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Review Article

Retrospective View of Airborne Dust Levels in Workplace of a Chrysotile Mine in Ural, Russia

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Abstract: The Bazhenovskoye chrysotile asbestos deposit has been exploited for 115 years. All the technological operations in the quarry are accompanied by the formation of high-dispersion asbestos-containing aerosols. The dust concentrations at the miner's working places for the last 30 years (1970–2000) were at or below the Russian MACs$_{m.s.}$ level (4.0 mg/m^3). The seasonal precipitation amount in the deposit area causes a rise in dust content in certain periods. The maximum density of asbestos respirable fibres exceeded 2.7 f/cm^3. All the identified fibres belonged to chrysotile asbestos, and no amphibole asbestos, such as tremolite asbestos, has been identified. An excessive dust level remains, despite the dust content level decrease, at the work sites of oversized lump drillers and unloaders, and oncopathology heightened risk remains in these occupational groups, as a result.

Key words: Bazhenovskoye chrysotile asbestos deposit, Chrysotile asbestos, Maximum allowable concentration, Asbestos-related disease, Asbestosis, Lung cancer, Russian Federation

Introduction

The Russian Federation is the largest producer and user of chrysotile asbestos in the world. Approximately 20 per cent of the world chrysotile asbestos output and over 47 per cent of the mining in Russia have been in the Bazhenovskoye deposit. The deposit was found on December 26, 1884 by the land-surveyor of the Ural Mining Management Aleksei P. Ladyzhenskiy[1]. Since 1886 the deposit has been exploited commercially for 115 years. During this period more than 4.5 billion tons of rock was mined and over 43 million tons of asbestos were produced[2]. The maximum asbestos production was 1.55 millions tons in 1975.

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The deposit is characterized by uneven asbestos richness in depth and length; the average asbestos content in ore is 2.3 per cent. Nowadays, the asbestos ores are mined from three mining open pits ("Southern", "Central" and "Northern") over an area of 16.5 km^2 and about 300 m deep.

Mining

During the first years of the exploitation the Bazhenovskoye chrysotile asbestos deposit was mined directly in the quarry[3]. The asbestos mind was sorted to length, packed and supplied to customers. Up to 1972 together with mechanized methods the ore mined in the pit was hand-sorted where the majority of the miners were engaged[4]. The pickers selected the ore with a content of 25–50 and more per cent of asbestos, starting

Table 1. Maximum Allowable Concentrations (MACs) for Occupational Exposure of Asbestos Containing Dust in the Russian Federation (mg/m^3)[7)]

1647. Natural asbestos (chrysotile, anthophyllite, actinolite, magnesio-arfvedsonite) and synthetic asbestos as well as mixed asbestos-rock dust with asbestos contained:	Maximum number density	Shift average concentration
Less 10	4.0	2.0
10–20	2.0	1.0
More 20	2.0	0.5
Asbestos Cement	6.0	4.0
Asbestos Bakelite	10.0	4.0
Asbestos Rubber	10.0	4.0

at 2–6 per cent.

At present asbestos ore extraction is done by complex mechanized methods[5, 6)]. Quarry mining is done with a system of quarry development transport consisting of moldboards and a sorting method. The bulk rock is excavated at 15 m benches with a 25–45 m operating beam width. The stripping is done by way of cul-de-sac passes. Truck transport is employed on lower and intermediate levels, and railroad transport on intermediate and upper levels.

To start the ore mining, vertical and inclined holes are drilled with roller-bit drilling machines. The operators and assistant operators of the drilling machine do drilling tool feeding and replacement, mouth hole cleaning, displacement, minor repair and cleaning of the drilling machine. The operators and assistant operators of the drilling machine work in the open pit.

The deep-holes are charged with explosives by a mechanized method. The area prepared is then exploded. Excavators on dump trucks having a load-carrying capacity of 30–120 tons load the exploded bulk rock, and remove it to the intermediate levels, where the dump trucks are unloaded onto the reloading base. Dump truck drivers perform the operation during their entire work shift.

There are separate reloading bases for the ore and enclosing rock. Unloaders regulate the unloading order on the reloading base; the time they are at the unloader working place takes up 75 per cent of the work shift.

