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Anthophyllite Asbestos: The Role of Fiber Width in Mesothelioma Induction

Part 2: Further Epidemiological Studies of Occupational, Domestic and Environmental Exposure to Finnish Anthophyllite Asbestos

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Abstract

Although people in all sectors of the Finnish anthophyllite industry, including their families, have been heavily exposed to anthophyllite there is no evidence for even a single proven case of attributable mesothelioma. A few cases have been claimed but the evidence either, that they were mesotheliomas or that amphibole exposure was solely to anthophyllite is, in every case examined, insufficient. Even among the population who lived in Karelia in Central Finland who were exposed domestically or enviromentally to anthophyllite released during agricultural and various domestic activities and during transport from the mines, Finnish epidemiology found no risk of mesothelioma. There is also an absence of mesotheliomas reported in the earlier Finnish literature. This anomaly compared to the effects of exposure to other amphiboles is strong support for the role of fiber width in mesothelioma production. Anthophyllite, though, is not without clinical effect. As screening techniques improved it was discovered that of every person over the age of 65 years, one third living in Karelia had bilateral pleural plaques. The area was henceforth called the Endemic Pleural Plaque (EPP) zone. Radiographic analysis of the residents living in the district of Kuusjarvi led to suggestions that the cases resulted from asbestos blown from the Paakila facility via fiber drift as far away as 30 km. Later studies showed that 'fiber drift' was very unlikely to be a factor in the radiological findings thus observed.

Keywords: Anthophyllite, Finland, pleural plaques, mesothelioma, fiber width

1. Introduction

Fiber width has been thought to be a major determinant of mesothelioma causation for nearly 50 years. This is strongly supported by epidemiological observations of workers exposed to Finnish anthophyllite (e.g. Ilgren & Hoskins, 2018, Part 1 of this series) and demographic studies of large populations residentially exposed to Bolivian crocidolite (e.g. Ilgren et al., 2012a,b and 2015). The first part of this study examined epidemiological studies of Finnish anthophyllite workers. This report summarizes observations of those domestically and environmentally exposed to Finnish anthophyllite in Finland. It also comments upon those occupationally, para-occupationally and environmentally exposed to Finnish anthophyllite outside of Finland.

Taken together, the Finnish experience in its totality provides unequivocal support for the 'fiber width' hypothesis. Moreover, the Finnish epidemiology indicates that environmental anthophyllite exposures, such as those allegedly incurred by the residents of Karelia in Central Finland, were not sufficient to cause any risk of mesothelioma. This is the case even though a high percentage of the residents also had pleural plaques. These observations totally undermine claims of significant contribution from 'fiber drift' and also underscore the very unusual nature of anthophyllite asbestos compared to other forms of asbestiform amphibole (also Ilgren & Hoskins, 2017, Part IV in preparation). The latter is particularly important. Even if exposures to Finnish anthophyllite were ‘supplemented’ by crocidolite and/or amosite, the intrinsic differences between them would reduce the ability of anthophyllite to contribute, biologically, to the total exposure dose of ‘equidimensional’ long fibers.

2. Environmental Studies of the Finnish ‘Endemic Pleural Plaque (EPP)’ Area near Paakilla and the Case against ‘Fiber Drift’

Hillerdal (1997) has studied pleural plaques for more than 40 years including those found in the so-called ‘Endemic Pleural Plaque’ zone in Finland. He wrote: “In many areas of the world, asbestos fibers occur in the soil, as remnants of broken down rocks. Since chrysotile is more easily destroyed than are the amphiboles, it is almost exclusively the latter that are found. Farmers working with the soil are exposed to the fibers, and in many places the locally occurring asbestos has been used for white-washing of houses, construction of fireplaces, or sauna stones. As a result, there are areas of the world where pleural plaques are endemic. Such 'endemic pleural plaques' were first described from Finland and since then many other areas have been reported”.

Paakkila is centered in the EPP zone situated one half way between Kuopio and Joensuu on Route 9 which connects the two. Paakkilla is in in the district of Tuusniemi just inside the province of north Savona. This abuts on an ancient province called “Karelia”[1]. Kuopio is at the western and Joensuu at the eastern border of “Karelia”[2].

Karelia was one of the oldest parts of Finland. The mining town of Paakilla, in what is now Finnish Karelia, is situated ca. 3 kms to the north and south of two very large lakes near the channel junction of the two (Fig. 1). Indeed, there are so many lakes that it is possible to go by boat from Paakilla to the Baltic sea via a series of smaller waterways and channels that connect one lake to the next (Auvenin, 2015 pers. comm.). This is important to the epidemiology for at least four reasons. Firstly, it enabled the Paakkila anthophyllite and various other minerals to be transported by boat to Kuopio or Joensuu and then, in some instances onwards more readily by train; because people from other parts of Finland and, indeed, wider Europe could enter Karelia; because, many thousands of years ago, it gave the stone age population access to the lake shores from which they could gather the anthophyllite asbestos to blend with the clay to make ceramic ware (see “The Ancient Finnish Anthophyllite Asbestos Ceramic ‘Combware’ Industry” in Ilgren & Hoskins, (2018)), and because Kuopio and Joensuu then became centers for ship and train manufacture and transport which periodically necessitated the use of commercial amphibole asbestos.

