microscopy and energy dispersive spectroscopy. The data were analysed using STATISTICA version 11.**

Results: **From 2003 to 2012, 1514 samples were analysed. Asbestos was identified in 59.9% of the bulk samples and crocidolite was present in 45.4% of these. Information about samples containing asbestos, including their origin and associated activities, are described.**

Conclusions: **Although asbestos is no longer mined or used in South Africa, workers remain at risk of exposure due to asbestos-containing materials which persist in the environment. Knowledge of these materials gained from routinely collected data may assist in the safe removal of asbestos and prevent further adverse health effects.**

Keywords: **asbestos-containing material, asbestos regulations, environmental contamination, mesothelioma**

INTRODUCTION

South Africa is a uniquely mineral-rich country and its economy was built on the exploitation of these minerals. From 1950 to 1978, South Africa was the world's third largest producer of asbestos.[1] The majority of the asbestos produced was exported, but some was used locally in manufactured products.[2]

Photo courtesy of the NIOH

Sample of asbestos containing material

Asbestos mining ceased in South Africa in 2002[1] and, in terms of the 2008 asbestos regulations, the use, transport, manufacture, import and export of asbestos and asbestos-containing products is prohibited.[3] Asbestos was used to manufacture a number of widely-used products, for example, asbestos-cement sheets for roofing low-cost housing or seaside homes. Its inherently useful properties, such as heat and acid resistance, insulation, strength and durability, led to its use in thousands of products.[4]

Despite the cessation of mining and the current legal prohibitions, numerous sources of environmental pollution persist. These include tailings dumps, discarded building material and a variety of other asbestos-containing materials which may be embedded in the fabric of buildings. Asbestos-containing products are durable and this leads to problems when they have to be repaired, replaced or demolished. Disturbance of asbestos-containing materials can liberate asbestos fibres which are a potential health hazard for workers and the general population. Replacing or demolishing asbestos-containing materials may lead to problems with regard to disposal, since asbestos is not biodegradable and cannot be incinerated.

It has been shown that even apparently trivial and easily forgotten short exposures to crocidolite asbestos, either in the workplace or in the environment, can produce malignant mesothelioma of the pleura. This tumour is resistant to all current modalities of treatment and is invariably fatal. Typically, it manifests some 30 years after exposure to asbestos. In South Africa it has been shown that patients who died of malignant mesothelioma commonly have retained crocidolite asbestos fibres in their lungs. In a study of 43 South African cases of malignant mesothelioma, crocidolite, apart from being the most common fibre retained in the lungs, was present in 81% of the cases and in 35 of the 37 cases in which asbestos fibres were detected. The second most common fibre type was amosite which was found in 30% of the cases. It occurred alone in only one case and, in the remaining, occurred together with crocidolite.[5]

The cases of malignant mesothelioma that we see at the National Institute for Occupational Health (NIOH) in Johannesburg are therefore historical in the sense that the exposure to asbestos antedates the current asbestos regulations. Thus, South Africa has a dual asbestos legacy: firstly, of disease related to historical exposures and second, of persistent environmental asbestos contamination. The sources of this contamination are historical mining and milling activities, and past and present uncontrolled disposal of asbestos waste and asbestos-containing products. In addition, there are asbestos-containing products embedded in the fabric of buildings and other structures which, in time, may lead to new sources of environmental contamination. Individuals at risk of developing malignant mesothelioma in the future will be those who are exposed to asbestos-contaminated environments or those who work with unrecognised asbestos-containing products.

To comply with the asbestos regulations[6] and Section 20 of the Environmental Conservation Act of 1989,[7] and to minimise further contamination of the environment, any demolition work on asbestos-containing structures must be carried out by trained contractors. These contractors draw up a work plan which must be submitted to an Asbestos Inspection Authority (AIA).The AIA must submit the work plan to the Department of Labour for approval. All asbestos and asbestos-containing materials must be identified before work can proceed. Any asbestos released while the work is being carried out must be monitored through air