On the reloading base the excavators load the ore or barren rock into dump trucks to transport them to the dressing mills and spoil banks.

In a number of cases oversized lumps are crushed. The drillers drills out the oversized lumps with the help of a hammer hand drill, eliminate small troubles, and clean up the outfit. The drillers are at the drillers workplace in the entire work shift.

Tractors, graders and other highway engineering machines are employed for to level the reloading area, and for intraquarry railroad and highway construction. The workers engaged in it are at the workplace in the asbestos pit during the entire working shift.

Maximum Allowable Concentrations for Asbestos

Since the 1930s in the USSR, and now in the Russian Federation, the Maximum Allowable Concentrations (MACs) index has been in use for dust content evaluation, and the total amount of dust content is expressed in mg/m^3. Before 1954 asbestos-containing dust MACs constituted 10.0 mg/m^3, and since 1954, for dust containing over 10.0 per cent of asbestos fiber, a new MACs has been reduced to 2.0 mg/m^3. The validated MACs developed on the basis of clinic-hygienic comparison has proved to be sufficient for the prevention of such asbestos-related occupational diseases as asbestosis and chronic dust-risk bronchitis. In 1989 new MACs were elaborated (oncology safety being taken into account) and sanctioned to be differentiated as to the asbestos content in the dust mix and the degree of its surface covering with bonding[7)]. Along with maximum single concentrations ($MACs_{m.s.}$), the shift average concentrations ($MACs_{s.a.}$) have been validated, ranging from 0.5 mg/m^3 (with asbestos content in dust exceeding 20.0 per cent) to 2.0 mg/m^3 (less than 10.0 per cent of asbestos) (Table 1). $MACs_{m.s.}$ ranging from 2.0 to 10.0 mg/m^3 are subdivided based on the same principle.

Dust Levels

The results of the research work done in various quarries of the Bazhenovskoye deposit prove that the asbestos content in the soaring dust mix does not exceeding 10.0 percent, so that in the introduction of dust content norms the standardized values $MACs_{m.s.}$ − 4.0 mg/m^3 and $MACs_{s.a.}$ − 2.0 mg/m^3