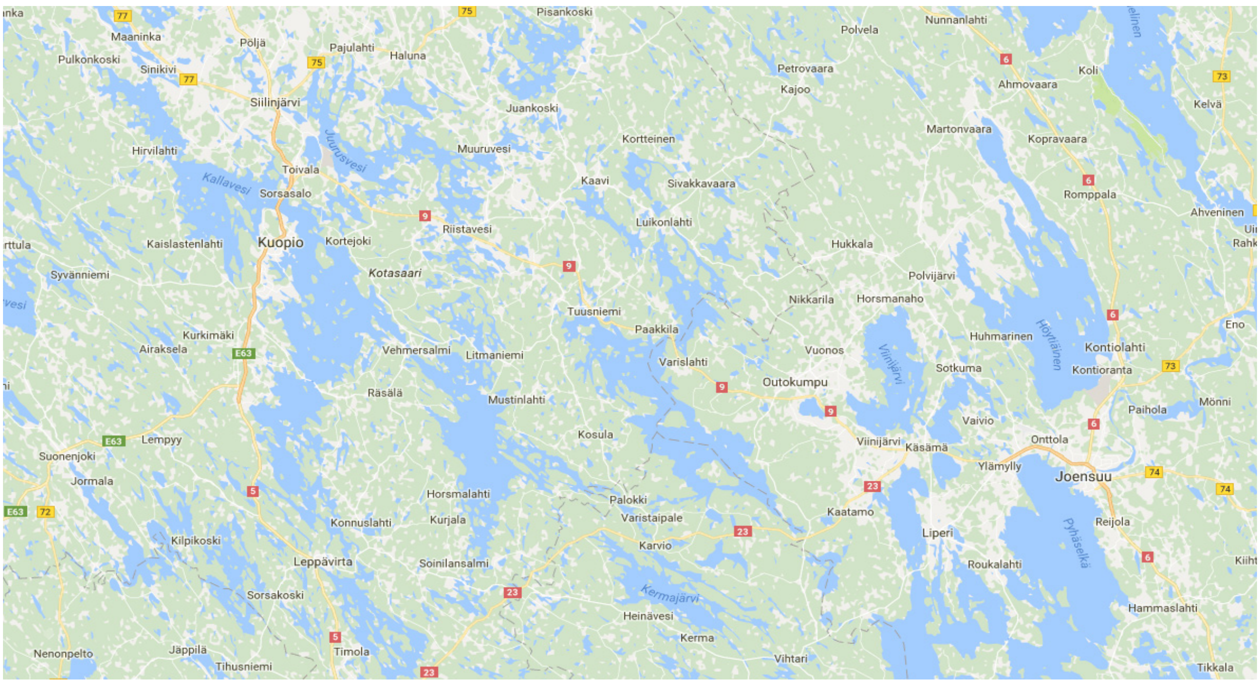

Figure 1. Showing Paakkila and the surrounding lakes, roughly halfway between Kuopio and Joensuu

[1] Karelia prior to 1918 included an area by the same name in Russia and there was no separation from what is now called “Finnish” Karelia. Today, there is a “Russian” and a “Finnish” Karelia. They are contiguous but separated by the Finnish-Russian border.

[2] For the sake of simplicity, to the extent it is in concert with the medical studies of the EPP, we shall however consider the entire area under discussion below “Karelia”. For the same reason, we shall say it consists of the 12 districts shown below in fig 3 from Raunio (1966).

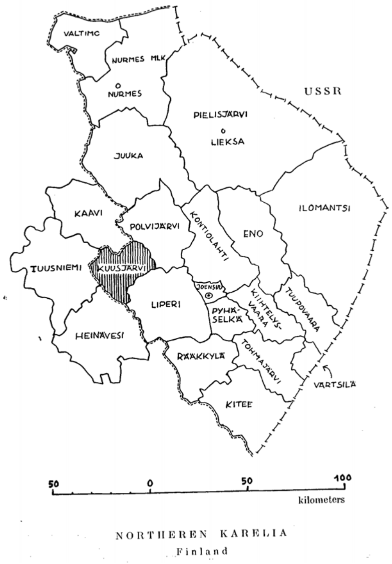

Figure 2. Area studied by Kiviluoto (1960)