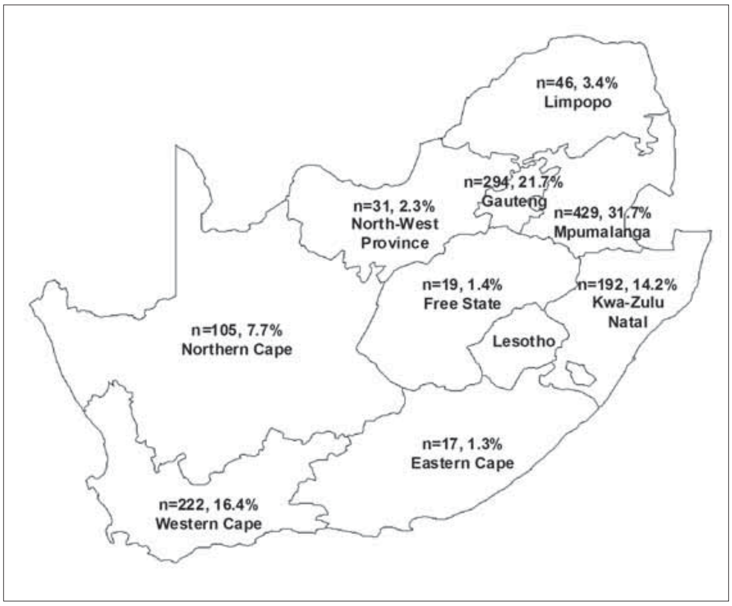

Figure 1. Map of South Africa showing the total number of samples that originated from each province (n = 1355)

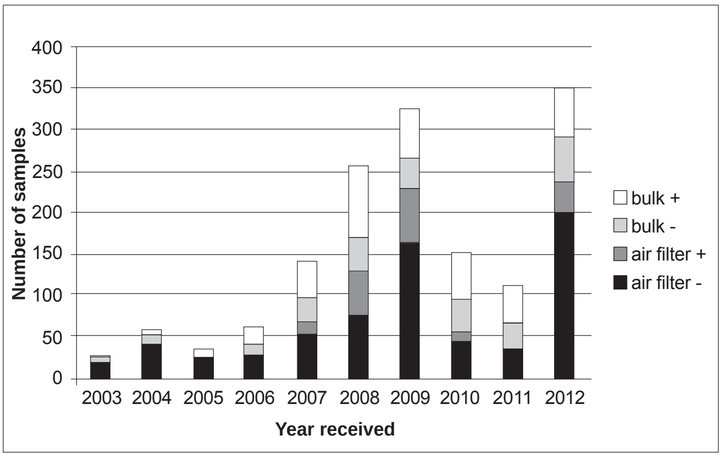

Figure 2. Graph showing the number of air filters and bulk samples positive (+) and negative (-) for the presence of asbestos fibres, 2003 - 2012

sampling. Asbestos and asbestos-containing materials must be safely removed and handled to prevent asbestos release. Any such material must be disposed of at sites designated for this purpose, such as Holfontein in Gauteng, Aloes in the Eastern Cape, and Vissershoek in the Western Cape. The air at these asbestos waste disposal sites must be monitored for asbestos fibres. In addition, the asbestos regulations require that, where asbestos forms part of the structure of a workplace, building, plant or premises, the employer or self-employed person shall keep an inventory of asbestos-containing material within the premises.

In order to work safely and comply with the asbestos regulations, asbestos must be confidently identified and, therefore, an analytical facility capable of identifying asbestos is required. At the NIOH, lung tissue is routinely examined for the presence of asbestos fibres. In 2002 the NIOH was approached to identify fibres in materials and products thought to contain asbestos. As the number of these requests increased, a formal service developed to meet the needs of contractors wishing to comply with the asbestos regulations. In due course, the number and variety of requests increased to include environmental and air monitoring samples and samples collected for inventory purposes in terms of the regulations. Two types of samples are received for asbestos analysis, viz. grab samples of bulk materials thought to contain asbestos, and gold coated polycarbonate filters used to monitor fibres in the air.

While studies have documented environmental contamination by asbestos due to mining and milling,[8-10] little information is available about the contamination of the environment by asbestos-containing products and industries other than mining.[11] This paper describes some of the data recorded in the database of samples received at the NIOH from 2003 to 2012, in an attempt to identify potential sources of continuing exposure to asbestos in the environment or workplace.

