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Environmental 'Low Dose' Mesotheliomas and Their Relationship to Domestic Exposures-Preliminary Report

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Abstract

Crocidolite is a fibrous mineral with unusual crystallography in that the fiber width varies according to geographical origin. The fibers from the mining areas of Western Australia and the Cape Province, in South Africa are 'thin' compared to those from Bolivian and some other mines. Regardless, the mineral is a well known causative agent for mesothelioma. The literature contains many reports of the disease occurring as a consequence of so called environmental exposures due to what some believe to be 'low' dose, ambient exposure. However, closer examination of these exposure conditions generally reveals an unrecognized (or simply ignored) strong domestic (para-occupational) exposure component. Oftentimes, the importance of such domestic exposures is not considered since they too are thought to be too low to contribute to risk. We have, for the first time, applied state of the art measurement methods to evaluate domestic (shake out) conditions created by workers in a historical unregulated crocidolite-cement based operating plant in Bolivia. Our results show that exposures can reach levels more usually associated with historic occupational exposures. The reason for studying the exposures in such a plant is that epidemiological studies have shown that 'thin' crocidolite fibers are associated with a high mesothelioma risk while exposure to the 'thick' Bolivian fibers are associated with a much lessened mesothelioma risk.

Keywords: crocidolite, mesothelioma, Bolivia, domestic exposure, environmental exposure

1. Introduction

Crocidolite is a fibrous mineral with unusual crystallography in that the fiber width varies according to geographical origin and it may be a unique mineral in this respect. This property was first studied by Shedd (1985) from the US Bureau of Mines who showed that the fiber dimensions of crocidolites from crocidolite mining regions in Western Australia and the Cape Province, in South Africa are 'thin' compared to those from Bolivian and some other mines.

Crocidolite is a major cause of the tumor mesothelioma and the relevance of fiber width to its pathogenicity has been reviewed by the authors (Ilgren et al., 2012a).

Environmental mesotheliomas are said to arise under 'low dose' conditions without occupational or para-occupational (domestic) exposure. In truth, environmental mesotheliomas thus labeled are actually domestic mesotheliomas which arise after high dose exposures (Browne & Wagner, 2001). Whilst there is strong evidence to suggest domestic exposures associated with asbestos disease are consistent with high occupational exposure levels (Sawyer, 1979; Browne, 1983; Gardner & Saracci, 1989; Gibbs, Jones, Pooley, Griffiths, & Wagner, 1989; Castleman, 1988 (Note 1); Huncharek, Capotorto & Muscat, 1989; Gaensler, McCloud, & Carrington, 1985; Newhouse, 1991 personal commun), data from direct measurements of historical operating facilities are lacking (Health Effects Institute, 1991). It is commonly presumed levels of exposure in households are lower than those in the workplace, though measurements are not available documenting such levels. We thus document, for the first time, using modern measurement methods in a fully operational historic unregulated manufacturing plant, that the exposures produced during domestic ('shake out') activities, are indeed very high. Taken together, these data provide further evidence that environmental mesotheliomas as currently defined do not exist (Browne & Wagner, 2001).

2. Materials and Methods

2.1 Study Location

Bolivia has several small crocidolite mines spread along both flanks of the headwaters of the Minasmayu river in the Alto Chapare District in the Cochabamba Department, Bolivia (Mindat, 2013).

2.2 Simulation Study and Measurement Details

A shake out simulation study was done in the setting of a historical crocidolite manufacturing plant. The operating conditions, lay out and other details of the plant as well as the methods used for fiber collection and measurement have already been described in detail (Ilgren, Van Orden, Lee, Kamiya, & Hoskins, 2012; Van Orden, Lee, Zock, Sanchez, & Kamiya, & Ilgren, E., 2012; Van Orden, Lee, Zock, & Sanchez, 2012). A worker sieving crocidolite in the fiberizing unit of the plant six days a week, 8 hours a day, was asked to put on new work clothes in the morning before coming to work. He wore a personal sampler throughout the day. The company changing room was cleaned at the start of the day. It was closed until all work at the plant was done 8 hours later. The worker from the sieving department then changed his clothes in the changing room at 5:00 pm and shook them out continuously for two minutes. A sampler was placed less than one foot from his breathing zone and another was placed three meters away at the same height on the other side of the changing room.

3. Findings

The concentrations recorded from the personal sampler and those found during shake out are shown below (Table 1). All of the readings are well into the occupational range. The fiber size dimensional profiles from each sample are also shown (Table 2) are not statistically different. Background concentration data were not available so the lowest reading in the plant has been used in its place. This was from a sample taken upwind of a worker drilling a crocidolite panel (Table 1).

Table 1. Observed PCM and TEM fiber concentrations (f/ml) for samples collected following the shake out of work clothes. (July 2011) (also see [11])

			Crocidolite fibers only[3]		
Operation	Distance, (m)	PCM mean conc. (Conc Range)	All ≥ 5 µm conc. (Conc Range)	PCME conc (Conc Range)	Stanton fibers conc. (Conc Range)
Sieving (SIE 1 and 2)[1]	0	188 (88-278)	514 (148-1391)	303 (73-826)	146 (25-434)
Shake out	0	101.9	116.7	87.9	40.8
Shake out	3	35.6	33.5	21.9	6.1
Background (Bol 042)[2]	2 (upwind of drill panel	0.009	0.028	0.018	0.009

[1] Personal samplers. Workers coded 1 and 2.

