Further Studies of Bolivian Crocidolite - Part IV: Fibre Width, Fibre Drift and their relation to Mesothelioma Induction: Preliminary Findings

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ABSTRACT

BACKGROUND: The hypothesis that fibre width is a major determinant of mesothelioma induction has been examined by comparative studies of two crocidolites from different sources. Fine fibres from Cape south Africa and the thicker fibre found and used similarly in Bolivia.

It is well established that 'thin' fibre crocidolite from Cape South Africa is extremely mesotheliomagenic. Bolivian crocidolite has a much wider width distribution and relatively little mesothelioma inducing potential.

METHODS: We analysed the mesothelioma demography in Bolivia where local crocidolite has been used for decades This was compared with the mesothelioma demography in the Italian City of Casale Monteferrato where Cape crocidolite was processed for many decades in the Eternit Asbestos Cement plant producing numerous cases of mesothelioma.

We also conducted a limited downwind study from the fiberizing part of the historical operating plant where products containing Bolivian crocidolite were made for sale and use in Cochabamba.

RESULTS: The demographic study confirmed the absence of a significant mesothelioma excess in Bolivia in stark contrast to the situation in Casale Monteferrato.

Despite the extremely high fibre concentrations measured in the plant, no significant fibre levels were detected 100 meters away.

CONCLUSION: We propose the difference in thickness and the attendant reduction in the percentage of Stanton fibres provides an explanation for the difference in mesothelioma patterns found in each city. These preliminary findings undermine claims such as those made at Casale that crocidolite fibre can drift up to 15 km and remain airborne in quantities sufficient to contribute significantly to mesothelioma induction.

Key words: Bolivian Crocidolite, Cape crocidolite, mesothelioma, Cochabamba, Casale Monteferrato, Fibre Drift Mesothelioma Preliminary Findings

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INTRODUCTION

Shedd [1] was the first to propose that the comparatively thicker fibres of Bolivian crocidolite are much less pathogenic for mesothelioma induction than the thinner types of crocidolite from Cape South Africa and Wittenoom, Australia. Both of these thinner fibres are responsible for the high incidence of mesothelioma observed in these areas. A recent epidemiological study of areas exposed to Bolivian crocidolite [2] is consistent with the reduced pathogenicity thus confirming the proposal originally made by Shedd [1]. These observations taken together support the existence of a mesothelioma threshold [3] on the grounds that the smaller fraction of Stanton size fibres in the Bolivian crocidolite (18-25%) [1,4] compared to that from the Cape or Wittenoom is insufficient to pose a significant mesothelioma risk.

The notion that a threshold exists for the induction of mesothelioma may not be widely supported but it is borne out by data [3], by the background incidence of the disease [10] and the inescapable fact that. all types of asbestos fibres are ubiquitous in the air we breathe, the food we eat, and the water we drink In consequence of this lungs of most normal people are found to contain large amounts of amphibole asbestos at death. If there was no threshold mesothelioma would be one of the most common tumours in human pathology. In fact, just the opposite is true. It is one of the rarest. While we cannot arrive at a precise exposure 'threshold' figure, an indication of the level can be proposed based on existing epidemiological studies with exposure duration and attendant exposure concentration data.

This paper examines two populations exposed over many years to either thick fibre (Bolivian) crocidolite in Cochabamba or thin (Cape) crocidolite used in the factories of Casale Monteferrato in Italy.

Study Areas and Background

Casale Monteferrato was home to a cement plant which used thin fibre Cape crocidolite. The plant was based just outside the town. Large amounts of crocidolite were also used in the town [5,6]. Cochabamba is the third largest city in Bolivia. At least three crocidolite plants operated in or very near the town centre for at least 20 years from the 1940's onwards although only one is in operation today. The populations of both Cochabamba and Casale Monteferrato were exposed to long fibre crocidolite for more than 60 years. The mesothelioma incidence in Cochabamba does not appear to be elevated above background [2] whilst that found in Casale Monteferrato is very high [7,8]. However there are potential confounders that should be noted with regard to this argument. For example, while there are similarities in the types of fibres used in Casale and Cochabamba, there are also differences which may have a bearing on the comparison being made between these two towns. Also, crocidolite use in Casale started before its use in Cochabamba: 1906 v 1949. In Casale it was also on a very large scale that not only exceeded the amount produced from the very small plant in Cochabamba but also in the extent to which it was used in the town itself and in the surrounding area and other parts of the country. Casale was a world leader in the production of asbestos cement pipe and crocidolite containing cement products were widely used in Casale and also in many villages in the province. By contrast, fewer types of crocidolite containing cement products were produced in Cochabamba and these were not used by a high percentage of the population. Instead many people used chrysotile based cement products marketed by Duralit for the same purposes. It will require ambient air studies and lung burden analyses of long term residents of Cochabamba, as is done in Casale, to clarify these points. These are projected for future work.