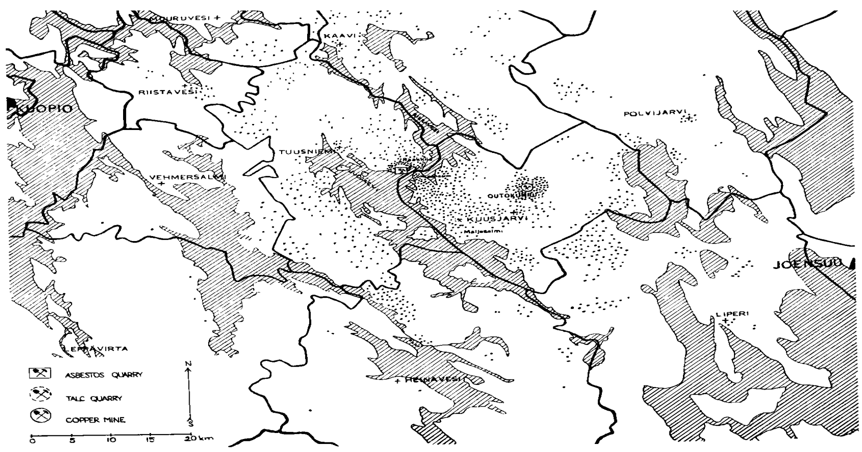

Figure 3. Area studied by Raunio (1966) – The domiciles in the 'calcification area' of 1,232 subjects showing pleural calcifications. Each point represents one case

Karelia consists of ca. 900,000 residents many of whom never worked in the Paakkilla anthophyllite mine or mill. Annual radiographic screening for TB in Karelia began in the late 1940s. By the early 1950s, it was discovered that one third of those over the age of 65 years living in Karelia had bilateral pleural plaques. The area was henceforth called the 'Endemic Pleural Plaque' (EPP) zone. Kiviluoto's (1960) radiographic analysis of the residents living in the district of Kuusjarvi allegedly suggested these cases were from asbestos being blown from the Paakila facility via fiber drift as far away as 30 km. The area under study by Kivoluoto (1960) is shown above in fig. 2 (hatched area). Paakkilla is near to Kuusjarvi several kms to the west in Tuusniemi as shown in fig 3 from Raunio (1966). Indeed, if Kivoluoto had studied the entire area in a manner similar to Raunio (1966), he would have immediately realized that the cases were not only to the south east 'in the direction' of the wind but also to the west away from the prevailing winds. Moreover, if he knew that the intense case cluster around Otokompu (Outokumpu in Fig. 1) was also related to the workings of one of the oldest copper mines in the world and the use of commercial amphibole, his theory would have been weakened even more. Nonetheless, Kiviuloto (1960,1965) also believed his 'fiber drift' theory was plausible as many of the cases were farmers and they and their wives appeared to have no clear occupational exposure at either the Paakilla mine or the mill. Nonetheless, the latter was potentially subject to historical recall bias since some may have worked earlier in their lives in different facilities. Moreover, long distance fiber drift has been shown not to be a biologically plausible explanation[3] (e.g. see Ilgren et al., 2015)

[3] First-hand view (Ilgren pers obs 2015) of the area also indicates how unlikely the fibre drift claim is given the very heavy forestation, serious

something Raunio (1966) suggested six years later on the basis of his much broader radiological survey that examined not only the area studied by Kivoluoto (1960) but 8 other districts as well. (fig. 2). Raunio's (1966) study was subsequently confirmed in a 1972 follow-up of 608 people with pleural calcification (T Partanen pers. comm. Hillerdal, op. cit. Hillerdal et al. (1984). Subsequently, it has been confirmed by ongoing radiological studies being done at the two medical centers, the one at Joensuu[4] where Kivoluto did his original work and the other in Kuopio[5] where Rauio did his.

2.1 Sources of Alternate Causation

Rauinio (1966) posed several questions one of which asked: "Apart from the asbestos dust emanating from the asbestos mine and mill, can any other causes be demonstrated which could be responsible for these lesions?" In response to his own question, he said: "North Karelia is the site of numerous asbestos deposits (small asbestos deposits, mostly detached stones) in the vicinity of their homes". This was subsequently confirmed in great detail by Kontinen et al. (2001) and Nikkarinen et al. (2001) at the Finnish Geological Service (GTK) who described all the known minor and major asbestos-bearing sites in the municipalities studied by Raunio, thus confirming the widespread presence of numerous varying sized asbestos deposits throughout the area.

2.2 Anthophyllite Exposure in the EPP Zone

Anthophyllite is released during agricultural activity (Hillerdal, 1986); from its local use in building saunas, gardens, and ovens with fire-proof anthophyllite clay mortar; and from repairing asbestos boards for various domestic purposes. Children may also be exposed playing with discarded rocks or anthophyllite soils. Re-entrainment of fiber may also occur in homes from polluted water. Long anthophyllite fibers are used as wicks for lighters and oil lamps. Anthophyllite transported along the main roads in open trucks is another source of exposure (Hillerdal, 1986).

2.3 Commercial Amphibole Asbestos Exposure in the EPP

People living in the EPP but not involved with the anthophyllite industry may also have incurred exposures from commercial amphiboles used in various metal mines such as the enormous copper mine at Otokumpu ca. 25 kms from Paakkila (5 km in the winter across the frozen lake), small industries like the fertilizer factory north of Paakilla, and from working with lagged boilers and steam pipes on the train and shipping lines from Kuopio and Joensuu, both inland sea ports with large docks. Joensuu was an important entry point for commercial exchange into the area around Paakkila and the second largest shipping port in Finland. Historically, it was associated with ship building and repair, steam sawmills, metal factories, hydroelectric plants, pulp mills, and a railway system. It also served as a conduit for water traffic through the Saimaa Canal and different regions of North Karelia, St. Petersburg and Middle Europe (see fig 1).