[2] No background readings were taken when the plant was not operating. This area sample was the lowest reading taken during operation [10].

[3] All concentrations are f/ml.

Table 2. Observed PCM and TEM fiber sizes for samples collected following the shake out of work clothes [July 2011] (also see [12])

		Crocidolite fibers only[2]		
Operation	Distance (m)	All ≥ 5 μm GM L/W GMAR	PCME GM L/W GM AR	Stanton GM L/W GM AR
Sieving (SIE 1 and 2)[1]	0	9.5 / 0.28 33.7	10.1 / 0.44 23.2	12.1 / 0.17 72.8
Shake out	0	13.4 / 0.42 32.0	14.5 / 0.56 26.0	13.2 / 0.20 66.2
Shake out	3	12.8 / 0.39 32.9	15.6 / 0.62 25.3	12.7 / 0.17 76.4
Background	2 (upwind)	10.6/0.21	6.1/0.26	18.4

[1] Personal samplers. Workers coded 1 and 2.

[2] Fiber parameters expressed as geometric means of length to width ratio and aspect ratio.

4. Discussion

4.1 Shake out Exposures

The domestic ‘shake out’ exposures described in this report done under simulated conditions produced exposures in the occupational range. It should be noted that the worker was exposed to airborne fiber levels in excess of 1000 f/ml of pure crocidolite and actively handled the crocidolite throughout the day. There is no reason to believe the conditions of fiber generation (that is, clothes shaking) produced in the plant would differ materially from that found in the home. The background fiber levels in the plant are assumed to be representative of those found in the cleaned changing room. As they were very low, these would not have contributed significantly to what was found after shaking out the workers’ clothes.

4.2 Domestic Exposures

Significant domestic exposure can also arise in ways aside from the shaking out of clothes. This is well illustrated in New Caledonian homes covered with ‘Po’, an asbestos containing whitewash (Figures 1 & 2) (Luce et al., 1994) (Figure 3), in which sweeping up can produce extremely high fiber levels (e.g. 78 to 200 f/ml - Luce et al., 1995; Pelletier, 2010, personal commun.) capable of producing mesotheliomas.

Figure 1. A village home in the New Caledonian highlands covered by a tremolite rich Po whitewash

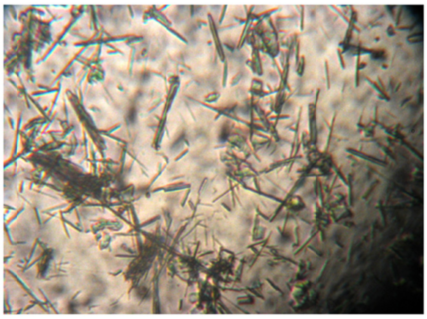

Figure 2. A photomicrograph of the whitewash demonstrating the vast number of long thin tremolite fibers

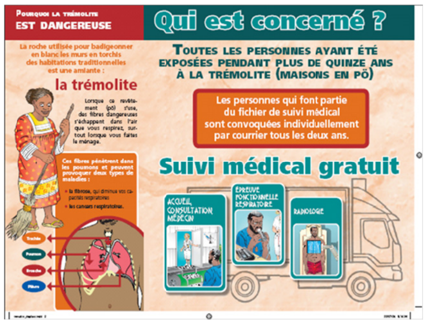

Figure 3. The warning issued to the New Caledonian villagers of the hazards of sweeping in their homes from the Po

4.3 Airborne Fibers

Fibers released after shake out and sweeping may remain airborne in the home for long periods of time (Sawyer, 1979; Newhouse, 1991, personal commun.). This is particularly so for the thinnest fibers (0.06 µm diameter, Note 2) (Dixon et al., 1985) that can also become readily re-entrained (Sawyer, 1977). Some also claim fibers released after shake out may be thinner than those from the source materials (Browne, 1991, personal commun.) but our preliminary data do not appear to support this proposal.

4.4 Environmental Exposure Measurements

4.4.1 Wittenoom: Environmental Mesotheliomas From Domestic Exposure

Roggli (2007) claims the ‘environmental mesotheliomas’ at Wittenoom were produced by exposures as low as 0.015 f-yrs. However, the risk estimates for these cancers (Hansen, de Klerk, Musk, Eccles & Hobbs, 1993; Hansen, 1995; Hansen, de Klerk, Musk, Hobbs, 1997; Hansen, de Klerk, Musk & Hobbs, 1998; Reid et al., 2007; Reid, Heyworth, & de Klerk, 2008) have never incorporated domestic exposures into their risk models. Indeed, at Wittenoon, virtually all of these so called ‘environmental’ cases lived with an asbestos worker (Hansen, 1995). Similarly, virtually none were found in residents who only lived there after the mining and milling operations ceased in 1966 (Hansen et al., 1997; de Klerk, 1993). In fact, given the extraordinarily high exposure conditions that prevailed throughout the entire 30 year (1937-1966) operating period at Wittenoon, vast numbers of ‘environmental mesotheliomas’ would have been noted if Roggli’s fiber year estimates were correct.