The fact remains that millions of pounds of crocidolite were put in place in Cochabamba so if very low dose down to 'single' fibres were sufficient to produce mesothelioma as many still suggest, we would see many clusters of mesothelioma in the City and other parts of Bolivia. Such clusters are not seen. We therefore believe the most probable explanation for this difference in mesothelioma incidence is therefore probably due to the variations in fibre width and/or the existence of a threshold exposure limit for mesothelioma. Ilgren et al. [9] have further strengthened this argument citing support from the studies of those exposed to Finnish anthophyllite, another form of 'thick' amphibole asbestos, exposure to which has shown an equally low incidence of mesothelioma.

Historically, bags of crocidolite were delivered to the three crocidolite plants in Cochabamba from the many mine sites and these occasionally broke en route. The fibre was manually unloaded, classified, milled, sorted and bagged at the plants [2]. It was then distributed to at least two other facilities in or near the city that used them to make various products [2]. The conditions were dusty. Sometimes fibre was carried in open wheelbarrows to the classifiers and it spilled during transport to and from the plants in the City. Three plants on the periphery of the city also used the crocidolite [2]. All of these facilities were sources of environmental and residential fibre exposure. Other sources also existed. For example, there were very large amounts of in-place crocidolite in Cochabamba particularly in the form of roof tiles, shingles, water tanks, and boiler insulation. Indeed, by 1960, there was approximately five million pounds of Bolivian crocidolite in the roof tiles alone. The application and repair of the roof tiles and shingles, particularly when cut to size before fitting to buildings, created significant dust levels. Simulation of the sawing of historical tiles containing 30% crocidolite (see Table 1) have produced levels up to 10.9 f/ml (>5 μm) of pure crocidolite fibres 6 meters from the sawing operation with Stanton size concentrations as high as 3.3 f/ml (Table 1). Other sources of residential fibre exposure would have come from the re-entrainment of dust inside and out of the homes from these sources, domestic exposure from occupationally exposed workers from the plants and the workers who installed the tiles. Environmental exposure also occurred through re-entrainment of the crocidolite waste that was dumped into the river running through the town (discussed in more detail in [2]). A further consequence of the differences between the fibre types is that exposure to Bolivian crocidolite can be used to dispel the notion that 'fibre drift' from a high concentration point source can produce significant exposures kilometres away. In addition, Bolivian crocidolite still contains some 18% of 'Stanton' fibres, albeit less than from Cape South Africa (ca 85%). The residents of Cochabamba were therefore clearly exposed to fibre concentrations significantly above background for decades yet residential mesothelioma incidence does not appear to be increased [2]. These observations thus support the notion of a mesothelioma threshold [3].

Fibre Drift and Mesothelioma Induction:

Cochabamba, Bolivia: To examine the issue of fibre drift more carefully, we took area samples up to 500 meters downwind of the plant in Cochabamba. Van Orden et al. [4] have described the sources of fibre production in each part of the plant and hygiene conditions in the plant in detail. The area sample measurements are shown below (Table 1). These were taken in the plant near certain operational activities and outside the plant downwind of the fiberizing unit. In addition to these sources, other sources include fibre generated by the hammer mills, the off-loading of raw fibre from the mine, the bagging of fibre after it was sieved and classified, and fibre blowing off storage piles. The sieving, shovelling and hammer milling took place in a separate room inside the fiberizing unit (Figure 1a). It was open on two sides to the storage area (see Figure 1b) where bags of crocidolite were offloaded from the mine. The area surrounding the storage unit was ca 40 x 22 m whilst the unit itself was ca. 16 x 22 m. The building is bordered on two sides (toward the shingle plant) by a brick wall that is approximately 3-4 m tall. There is corrugated galvanised siding on the opposite side and on the roof. Part of the galvanised side is open, allowing for some natural ventilation of the pulverising and sieving operations. The continuous emission of large amounts of dust from these sources to the outside of the plant was easily recognised through a Tyndall lighting effect (Figure 2). There is no baghouse or stack, so vertical emission of fibre from the plant is limited.