MATERIALS AND METHODS

All available information provided by the sender regarding the source of the sample was recorded in an electronic database. When this information was incomplete, attempts were made to contact the sender to ascertain more detail. In some cases the sender could not or would not supply more information regarding the sample. Bulk materials were photographed, measured or weighed, and examined for the presence of fibres using a stereomicroscope. Any macroscopically visible fibres, together with additional portions of the material, were sampled with forceps in a Class 2 Biological Safety Cabinet and mounted on pure carbon discs. Bulk samples of soil were processed according to a previously published technique[12] in which a portion was suspended in water and allowed to settle for one minute. The supernatant was passed through a 0.8 μm gold coated polycarbonate filter. Once dry, the filter was mounted on a carbon disc.

Filters received from personal or strategic air sampling were removed from the sampling cowls and the effective diameter was measured. The filters were mounted on carbon discs. All samples were then coated with gold using an Emitech K550X sputter coater. Samples were examined and analysed in a Jeol JSM 5600 Scanning Electron Microscope (SEM) equipped with a Thermo Noran system 6 for energy dispersive spectroscopy (EDS).

Bulk material preparations were examined by SEM-EDS for the presence of fibres. Gold coated filters were examined in accordance with standard methods.[13-14] For each filter received, 420 fields were examined at a magnification of 2000, and any particle with an aspect ratio greater than 3:1 was counted, provided it fulfilled the counting rules (i.e.it was not attached to a particle greater than 3 µm in diameter). All fibres were analysed using EDS and the spectroscopy traces were compared to standard World Health Organization (WHO) and Union Internationale Contre le Cancer (UICC) asbestos sample traces.

To ensure the quality of the analysis, the NIOH laboratory participates in the Asbestos in Material Scheme (AIMS) proficiency testing. The laboratory has also been accredited by the South African National Accreditation Service (SANAS) to ISO/IEC 17025 standards.

Each sample was allocated an unique number and data accompanying the sample, along with its physical characteristics, were recorded on a data capture sheet. The source industry and the activity associated with the sample were classified according to the Standard Industrial Classification Coding System (SICCS).[15] Summary statistics of the data were generated using STATISTICA, version 11.

RESULTS

A total of 1514 samples was received from January 2003 to December 2012. Of these, 1472 (97.2%) were from South Africa, and 42 (2.8%) were from other African countries, including 24 (1.6%) from Botswana and 12 (0.8%) from Lesotho. The provincial origin of 117 samples (7.7%) was unknown because the sender failed or refused to supply details of their origin other than that they were from South Africa. The remaining 1355 samples from South Africa came from all nine provinces, as illustrated in Figure 1. Mpumalanga province was the origin of the largest number of samples (n = 429, 31.7%). North-West, Eastern Cape, Free State, and Limpopo provinces together supplied less than 8.5% of the samples received.

The number of samples received gradually increased until 2009 (325 samples) and, after a decline in 2010 and 2011, peaked at 349 samples in 2012 (Figure 2).

BULK SAMPLES

Of the 1514 samples received, 654 (43.2%) were bulk material. The majority (48.1%) were described as asbestos-cement building material, and 392 (59.9%) contained at least one type of asbestos fibre. The types and mixtures of asbestos in these 392 samples are shown in Table 1.

The most frequently found asbestos type in bulk materials was amosite (found in 35.9% of all 654 samples), followed by chrysotile (19.7%), crocidolite (27.2%) and tremolite (0.5%). In mixtures, amosite and chrysotile occurred most frequently, followed by amosite and crocidolite, and chrysotile and crocidolite. Although, overall, amosite was the most frequently detected asbestos type, crocidolite was identified in 45.4% of asbestos-containing bulk samples.