2.4 Tremolite Asbestos Exposure in the EPP

Maljasalmi, 6 kms south of Paakkila, not only supplied workers to the Paakkila anthophyllite operation from 1944 to 1963 but also produced tremolitic talc (Meurman et al. 1974). The talc quarries at Jormua and – or Leppalathi (see below) both contained tremolite. Jormua used the tremolitic talc to produce asphalt roofing and as a dust for insecticides and nitrogen fertilizers to prevent the material from getting lumpy (Aurola & Nieminen, 1954). Clearly, the spraying of insecticides and fertilizers containing tremolitic talc could produce plaques. Historically, the local inhabitants of Jormua also used tremolitic talc to make fire-proof bricks amongst other things. A local stone containing tremolitic talc (a form of soapstone) was also used to make jewellery and ornaments (Santii, 2015 pers. comm.). Regional talc tremolite quarries in Miihkal and Haukavann may also be a source of building dimension stone. Tremolite unassociated with talc is also found throughout many parts of Karelia as well (e.g. Saanti et al., 2006, 2015 pers. comm.; Lulaka, 2015 pers. comm., Lavento 1995,1996; Huuskonen et al., 1980; Palomaki, 1968)

3. The Finnish EPP Zone, "Fiber Drift" and "Selikoffian Drama" – State of the Art Issue

From an historical perspective, it is interesting to note that 11 years after Raunio (1966) effectively debunked Kiviluoto's (1960) 'fiber drift' proposal and when others went on to do the same thereafter (see Fiber drift discussion - Ilgren et al., 2015), Dr Irving Selikoff wrote to Dr. David Raul, the then Director of the NIEHS (13 June 1977) to advise him that Kiviluoto had recently written "concerning the possibility of obtaining some

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undulation of the terrain, and long periods of snowfall. The chances of fibre drifting such long distances in sufficient quantity to cause any clinical effect are extremely low.

[4] then the "Central Hospital of Northern Karelia

[5] then the Central Sanatorium of the Tuberculosis District of Northern Savo

for a follow up study of the Eastern Karelia population reported by him in 1960". Selikoff went on to say that:

"This is a unique population; no counterpart exists anywhere in the world. Briefly, in a survey of over 6,500 residents of a county in Eastern Finland, 499 instances of radiologically evident pleural calcifications were seen. The county had an asbestos mine and mill. The people with calcification did not work there but were rather farmers, farmers' wives, etc. simply living in the same county. Air sampling showed fibers characteristic of the type of asbestos produced by the mill some 20 km away. In a neighbouring county, no instances of pleural calcification were seen in more than 7,000 people surveyed. These were X-ray studies and asbestos 'disease' was neither sought nor recorded. Pleural calcification was simply considered a 'marker' for asbestos exposure over the years. Consistent with this was the finding of asbestos bodies in the lungs of cows grazing in the fields of that county. Kiviluoto now has the opportunity of tracing these people, to see what happened to them. A straight–forward mortality study would provide unique information concerning the disease potential of environmental asbestos exposure. The information that could be derived would be, I suggest, very useful in allowing us to evaluate the potential effects of environmental asbestos exposure in situations such as Rockville, Maryland. We would propose a joint study with Dr. Kiviluoto, as a special enrichment project. To repeat, this is a unique population, a very capable investigator with intimate knowledge of and access to the group. We would be prepared to help in any way that we could to help obtain this badly needed information." (Available upon request).

The letter concludes by citing Kiviluoto (1960) as the sole supporting reference. However, in an appendix to the letter, Selikoff requested a total of $47,300 for the entire project (Available upon request). He also indicated that $20,000 of this amount would come from the American Cancer Society (ACS) (see "Mortality experience (1960-1978) of Finnish farm residents following environmental asbestos exposure: Budget 1977 – 1978: upon request). Moreover, in the same US FOIA[6] file in which the "Selikoff to Raul letter" was provided, also a note regarding Selikoff's attempts to get the requested funding from the NIEHS. And whilst 'Finland' was not mentioned and a date was not provided, the placement of the note and the wording make it clear that it referred Selikoff's efforts to get Kiviluoto funding. Thus:

"We should insist that Dr. Kiviluoto have to apply for an RO1 type grant[7] or contract for this project. Dr. appears to be flagrantly trying to bypass the peer review system lately. He has succeeded twice already within a year or so. I feel we should strongly resist being a party to this tactic again. If the population and the proposed are so unique, it should have no problem in the peer review process" initialed RGO (Available upon request).

In addition, Selikoff, in his letter to Raul, strangely failed to even mention Raunio (1966) or other contemporaneous Finnish workers e.g. Nurminem (1975) and Partanen (1976) (Pers. comm. to Hillerdal, op. cit. Hillerdal et al. (1984). Indeed, Partanen (1976) said that "In a follow up examination of 608 people with pleural calcification detected in mass radiography in 1972 in selected communities in Finland, no pleural mesothelioma was registered until the end of 1976."