Area readings taken near five operations: The area readings taken near five operations namely panel drilling, sawing, mixing, finishing, and sieving / shovelling are shown in Table 1. The area readings from the sawing, mixing and finishing operations were assessed in the plant itself. Those from the drill panels were taken in the street. Small air currents in the plant caused the downwind concentration at 6 meters from simulation sawing process (Bol 046) to be higher than the point source itself

TABLE 1

OBSERVED PCM AND TEM CROCIDOLITE FIBRE CONCENTRATIONS (F/ML) FOR AREA SAMPLES COLLECTED IN PROXIMITY TO VARIOUS PLANT OPERATIONS, JUNE & JULY 2011 (ALSO SEE [4])

OPERATION SAMPLE #	DISTANCE METERS LOCATION	PCM MEAN (RANGE)	ALL ≥ 5 μM (RANGE) GM L/W	PCME (RANGE) GM L/W	STANTON (RANGE) GM L/W
Drill New Panel Bol41	Personal (n=1)	0.53	0.82 8.6/0.21	0.32 9.7/0.42	0.16 11.3/0.12
Upwind Bol42	2 (n=1)	0.009	0.028 10.7/0.22	0.018 6.2/0.26	0.009 18.5/0.18
Downwind Bol43	1 (n=1)	0.018	0.018 15.4/0.18	0 ND	0.018 15.4/0.18
Sawing Process Bol 32,33	Personal	1.71 (1.69-1.74)	3.0 (2.7-3.2) 9.9/0.34	2.0 (1.9-2.0) 10.3/0.57	0.42 (0.38-0.46) 15.1/0.12
Downwind Bol35	6 (n=1)	0.68	1.03 9.5/0.29	0.50 9.6/0.47	0.28 13.2/0.18
Downwind Bol36	4 (n=1)	0.32	0.44 11.3/0.38	0.32 12.5/0.49	0.02 17.4/0.18
Sawing Old Panel Bol44	Personal	8.6	10.5 8.7/0.33	6.7 8.5/0.47	1.5 12.8/0.17
Downwind Bol45	2 (n=1)	8.1	11.1 8.9/0.31	7.2 9.3/0.51	1.6 12.0/0.14
Downwind Bol46	6 (n=1)	10.9	21.7 9.0/0.30	13.5 9.5/0.51	3.3 13.0/0.15
Mixing Bol 12, 17, 37, 38, 39	Personal	5.6 (2.8-8.9)	15.4 (7.6-26.5) 8.5/0.30	8.8 (4.3-14.6) 8.8/0.50	2.6 (1.5-4.6) 11.3/0.16
Upwind Bol40	4meters (n=1)	2.1	4.8 8.7/0.33	2.7 9.2/0.53	0.7 11.6/0.16
Finishing Bol 5,10, 15, 23, 24, 25	Personal	1.9 (0.58-5.7)	2.8 (0.9-8.8) 9.0/0.32	1.8 (0.6-5.7) 9.3/0.53	0.39 (0.1-1.1) 13.3/0.14
Downwind Finishing Bol 26	10meters (n=1)	0.51	0.33 7.8/0.24	0.12 7.5/0.44	0.08 11.3/0.18
Sieving	Personal	187.8 (88.5-278.3)	514 (134-1391) 9.3/0.27	303 (73-826) 9.9/0.42	146 (25-434) 12.1/0.17
Shoveling	Personal	269.5 (73.7-397.3)	744 (277-1133) 9.8/0.30	453 (203-729) 10.4/0.45	195 (82-335) 12.1/0.17
Sieving & Shoveling Bol 30, 31	10-15 meters outside (n=2)	3.2 (3.1-3.3)	5.9 (4.7-7.1) 9.1/0.29	3.2 (2.7-3.7) 9.7/0.45	1.2 (0.5-2.0) 12.1/0.17
Downwind 'Sieving' & 'Shoveling'	100 meters outside (n=2)	0.022 (0.015-0.028)	0.005 (0.002-0.009) 11.0/0.32	0.004 (0.002-0.006) 13.1/0.38	0.001 (0-0.002) 12.5/0.25
Downwind 'Sieving' & 'Shoveling'	500 meters outside (n=2)	0.012 (0.007-0.0176)	0.002(0-0.004) 12.5/0.70	0.002 (0-0.004) 12.5/0.70	0

(1) Sample collector on the lapel of the employee.
(2) Bol 045 was 2 m downwind on a post about 1 m elevated above the circular sawing of the old cement panel.
(3) Bol 046 was 6 m downwind on the dust box covering the sawing station where all of the panels are sawed to dimension. Estimated to be about 1m elevated relative to the circular sawing of the old. The video of the operation seemed to show the dust cloud coming toward the further sampler and bypassing the close sampler.