Table 1. Types and mixtures of asbestos found in bulk samples (n = 392)

Asbestos type	Samples containing asbestos fibres	
	n	%
Chrysotile only	45	11.5
Amosite only	159	40.6
Crocidolite only	32	8.2
Tremolite only	3	0.8
Amosite & chrysotile	7	1.8
Chrysotile & crocidolite	77	19.6
Amosite & crocidolite	69	17.6
Any type/mixture	**392**	**100**

Table 2. Types and mixtures of asbestos fibres found on air filters (n = 193)

Asbestos type	Filters containing asbestos fibres	
	n	%
Amosite only	117	60.6
Chrysotile only	21	10.9
Crocidolite only	19	9.8
Tremolite only	5	2.6
Tremolite-actinolite only	1	0.5
Amosite & crocidolite	11	5.7
Chrysotile & crocidolite	4	2.1
Amosite & chrysotile	15	7.8
Any type/mixture	**193**	**100**

Air filters

Air filters were the most common type of sample submitted; 860 were received and asbestos fibres were identified on 193 (22.4%). The types of asbestos found on these filters are shown in Table 2.

Again, amosite was the most common fibre type found on the 860 air filters (16.6%), followed by chrysotile (4.7%), crocidolite (4.0%) and tremolite (0.7%). The most common mixture of fibre types was amosite and chrysotile, followed by amosite and crocidolite, and chrysotile and crocidolite. Crocidolite was identified on 17.6% of air filters that had asbestos fibres on them.

Industrial sectors

The industrial sectors from which the samples originated are shown in Table 3A for bulk samples and Table 3B for air filters. Of the 1514 samples received, the origin was unknown for 192 (12.7%). Where the origin was known, the majority (bulk samples and air filters) came from the electricity, gas and water supply sector (n=468, 35.4%), followed by the personal services sector (n=339, 25.6%). The major sources in the personal services sector were separated to show samples and filters from the education, health care, military, and waste management sectors. The remainder of personal services were grouped as 'miscellaneous'.

A large number of samples was received from both the mining (n=185, 14%) and manufacturing (n=115, 7.6%) sectors. Fewer samples were received from business services (n=76, 5.7%), transport, storage and communication (n=72, 5.4%), and the wholesale and retail sectors (n=45, 3.4%). Only a small number of samples was received from the construction (n=15, 1.1%) and agricultural sectors (n=7, 0.5%).

Table 3A. Industrial sectors from which bulk samples were received, and the proportion that contained asbestos

Industrial sector	Samples received		Samples containing asbestos fibres	
	n	%	n	%
Agriculture	7	1.1	4	57.1
Business services	62	9.5	37	59.7
Construction	13	2.0	10	76.9
Electricity, gas & water supply	67	10.2	40	59.7
Manufacturing	99	15.1	54	54.5
Mining	59	9.0	28	47.5
Personal services	144	22.0	86	59.7
a. Education	45	6.9	33	73.3
b. Healthcare	35	5.4	19	54.3
c. Military	19	2.9	11	57.9
d. Waste management	11	1.7	3	27.3
e. Miscellaneous	34	5.2	20	58.8
Transport, storage & communication	52	8.0	31	59.6
Wholesale & retail trade	34	5.2	24	70.6
Unknown	117	17.9	78	66.7
Total	**654**	**100**	**392**	**59.9**

Table 3B. Industrial sectors from which air filters were received, and the proportion that contained asbestos

Industrial sector	Filters received		Filters containing asbestos fibres	
	n	%	n	%
Business services	14	1.6	3	21.4
Construction	2	0.2	1	50.0
Electricity, gas & water supply	401	46.6	130	32.4
Manufacturing	16	1.9	7	43.8
Mining	126	14.7	20	15.9
Personal services	195	22.7	16	8.2
a. Education	5	0.6	3	60.0
b. Waste management	187	21.7	12	6.4
c. Miscellaneous	3	0.3	1	33.3
Transport, storage & communication	20	2.3	2	10.0
Wholesale & retail trade	11	1.3	6	54.5
Unknown	75	8.7	8	10.7
Total	**860**	**100**	**193**	**22.4**

Work processes and activities

The activity associated with each sample describes the process which led to the submission of the sample. The activities associated with bulk samples are shown in Table 4A. The most frequent activities were renovation and demolition of buildings, and asbestos surveys. The majority of air filters were submitted as a result of air monitoring of a work process (Table 4B). The work processes fell into three categories: renovation of power stations, renovation of buildings, and demolition of buildings. Overall, 31.6% of filters exposed during work processes contained asbestos. As part of the monitoring process at landfill sites where hazardous waste is disposed of, 206 filters were submitted; of these, only 6.3% contained asbestos fibres.