4.4.2 Wittenoom: Environmental Exposure

The studies of environmental mesothelioma at Wittenoon and in other parts of the world ignored various sources of gross domestic exposure. This confounds their claims that so called ‘environmental mesotheliomas’ arise from low dose exposure. One can readily see why this is so. At Wittenoon everything was ‘blue’ (Wagner, 1996 personal commun.; McNulty, 1997, personal commun.). From 1937 to 1950, the residential area (the ‘Settlement’) was next to the mine. It was constantly shrouded in blue dust from the mill. The dust from the mill was so bad aviators used the blue plume as a navigational guide. When the residents shifted to the town of Wittenoon 10 miles away from the Settlement in 1950, crocidolite-containing ore and tailings were used to build homes, schools, the hospital, airport runway, the golf course, and the race track amongst other things. One of us (EI) had the opportunity to spend several days at Wittenoon in 1997 to interview various long term residents. According to their accounts and those of others (McNulty & Wagner, personal commun., 1996, 1997), clouds of blue dust leapt from the runway as planes landed or as horses ran around the race track. Children's sandboxes were topped up with blue tailings (Doust, personal commun., 1997). Their nappies (diapers) were of consequence frequently 'blue' (Doust, personal commun., 1997). Crocidolite was also used as a garden mulch to 'keep the tenacious red (iron ore) dust down' (Doust, personal commun., 1997). The contamination was so bad that 12 years after the mine had closed, levels as high as 10 f/ml of crocidolite could be measured as a car drove through the town (Cumpston, 1978).

4.4.3 Wittenoom and South African Mines Compared

The Wittenoom story is fully supported by the 'environmental' situation in South Africa notable for the discovery of the association between asbestos and mesothelioma (Wagner, Sleggs, & Marchand, 1960). Indeed, so called environmental mesotheliomas comprised many of Wagner et al.'s original series. This is because the conditions of gross exposure were nearly identical in both places (Wagner, personal commun., 1996). This follows from the fact that the geological conditions under which South African and the Western Australian crocidolite arise are basically the same. As Hodgson (1986) has stated "there may well be some correlation between the amphibole asbestos deposits of South Africa, India and Western Australia in the Archaen Gondwana platform" as "much evidence exists in the form of Paleozoic stratigraphical correlations and in the trends of basement rock structures to indicate the unity of Gondwanaland". The aridity and attendant dusty conditions were instrumental in the production of the asbestos related mesotheliomas initially recognized by Wagner et al. (1960). One of the first cases reported by Wagner et al. (1960) was a woman (Figure 4) cobbing crocidolite sitting in an area literally strewn with blue asbestos. This would not have been her only exposure. The husbands of such women, who worked in the mines, also brought home very dusty clothes that seriously contaminated their living quarters further exposing not only themselves but their children from birth onwards on a continual basis.

Figure 4. A photo of a lady who was one of the first mesothelioma cases reported by Wagner et al. [27] cobbing crocidolite whilst sitting in a field strewn with blue asbestos. Given to EI by Dr. Wagner in 1996

5. Conclusions

5.1 Rationale of the Study

This is not an epidemiological study. It is a first attempt to study the asbestos fiber concentrations generated in an historical asbestos facility using the most modern measurement methods. The concentrations measured simulate those generated when a heavily exposed worker takes off and shakes out his clothes at the end of a work day. Measurements showed that his occupational exposure in a historic manufacturing plant was to crocidolite at fiber concentrations exceeding 1000 f/ml. Such exposure appears to be towards the assumed (Note 3) historical limit for sieving and shaking pure blue asbestos to place it into different grades. Such exposures have never been directly measured either before or after shake out. Time/cost constraints limited the number of measurements that could be done. Nevertheless, they provide a unique record of conditions in a real rather than simulated environment.

5.2 Exposure Perspectives

Although the study is limited it is a contribution to our understanding of the causation of mesothelioma following shakeout. A mesothelioma risk cannot be due solely to environmental exposures absent significant domestic exposure. The vast majority of environmental mesotheliomas are really 'forme frustes' of domestic mesotheliomas (as discussed by Browne and Wagner, 2001). This is because fibers must reach and remain in the breathing zone for significant periods of time to produce the lung fiber burdens necessary to produce disease. Such exposures are not possible with environmental exposure alone. Therefore, a significant domestic component is required to produce so called environmental mesotheliomas. We hope to be able to further confirm and extend this work in the future in this and other settings in the area including workers' homes.

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Notes

Note 1. Citing 1976 OSHA Testimony of Dr. Paul Kotin.

Note 2. "Fibers 1.6 um in diameter would theoretically fall three meters in about one hour while single fibrils would require over 15 days". (Dixon et al., 1985) see Figure 2, p. 22.

Note 3. Early measurements were in millions of particles per cubic foot which cannot be accurately converted to the modern fibers/ml.