(Bol 044). This was captured in a video of the operation which seemed to show the dust cloud coming toward the more distant sampler whilst bypassing the closer one. The area sample (Bol 042) taken upwind from the drill panel work was the lowest operational reading (0.018 f/ml). This was used as a background reading since no readings were taken when the plant was not operating. Three area readings were taken outside the plant at 10, 100 and 500 meters

FIGURE 1A

THE FIBERIZING UNIT

downwind of the fiberizing unit when the fibre was being milled, shovelled and sieved. The point source readings for these operations were measured on personal samplers worn by the siever and the shoveller. All were exceedingly high. The upper boundary PCME counts for each operation ranged from 729 to 826 f/ml. Remarkably, the concentrations 10 meters outside the plant ranged from 2.7 to 3.7 f/ml, more than a 200 fold decrease. By 100 meters, these fell more than a 1000 fold (0.002 – 0.006 f/ml). At 500 meters, virtually no crocidolite fibres were detected. Indeed, the one fibre found at 500 meters could have come from re-entrainment of accumulated ground dust.

Casale Monteferato, Italy: The Eternit Pietra asbestos cement plant operated between 1906 and 1986 just outside the town of Casale Monteferrato in Northwest Italy. This plant was the first in the world to manufacture asbestos cement for water mains and this division of their business greatly expanded within a very short time. 'The Company had branches and agents in practically every European country, India and other parts of the world. The British firm operating under the name Eternit Pietra Artificiale (London) Ltd, was the largest distributor of asbestos cement roofing outside of the Turner – Newell Combine' [11]. It was particularly famous for producing the 'Italit' brand of asbestos cement shingles, sheathing and pipes. The historical composition of these materials is not known. Magnani et al. [12] noted 'The factory produced a large variety of asbestos cement products (flat and corrugated sheets, chimney tubes, and pipes). Both chrysotile and crocidolite were used throughout the period in which the factory was active. In 1980, (Cape) crocidolite accounted for 10% of the asbestos used' [13]. No data are available for the previous years. The fibre levels produced at the plant were very high and believed to be in excess of 80 f/ml [5], although the results of the current study suggest they could have been as much as 10 times higher than estimated.

Large amounts of crocidolite were also used in the town [5,6]. Fibre was released (and continues to be to a lesser extent)

FIGURE 1B

PHOTO OF THE STORAGE AREA SHOWING PILE OF CROCIDOLITE BEFORE BEING MILLED

from the installation and manipulation of crocidolite containing materials in sheds and courtyards; the use of soil admixtures for pavement hardening and enhanced water absorption; home thermal insulation [5,6] and maintenance [14]. It was also in diverse local commercial building materials [6,15] and contaminated river waste (Mirabelli, pers. commun. 2011) so it was not surprising to find that construction workers were also found to be at risk [16]. Five years after the Casale plant closed, 50% of the fibres in air samples from the town still contained long fibre crocidolite and the incidence of mesothelioma remains, to this day, grossly elevated [7, 8].

Even though materials containing Cape crocidolite were used extensively throughout the province, this has been dismissed as non-contributory to the pattern of excess mesothelioma found both in the town and in other parts of the region [5,7,14-16]. Indeed, mesotheliomas found as far as 15 km from Casale are claimed to have been due, in significant part, to 'fibre drift' from the asbestos cement plant [7] However, fibre drift is unlikely to have been a significant contributor since the Stanton fibre concentration required to reach a mesothelioma threshold could not occur at this distance. This is supported by the fibre drift studies done in Cochabamba and the literature reviewed below.

The notion that thick fibres are less causative for mesothelioma is also supported by using the UTM coordinates [Universal Transverse Mercator] of each of the cases alleged to be due to fibre drift alone given by Maule et al [6] to determine where in the Province each case was located. By doing this, we were able to identify through co-location, potential sources of alternate exposure for many of the cases alleged to be due only to fibre drift (Data not shown - available on request).