Selikoff also stated that there were no instances of pleural calcification in a neighboring county. That is blatantly incorrect. Raunio (1966) demonstrated these in the neighbouring county, Tuuniemi, where Paakkila was actually situated and where Kiviluoto failed to look. Similarly, the air samples could not discriminate fiber type and calcification was not simply thought to be a "marker for asbestos exposure" over the years. It was related to tuberculosis. Kivuoloto (1960) was the first to raise the possibility that asbestos might play a role. That Kiviluoto and Selikoff did not even mention Raunio's (1966) work and what followed from then until 1977 (vs) is also puzzling.[8] Selikoff was clearly trying to find a way to justify his position on asbestos exposure from the Maryland serpentine quarry. Rockeville (Rohl et al., 1977; Langer et al., 1978) was clearly another Selikoffian attempt, in a manner similar to the massive Reserve Taconite Mining case, to unjustifiably sow "environmental panic" amongst the public (Telegrams to and from Mayor of Silver Bay Selikoff (Available upon request); W., Director, EPA Office of Air Quality to Hon. John Dalton, Gov. of Virginia: 7 Apr 80 re informing the "county and local governments and residents of potential problems; taking steps to reduce emissions …; and to stop crushed stone that contains chrysotile for surfacing unpaved roads": Available upon request). Indeed, according the Maryland Cancer Registry, the incidence counts for mesothelioma for women in Montgomery and Baltimore counties for the years 1992 to 2003 were not elevated (10 Apr 2008: Hayes to Ilgren pers. comm.) and no mesothelioma clusters have ever been found that could be attributed to such allegedly harmful widespread asbestos exposure.

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[6] Freedom of Information Act

[7] Research Project Grant (R01) is the original and historically oldest grant mechanism used by NIH.

[8] Except perhaps for the fact that Selikoff's zeal may have been dampened by Kiviluoto et al. (1979) which failed to find a relation between the EPP zone and neoplasia and may have appraised him of this fact whilst his attempts to get him funding were underway (vs).

Finally, it should be noted that the first formal study of the Paakilla miners and millers (Nurimen, 1972) was funded by QAMA[9] and portions of an earlier Finnish study (Kiviluoto 1960) were funded by the company Suomen Mineralli.

4. The EPP and the Risk of Mesothelioma

Noro (1968) said “The Finnish Cancer Register shows that the incidence of cancer of the lung and pleural and peritoneal tumors is not higher in the "calcification area"[10] than in the other rural districts of east Finland during the years 1953-62, as Dr. Raunio has stated. Kiviluoto came to the same conclusion. Only one case of pleural or peritoneal mesothelioma has been detected during autopsies from this district (Kiviluoto)”.

Nurminen (1975) also wrote “There were no mesotheliomas reported from the communes surrounding the anthophyllite asbestos mine at Paakkila in the county of Kuopio, a finding which concurs with earlier reports.” This was confirmed by Hillerdal (1986) and Huskonen et al. (1995), ten and twenty years later respectively, wherein the latter said “It was concluded that cancer rates were not higher among the inhabitants in the communes around the Paakkila anthophyllite mine than in other rural populations.”

Others have confirmed the failure to observe an attributable increase in mesotheliomas in the endemic pleural plaque area. (Kiviluoto, 1979; Nurminen, 1975; Partanen pers comm to Hillerdal (op cit Hillerdal 1984); Hillerdal, 1984, 1986, 1997, pers comm 2015 ; Partanen et al., 1992; Huuskonen et al., 1995; Meurman et al., 1994; Kokki et al 2001, Pukkala, 2015 pers com, Kaarteenaho & Suntinen 2015 pers com). The incidence of mesothelioma in the so–called ‘endemic pleural plaque zone’ of Karaelia is not increased despite the presence of numerous deposits of anthophyllite in the area and their use in many homes (see below). Therefore, whatever environmental anthophyllite asbestos exposures Karelia residents may have incurred were clearly not sufficient to constitute either alone or in conjunction with other forms of asbestos, a mesothelioma risk.

4.1 Migration as a Source for other Amphibole Asbestos Exposure in the EPP

Migration and its potential effects on mesothelioma causation were discussed in some detail by Ilgren and Hoskins (2017, part 1 of this series). However, cases of asbestosis have been found in people working near Kuopio coming from Eastern Europe (Kaarteenaho & Suntinen, pers. comm. 2015). The asbestos exposure from sources in Eastern European factories is well known and could be confounding in the analysis of attributable disease in Karelia.

No doubt many left Karelia for a better life 50 years ago. A high percentage returned to Finland but not to their native homes, at least not on a permanent basis (Snellman, 2005[11]). In so doing, many brought asbestos exposure risk factors back with them particularly from working in jobs such as shipyards and factories associated with the use of crocidolite and amosite e.g. in other parts of Finland or Sweden. Therefore, if the Nynas study (Nynas et (2017)) missed a significant number of people who emigrated and then re-immigrated back to Karelia, they may not have recognized that the mesothelioma cases were not due to anthophyllite asbestos but to the risk factors acquired elsewhere from crocidolite and / or amosite.