DISCUSSION

A limitation of this database is that it comprises samples submitted to the NIOH by clients who wish to use the asbestos analytical service. This is an inherent selection bias. In addition, we have no means of verifying the information submitted with the samples. Samples may be submitted by contractors or sub-contractors and information about each sample is sometimes incomplete.

The primary aim of this description of the samples received at the NIOH is to add to our knowledge of the asbestos legacy in South Africa. It also demonstrates the importance of a simple register and the systematic collection and collation of routinely collected data as a resource for research.[16] In addition, it enables us to compile a permanent record of air monitoring, asbestos investigations and the location of identified asbestos-containing materials. In future, we may be able to document the locations more accurately, using technologies such as GPS.

The analysis of the database serves to generate new research questions. For example, few samples were received from the education and health care sectors. Taking the education sector as an example, 45 bulk samples were submitted from a minute fraction of South Africa's approximately

30 000 schools. Almost three quarters of these samples contained asbestos fibres derived from structural components of the schools. Only five air filters were submitted from the education sector, of which three contained asbestos fibres. These findings suggest that a larger study of school buildings is justified. Those schools found to have buildings that contain asbestos should have warning notices placed in prominent places in the event of any refurbishment, reconstruction or demolition that might otherwise be undertaken without this knowledge and without adhering to the asbestos regulations.

South Africa stopped mining asbestos in 2002 and the use of asbestos was effectively banned in 2008.[3] Until now, the majority of cases of asbestos-related disease, including malignant mesothelioma, has been associated with exposure in and around asbestos mines, mills and manufacturing industries. Apart from continuing environmental exposure from unrehabilitated mines, related operations, and their transport routes,[7-10] the majority of the disease we are currently seeing is due to historical exposure.

Because of the extensive and ubiquitous use of asbestos and asbestos-containing products, South Africa has a persistent environmental legacy of asbestos. The extent and location of this legacy is largely unknown. It is important, however, as it is a potential source of continuing occupational and environmental exposure. Routinely collected data presented here add to our knowledge of the extent and location of this legacy.

Over a 10 year period, 1514 samples were submitted for analysis and the number appears to be increasing. The lower numbers of samples submitted in 2010 and 2011 cannot be explained. However, anecdotally, some of our clients who submit samples have cited the economic recession as a possible reason.

Many samples were received from the main centres of economic activity in Gauteng, Western Cape, KwaZulu-Natal and Mpumalanga provinces. Fewer samples were received from the Northern Cape and Limpopo provinces where the majority of asbestos mining was carried out until the late 1990s/early 2000s. The Eastern Cape province submitted few samples, despite having a large motor manufacturing industry and ports, where asbestos is expected to occur. All provinces have asbestos-cement products in high density housing areas[11-12] and the reason why some submitted small numbers of samples for analysis requires further investigation. This may reflect the distribution of AIAs in the provinces or, more worringly, an unwillingness or inability to comply with the regulations.

The use of SEM-EDS allows for the identification of the type of asbestos in the samples submitted. Most of the asbestos fibres identified were amosite, chrysotile or crocidolite, the three types of asbestos that were mined on a large scale in South Africa. Amosite was the most

Table 4A. Activities associated with bulk samples and the proportion that contained asbestos

Activity	Samples received		Samples containing asbestos	
	n	%	n	%
Asbestos survey	207	31.7	122	58.9
Demolition	96	14.7	55	57.3
Environmental survey	32	4.9	17	53.1
Renovation	223	34.1	135	60.5
Unknown	96	14.7	63	65.6
Total	**654**	**100**	**392**	**59.9**

Table 4B. Activities associated with air filters and the proportion that contained asbestos