FIGURE 2

PHOTO SHOWING THE CONTINUOUS EMISSION OF LARGE AMOUNTS OF DUST FROM THESE SOURCES TO THE OUTSIDE OF THE PLANT EASILY RECOGNIZED THROUGH A TYNDALL LIGHTING EFFECT

DISCUSSION

Role of Fibre Width: The demographic pattern of mesothelioma incidence found in Cochabamba, Bolivia and Casale Monteferrato Italy, low in the former and markedly elevated in the latter, could be explained, at least in part, by the difference in the fibre width distributions of the types of crocidolite used in each location, particularly the percentage of Stanton fibres each contained. The percentage of Stanton size fibres in Casale would have been ca 85% [1,2,9] but ca 18% in Cochabamba [1,2,4,9]. The paucity of mesotheliomas seen in long term epidemiological studies of other populations exposed to high concentrations of 'thick' amphibole asbestos fibres, albeit of another type (anthophyllite), also supports of the role of fibre width in mesothelioma induction [9].

Fibre Drift: Fibre exposures capable of producing disease must reach and remain elevated in the breathing zone long enough to generate a dose capable of causing disease. No reliable quantitative studies exist to demonstrate definitively that significant quantities of asbestos are able to produce a human health risk at a distance from a known point source purely via 'fibre drift'. The 1984 National Academy of Sciences report said 'discharges from mines and mills are presumably deposited relatively close to their sources and do not contribute much to general ambient concentrations' [17]. Dixon et al. [18] similarly said 'Both turbulent diffusion and wind disperse asbestos from its point of emission' through mixing of released fibres with ever increasing volumes of air 'dramatically reduce concentrations in areas peripheral to the asbestos source.'

Commercial Emission Fibre Sources: There is a paucity of data on fibre emissions from commercial sources. This is underscored by the exhaustive study conducted by Williams et al. [19]. This reviewed more than 60 years of published and unpublished literature on historical airborne fibre concentrations during specific tasks performed by skilled craftsmen in various settings but found only two studies that reported analyses of fibre concentrations at set distances from a point source. One was a study [20] of asbestos spraying operations conducted without pre-damping. This produced fibre levels in excess of 100 f/ml. The levels found 20 to 30ft from the spraying operation were said to be '1/10th' that found at source. The other was a study [21]. that compared readings 20 ft from a spray operation (5 f/ml) with those found near the operation itself (80 f/ml).

Kuryvial et al. [22] took area samples up to 2.5 miles from two plants and said no excessive asbestos emissions were identified in their vicinity. They concluded that the 'substantial populations surrounding the mine sites where asbestos is present as an accessory mineral' do not appear to be 'exposed to significant concentrations in air' so 'the hypothesis that a health hazard existed' (from them) cannot be supported."

Dixon et al. [18] described studies based on the use of an ATM-SECOP model in which St. Louis was chosen as a 'representative site' to assess exposures allegedly released from exfoliation plants that could place millions of people living within a 50 km radius of such facilities at risk of asbestos disease. The model was used to support claims that exposures within 1 km of such plants put residents at high risk of asbestos disease. However, Dixon et al. [18] listed numerous sources of uncertainty in these analyses that undermine the validity of any claims of attributable risk.

Selikoff and Lee [23] cited four examples of putative fibre drift related health hazards. None of these can be supported. Thus, the first was described by Reitze et al. [24] who surveyed the concentrations of asbestos when insulation was being sprayed on buildings. Their findings are confounded by the 'great variability in the concentrations with distance from the nozzle man (10ft: 70f/ml; 15ft: 17f/ml; 20 ft: 37-66f/ml; 35 ft: 10 f/ml; 75ft: 46 f/ml). This could only be explained by changes in application flow rates and other factors that would confound the data. The second was Nicholson and Pundsack's [25] studies of samples taken up to one mile from asbestos spraying operations but the findings were only given as mass concentrations. The third was a study done by Wesolowski [26] and John [27] by the Calif. State Dept of Health near an asbestos processing plant with asbestos in unprotected heaps on the ground. They said concentrations as high as '1 f/ml' were found over a community 3.3 miles downwind'. However, none of the fibres were longer than 5 µm. Finally, they cited studies done in the neighbourhood of an anthophyllite mine by Laamanen et al. [28] and claimed that 'measurable' amounts of asbestos were found 27 km from the mine. However, these were only measured in grams/100 m2/month. Unrelated naturally occurring ground contamination was also probably contributory [29].