4.2 Environmental Radiation as a Possible Causation of Mesothelioma

Nurminen (1975) was not able to find an asbestos association for 30% or more of the Finnish cases and said “it is also possible that mesothelioma of the pleura is not induced by asbestos… but even if asbestos fibers are not involved, other suspected environmental agents may be present”. Many areas in Finland are situated on diverse gneisses that are part of the Baltic shield and have similarities to those commonly associated with radon release from Uranium 238 in other parts of the world, e.g. the Reading Prong - a physiographic subprovince of the New England Uplands section of the New England province of the Appalachian Highlands consisting of mountains made up of crystalline metamorphic rock.) (Reading Prong, Schutz, D. (1987)). Similar geologic formations might also be sources of environmental radiation in some parts of Finland as well.

4.3 Domestic Exposure at Paakilla

Historically, the town of Paakkila consisted of ca. 50 to 100 homes. Most people living in the town worked in the mine and the mill. On average 120 men and women comprised the annual workforce. Some were as young as 12 years old. The mine and the mill were in operation from 1918 to 1978. The dust levels were horrific.

9 Quebec Asbestos Mining Association. Even more curious for the fact that Dr. Nurimen would not meet to discuss the work in 2015.

10 For clarity, the ‘calcification area’ was, according to Meurman et al. (1994), the administrative unit containing 900,000 people which also included Paakilla.

11 Snellman said she could not help us trace migrants since she would be in conflict with Partek (available on request)

hundreds of family members of the Paakkila miners and millers were seriously 'para-occupationally or domestically' exposed to anthophyllite asbestos. None has ever been shown to demonstrate an attendant mesothelioma response. Indeed, fifty years ago, Noro (1968) wrote "Knowing that the area has had 4,500 years of endemic exposure, in the last 50 years has been rather heavy in occupational exposures and has been increased among the neighborhood population by industrial air pollution and knowing that every third man over the age of 65 has pleural plaques, one could already expect more mesotheliomas in this district!" This was further supported by Nurminen (1975) who said that the "absence of residential clustering among the cases in Finland is a feature against environmental influence".

Huuskonen (2015 pers com), former Director General of the FIOH[12] from 1978 to 1988, personally examined all the asbestosis patients from Paakkila in the 1970s and 1980s but said (Huuskonen, 2015 pers com), "they never looked at the domestic exposure" issue. This is consistent with what he (Huuskonen, 1978) wrote forty years ago. Thus, "Para-occupational exposure of the family and the neighborhood and during leisure time work with products containing asbestos are areas of their own." Still, Huuskonen (1978) strongly suggested that such domestic did not put the residents at risk of mesothelioma saying "No convincing evidence exists that ambient exposure to asbestos – in air, water – increases the risk of asbestosis or malignancies". This is particularly compelling evidence against the role of domestic exposures to produce mesothelioma with anthophyllite asbestos given the tremendous historical doses, the long period for observation, the more than sufficient latency, and the fact that one of primary duties was his oversight responsibility for the health of the Paakilla workers.

Hillerdal (1986) said "Mesotheliomas have not been seen in the general population living near the former anthophyllite mines in Finland". Similarly, when I met Hillerdal in Stockholm nearly 30 years later, he again confirmed this to me in person (Hillerdal 2015 pers. comm.).

Mr. Matti Auvenin (2015, pers. comm.) a long-term resident of Paakilla from birth to the age of 21 said that he, his wife (Mrs. Paiva Auvenin, the Professor of Oncology at the University of Kuopio) and those of his extended family and friends that still lived in the town and nearby area, were unaware of any mesothelioma cases in the children of the workers. This was so even though he could remember large amounts of dust taken home on workers' clothes as well as the exposures he and his friends also got at riding their bikes over huge tailing piles, when they were "rained" on with dust during hockey matches in Paakilla, and when the mining and milling operations would blow dust into their homes that accumulated in their yard and covered their cars.

4.3.1 Environmental Studies of Family Members of the Finnish Anthophyllite Miners and Millers

As noted above, most people living in Paakkila who did not work in the mine or mill were still seriously exposed to anthophyllite asbestos dust from mining and milling operations but have never been shown to demonstrate an attendant mesothelioma response

4.3.2 Occupational, Domestic and Environmental Exposure in Relation to Finnish Anthophyllite Factories and the Products They Made and to Which They Were Exposed