Activity	Air filters received		Air filters containing asbestos fibres	
	n	%	n	%
Air monitoring of a work process	456	53.0	144	31.6
a. Renovation of power stations	401	46.6	130	32.4
b. Renovation of buildings	41	4.8	10	24.4
c. Demolition of buildings	14	1.6	4	28.6
Environmental air monitoring	123	14.3	28	22.8
Landfill air monitoring	206	24.0	13	6.3
Unknown	75	8.7	8	10.7
Total	**860**	**100**	**193**	**22.4**

Photo courtesy of the NIOH

Asbestos cement pipes in a cooling tower of a power station

commonly identified fibre type on its own, in both bulk and air samples. Crocidolite was found on its own in less than 10% of the bulk and air samples that contained asbestos. Mixtures of fibre types were more common in bulk (39.0%) than air samples (15.5%). In bulk samples that contained mixtures of fibre types, crocidolite was present in more than 95%. In a study of the asbestos fibres retained in the lung, crocidolite was the predominant fibre type found in patients with mesothelioma.[5] Malignant mesothelioma may result from apparently trivial exposure to crocidolite and accounts for over half the claims for compensation from the Asbestos Relief Trust for environmental asbestos-related disease.[17] Residual deposits of waste material containing crocidolite fibres are a source of persistent environmental exposure which may continue to cause mesotheliomas for many years to come.

More than 46% of the air samples came from the electricity, gas and water supply sector. The majority of these filters were exposed in power stations where renovation work was being carried out, and 32.4% of these contained at least one asbestos fibre. Renovation work at power stations needs to be monitored as there is a risk of asbestos exposure.

Because asbestos is neither biodegradable nor combustible it is, by regulation, disposed of at designated landfill sites. These sites are monitored by static air sampling. Only 12 (6.4%) of the 187 filters submitted by the waste management sector contained asbestos, suggesting that the disposal of asbestos waste is being managed appropriately.

There is a legacy of asbestos-containing materials in a wide variety of industrial sectors, as demonstrated by the presence of asbestos fibres in bulk samples and on air filters exposed in the workplace. Workers who perform renovation and demolition work are at risk of exposure to asbestos. More than half of the bulk samples associated with these activities contained asbestos. The majority of air filters (53.0%) were submitted as a result of monitoring a work process. Of these, 31.6% contained asbestos fibres. The monitoring of work processes is important and our data show that workers may be exposed to airborne asbestos fibres.

The asbestos regulations were promulgated to address the problem of asbestos-related disease in workers and environmentally exposed persons, and to prevent the persistence of the problem into the future as a result of continued exposure. Compliance requires that certain procedures be adopted and carried out. The first step, however, is to identify asbestos with certainty and the use of SEM-EDS allows for this. Routinely collected data[16] when displayed and analysed, can contribute to our knowledge of the extent of the asbestos legacy.

A recent study of the location of asbestos waste dumped on the Pacific Islands after the Second World War supports the reasoning behind the collection of routine asbestos

Photo courtesy of the NIOH

A damaged asbestos cement pipe

analyses. The authors suggest that gaps in data concerning asbestos in the environment will impede progress in removing asbestos and reducing its health effects.[18] Thus, action to identify and close these gaps is crucial.

CONCLUSION

Asbestos-related disease will develop in a proportion of historically exposed workers. Environmental exposure may continue as a result of unrehabilitated mine dumps, and past or continuing uncontrolled dumping of asbestos-containing waste material. Asbestos-containing materials in the environment, and in the fabric of buildings, remain a potential source of exposure for workers and the population as a whole. The extent and location of these asbestos-containing materials is unknown and it is clearly important to fill the gaps in our knowledge by gathering and collating all available data. This knowledge will assist in the safe removal of asbestos and in reducing its adverse health effects.

LESSONS LEARNED

- The display and analysis of data collected routinely as part of an analytical service may provide useful information about the asbestos legacy.
- Despite the cessation of mining and the current legal prohibitions, numerous sources of asbestos pollution persist.
- The province that submitted the most samples was Mpumalanga; the majority of these samples were associated with the refurbishment of old power stations.
- Asbestos-containing materials in the environment and in the fabric of buildings remain a potential source of exposure for workers and the population as a whole.

“Because of the extensive and ubiquitous use of asbestos and asbestos-containing products, South Africa has a persistent environmental legacy of asbestos.”

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