Natural Large Scale Fibre Emission Sources - Klein [30] described the pattern of long distance dispersal of California Coalinga chrysotile and Wittenoom Western Australian crocidolite from two of the largest exposed asbestos deposits in the world, the Californian New Idria Serpentinite and the Australian riebeckite deposit in the Hammersley range, respectively. These immense naturally occurring prehistoric 'point sources' are sources of global fibre dispersion. The immensity of the deposits is well illustrated by Klein's description of the Hammersley deposit. Klein [30] said the volume of crocidolite containing rock removed through erosion over the last 150 million years would be equivalent to the removal of a one mile high rock pile on an area the size of the State of Oregon capable of providing a very large and unique source of sodic amphiboles in the southern hemisphere for an extremely long time'. The New Idria Serpeninite from which Coalinga chrysotile is formed covers an even larger area than that found in the Hammersley range.

It is not surprising that the immensity of the deposits and the consequent natural release of fibre from airborne and fluvial sources totally dwarf any man made mining contributions to the atmospheric dispersion of either fibre type.

Natural Superficial Erosion of In Place Asbestos: Spurny [31] said superficial release of asbestos fibres in the vicinity of buildings containing corroded and weathered asbestos cement products such as roof tiles and claimed these could produce fibre concentrations in the range of 0.0002 to 0.0012 fibres (>5 µm) /ml.

Many of these fibres will be chrysotile whose surface may be chemically altered both by contact with cement [32] and attack by lichen [33]. Nonetheless, given the dispersion of fibre from natural sources, the ability of these man-made sources to significantly contribute to disease risk is highly questionable.

Re-entrainment of fibre from waste pile emissions: Fibre released from waste piles do not appear to cause significant fibre drift from a point source. Thus, Dixon et al. [18] suggested fibre-entrainment could be responsible for most asbestos emissions from waste piles in urban areas but the fibre concentration data are only presented as mass doses (μg/m^3). An EPA report notes: 'During periods of high winds, asbestos has been observed at a playground and in houses near one dump.' [34]

Dixon et al. [18] also said 'Atmospheric asbestos emissions downwind from industrial dumps studied by Harwood and Blaszak' [35] at the JM Coalinga, California (224 meters), JM Waukeganw, Illinois (356 meters) and JM Denison, Texas (720 meters) plants demonstrated the highest values at Coalinga (ca 0.1 f/ml) and Waukegan (ca 0.01 f/ml). However, Dixon et al. [18] said the former possibly reflected the gross natural contamination [36] of the 224 meter test area whilst the findings at the latter were probably consistent with background since not all of the fibres may have been asbestos. Dixon et al. [16] also noted PEDCO's [37] study of 'Particulate emissions from tailing piles under various climatic conditions' but the fibre concentrations were only reported in mass doses (μg/m^3).

Fibre Width and Settling Velocity - It might be argued that differential settling velocity will confound the analysis of the issue of fibre drift due to the increased diameter of Bolivian crocidolite since gravitational settling rates determined either experimentally [38] or by modeling fibre aerodynamics [39] for asbestos fibres in the absence of turbulence depend principally upon fibre diameter (discussed by Dixon et al. [18]). However, the range of geometric mean diameters of Cape crocidolite (0.06 – 0.17 μm) and Bolivian crocidolite (0.30-0.48 μm) fibres [9] are sufficiently similar that their settling velocities will probably not differ significantly. Indeed, fibres ca 1.6μm in diameter would theoretically fall three meters in about one hour (see Dixon et al. [18] see theoretical settling velocities per their figure 2). Furthermore, Dixon et al. [18] also say that 'In the atmosphere, settling velocities for most asbestos fibres will be negligible in comparison with turbulent vertical velocities. This is true for fibres… with diameters up to 6.4 μm.' Therefore, given equal rates of dispersion and concentration, any differences in gravitational settling velocity should be nullified by the overwhelming effect of vertical turbulence.

CONCLUSION

Concentration data derived from a limited series of area samples taken downwind at precise distances from a historical largely unregulated operational crocidolite manufacturing plant provide no support for the notion that 'fibre drift' results in significantly elevated downwind exposures. Stanton size fibre concentrations decrease rapidly with distance from the point source so that by 500 meters, they are within a general background level (measured as PCME 0.002f/cc as one fibre and no Stanton size fibres). Such levels pose no risk of mesothelioma. Demographic comparison of the mesothelioma incidence in two cities where 'thin' and 'thick' forms of crocidolite were used demonstrates the expected difference in risk. Thus, in Cochabamba where thick Bolivian crocidolite was used the mesothelioma incidence is very low. By comparison, in Casale where thin Cape crocidolite was used the mesothelioma incidence is very high.

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