Five factories received and processed the anthophyllite asbestos from Paakkila. Thousands of workers (> 5,000) worked in these five factories. High turnover increased the real worker numbers significantly. None of these factories has been formally studied epidemiologically (Osksa 2015, pers. comm.). Workers were exposed to astronomically high levels of anthophyllilite asbestos. This was compounded by very poor hygiene conditions including almost non-existent ventilation. Some describe working in snow storm dust conditions that prevented workers from seeing each other a few feet away (Paakkila Video 1978). This is reflected in the high levels of asbestosis found in those working in such environments where some data indicate nearly one half of the workers eventually developed asbestosis with five years exposure (Ahlman et al. 1973). Despite these long term, high dose exposures, mesotheliomas were not found in the five Finnish factories that processed Paakkila anthophyllite (Ans to Interogs Partek, 1996; Huuskonen, 2015 pers com by email). The failure to definitively identify a single *bona fide* case of attributable mesothelioma in these factory workers, their families and their neighbours despite more than adequate latency, extensive and intensive exposure, in more than an estimated total of 5,000 workers is remarkable. The Finnish factories also manufactured asbestos cement products with anthophyllite from Paakilla. The annual consumption of asbestos cement and asbestos cellulose cement products totaled 65,000 tons of which nearly all was made in Finland. Two other factories used 600 tons of raw asbestos a year for vinyl floor tiles (Huskonen, 1980).

5.

[12] Finnish Institute of Occupational Hygiene

5.1 Tapanila Asbestos Cement Plant, Helsinki

Aureola & Vesasalo (1954) was probably the first reference to Tapanila in the published literature. They said "Besides the production plant that operated in the immediate vicinity of the quarries, this firm owns a modern manufactory at Tapanila (near Helsinki) for turning out asbestos products." Tapinilla was the largest factory of five to receive anthophyllite asbestos from Paakilla. It operated from 1928 to 1978. The Tapilla Factory was originally situated 15 km north of the centre of Helsinki in a slum. The workers were very poor. (Snellman 2015 per com). Tapanila was chosen as the site for the factory since it was near the rail road lines and in 1910 situated only 10 minutes from the city centre. The anthophyllite probably went from Paakila either by boat or truck to Kuopio then by train from Kuopio to Kontiomaki and on to Tapanila. The worker population came from the northern and eastern Finland ca. 1920. There was relatively little migration from the town from 1920 to 1990 and many retired there.

Tapanila was the oldest of the five asbestos cement factories and was said to employ simultaneously about 250 workers between 1930 and 1965. The worker population declined to 150 thereafter. About 50 people also worked in the factory weaving imported asbestos textiles and manufacturing insulated masses. Between 1930 and 1972 this factory employed 2,000 people for at least three months and 1,300 for at least five years (Huuskonen & Tossavainen, 1978 - FIOH Annual Report). There was a very considerable turnover of labour.

A considerable part of the Paakkila asbestos was processed at the Tapanila plant owned by "Suomen Mineraali Oy" to produce asbestos cement, textiles, braided tight-materials, "Eternite", asbestos millboard, asbestos paper, mass for heat-insulation, granular product and grit for asphalt roofing factories. Grit and the short-fibered product are used for floor-mass, fire and acid-proof mortar. In 1952, 1246 tons of anthophyllite asbestos were processed by the Tapanila factory and 1586 tons by other domestic manufacturers, while 2,267 tons were exported.

"Air sampling data from Finnish asbestos cement factories were not available prior to the end of the 1960s. However, between 1970 and 1976 the average fiber concentrations were 1.5 fibers/cc (range 0.1 to 5 fibers/cc) in the oldest asbestos cement factory and the total dust concentration averaged 2 mg/m^3 (range 0.1 to 6.31 mg/m^3). These results do not reflect the conditions of the earlier decades, but do represent the situation in the 1970s in Finland's oldest factory and the current conditions of two other factories, which started their operations in 1959 and 1960" (Huuskonen et al., 1980). Tapanila IH data (fibers/cc) are only available after 1970. While the hygiene conditions had greatly improved by that time, the upper concentrations were still very high by modern standards (e.g. 8.5 fibers/ml). Earlier conditions were "exponentially" worse (Huuskonen et al., 1980).

Partek paid the FIOH to monitor workers and IH conditions annually from 1944 into the 1970s (Halonen, pers. comm. 2015). Huuskonen (pers. comm. Email, 2015) the former Director General of the FIOH, who personally oversaw the employees of these Finnish factories said he found no mesotheliomas as of 1978 at Tapanila after 50 years of operation. Table 2 in Huuskonen et al. (1980) provides data for Tapanila but it is only referred to as 'an asbestos product factory'.

Huuskonen and his colleagues diagnosed more than 144 cases of asbestosis from 1966 to 1978 but may have only seen 70% of the workers (Huuskonen & Tossavainen, 1978 - FIOH Annual Report). Huuskonen reported 107 other cases from 1941 to 1965 (Huuskonen & Tossavainen, 1978 - FIOH Annual Report).

I estimate there could have been as many as 500 asbestosis cases out of more than 2,000 workers, not just the 130 cases reported by Huuskonen et al (1980). Cases were also distributed approximately equally in men and women and the average age at diagnosis was 54 years (range 36-77). Asbestosis findings were also reported in detail in the 1978 FIOH Annual Report. Some "Tapanila" data were reported by Huuskonen (1978) but the workers were called 'Asbestos Factory Workers'; Tapanila was not mentioned. Huuskonen was the Director General of the FIOH when the data Tapanila data were produced but according to Oksa (pers. Comm. 2015) Tapanila has never been formally studied epidemiologically. When I suggested to Dr Oksa (2015 pers. comm.) this should be done, he said "that's a good idea".

The only peer reviewed scientific publication I am aware of that mentions Tapanila by name, aside from Aurola & Nieminen (1954) is Partanen et al. (1992). These workers demonstrated an increase in pleural plaques in the region of Tapinila. Indeed, the asbestos morbidity and mortality data for the specific factories are not mentioned in detail in the peer reviewed scientific literature; only cross cited in Finnish largely in the FIOH Annual Reports.

5.2 The Muijala Asbestos Cement Plant

The Muijala Plant located outside Helsinki was also owned by Partek and employed some 300 workers from to 1988. It produced asbestos cement sheets ('Luja wall sheets' and 'Vartti roof sheets'). Muijala was inspected the FIOH during the 1960s and the 1970s. As of 1996, only asbestosis was reported; no mesotheliomas (Ans to

Interogs).

5.3 Pargas Plant, Turku, Finland

The Pargas Plant situated in Turku in Eastern Finland employed ca. 50 workers per year. It was inspected by the FIOH during the 1960s and the 1970s. Pargas produced asbestos cement pipes from 1960 to 1978. (Himanit pipes – 1960 – 1978). Only asbestosis was reported as of 1996 (Ans to Interogs, 1996).

5.4 Studies of Family Members of the Finnish Anthophyllite Factory Workers

Thousands of children of the anthophyllite asbestos factory workers in Finland were probably seriously exposed domestically to anthophyllite asbestos. None has ever been identified in the literature as showing an attendant mesothelioma response

5.5 Environmental Studies of People Living around the Finnish Anthophyllite Factories

Thousands of people living around the anthophyllite asbestos factories in Finland who did not actually work in them were 'environmentally' exposed to the anthophyllite asbestos dust from the factory operations. The dust blew into their homes, accumulated in their yards, and covered their cars. No mesotheliomas have ever been reported in those thus exposed even though Partanen et al. (1992) reported an excess of pleural plaques around Tapinilla.

5.6 Occupational Studies of People Who Worked with Products from the Finnish Anthophyllite Factories

Thousands of people in Finland applied, repaired, and / or installed many different anthophyllite asbestos products made by these factories. Between 1918 and 1968, Paakilla processed ten different fiber grades of anthophyllite asbestos. These were used to make, amongst other products, fillers in acid and alkali-resistant products, thermal damping materials, welding electrodes, paints, corrosion preventives (Palomaki 1968); insulation material (Meurman et al. 1974). During the 1920s and 1930s, anthophyllite was used in asbestos sheet, insulation, roofing material (Huuskonen et al., 1980) and asbestos cement amongst other uses. None of those who have ever worked with these or other anthophyllite containing products has ever been shown to have an attributable mesothelioma.

5.7 "Domestic" Exposure of Family Members of the Finnish Anthophyllite Product Workers

Thousands of children whose families worked with these anthophyllite asbestos products may have been seriously exposed domestically to Anthophyllite asbestos. None has ever been shown to have developed an attributable mesothelioma.

5.8 Occupational, Domestic, and Environmental Studies of those exposed to Anthophyllite Asbestos Products living in other Parts of the World to which Finnish Anthophyllite Asbestos was exported either as Raw Asbestos and – or Finished Products

Finnish anthophyllite asbestos was exported to as many as 22 countries and 50 cities in other parts of the world. (Lunden, 1991). "In 1952, 1246 tons were processed by the Tapanila factory and 1586 tons by other domestic manufacturers, while 2,267 tons were exported" (Aurola & Nieminen, 1954); 90% of the processed fibers exported (Palomaki, 1968). Since 1975, 350,000 tons of anthophyllite have been mined in Finland, of which amount 120,000 tons have been used domestically" (Huuskonen et al., 1980). Potentially innumerable individuals may have incurred exposures in a manner similar to those in each of the aforementioned exposure categories to anthophyllite asbestos in the countries to which this fiber was exported. None has ever been shown to demonstrate an attributable mesothelioma response.

5.9 Lung Burden Studies of Non-Occupationally Exposed Individuals in Finland

The lungs of non-occupationally exposed individuals in Finland with no evidence of asbestos related disease have been shown to contain up to one million fibers per gram lung. A significant percentage (e.g. >25% if not greater) of the fibers also to be greater than 10 μm in length (Karjalainen et al., 1994a,b,c; Uibu et al., 2009; Tuomi et al., 1992).

6. Conclusion

Vast numbers of people in all sectors of the Finnish anthophyllite industry including their families have incurred significant exposures to anthophyllite asbestos. However, there has not been, to my knowledge, a single proven case of attributable mesothelioma amongst them. A few claims to the contrary have been based upon insufficient evidence. This conclusion is very robust since 70 years of mining, milling and manufacturing Paakilla anthophyllite asbestos has failed to produce one single clear case of attributable mesothelioma. This absence of mesotheliomas is best explained by anthophyllite asbestos' anomalous increase in width and particular intrinsic structural features.

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