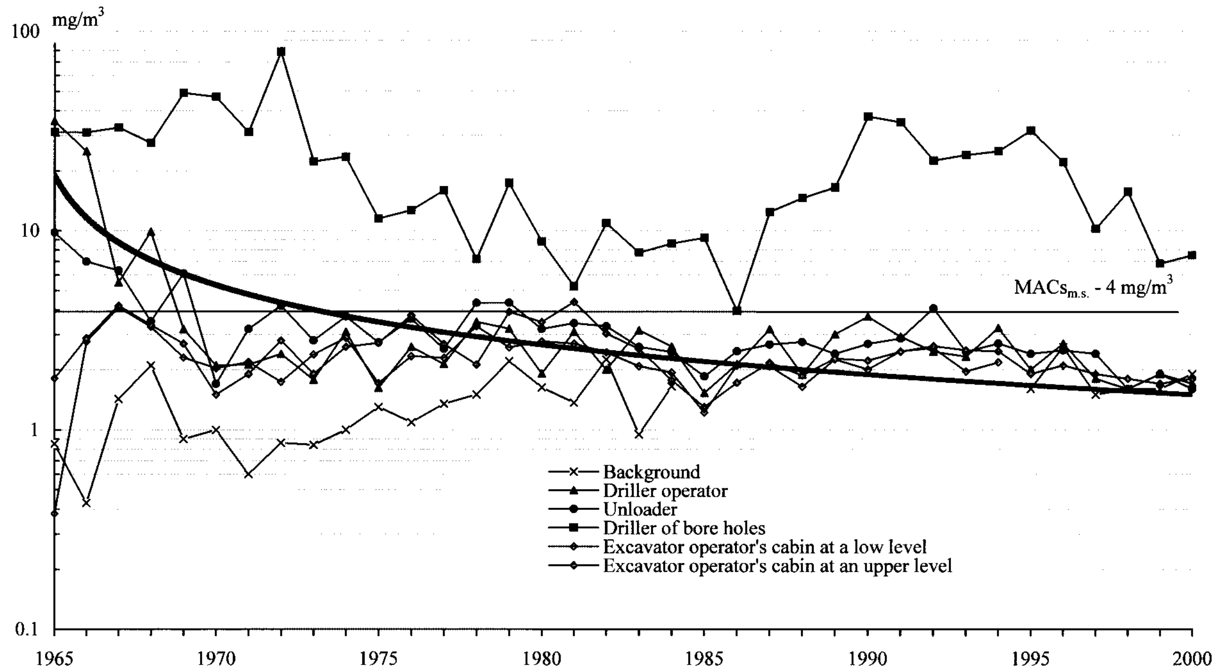

Fig. 1. Dust concentrations in mine (1965–2000), thick line has shown of the total trend dust level.

should be adhered to.

All the production operations in the process of chrysotile ore mining are followed by dust separation of varying intensity. The dust content levels in the main working places in the quarry for the period 1965–2000 are given in Figure 1. According to the analysis of dust content for the period covered, the dust concentration at the most of the operator's working places has decreased, despite the variability of results obtained as a whole in the open pit, and irrespective of bulk rock mining output increase as well as the capacity augmentation of the equipment employed. The gradual decrease in dust content has been attained due to the implementation of dust-attacking system measures, such as the use of dustproof driver's cabs on the mining machines and their outfitting with dust-exhaust fans and dust filters, drilling with a water dust-trapping system, refusal of ore hand-grading in the pits, intrapit roads treatment with alcohol-sulphide wash and the main roads covered with asphalt.

As has been shown herein, drillers of oversized lumps and unloaders belong to the unhealthy occupations accompanied by a high level of dust content at the work sites. Dust content in the productive activity of the occupational groups reached 101.3 and 24.1 mg/m^3, respectively before 1965[8]. The analysis of dust content at the miners' workplaces has proved that the concentration at the absolute majority of the miner's working places has constantly decreased for the past 30 years. The dust

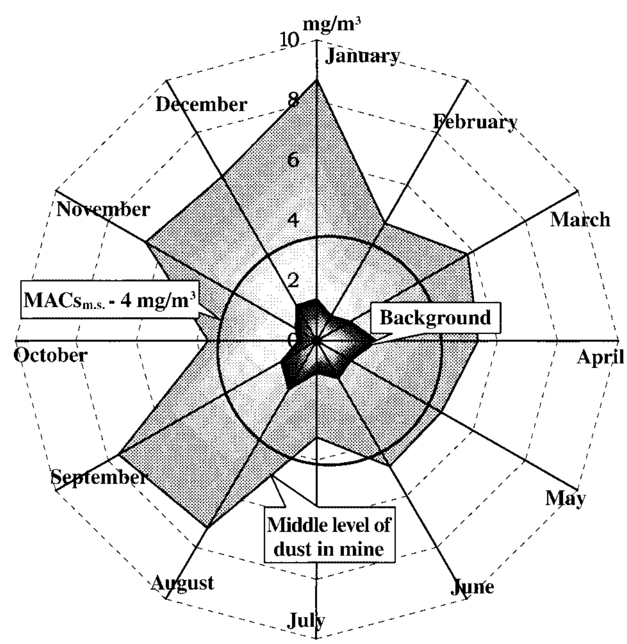

Fig. 2. Seasonal distribution of the dust concentration in mine.

concentrations, as a rule, were at the level or below MACs$_{m.s.}$.

The dust concentration at most operators' workplaces in the pit depends on weather conditions. Dust content seasonal dynamics for the same period of observations is given in Fig. 2. The seasonal amount of precipitation in the deposit area determines the dust content increase at some periods of the year. The dust level of the work place in the quarry is not great during February–March, June–July, and September–October, because there is much precipitation in these seasons.

Fiber Levels

When the Finnish-American-Russian project "The Health Surveillance of Siberian Asbestos Miners" (1995–1997) was in progress, the Russian and American hygienists made measurements of the mass concentration and number density of asbestos fibres at the main miners workplaces in the pit in the process of chrysotile ore mining (Table 2)[9]. The number density of asbestos respirable fibres ranged from 0.01 (repair men's working place) up to 0.27 f/cm^3 (excavator cab). Background fiber concentrations were recorded up to 0.08 f/cm^3. The maximum number density of asbestos respirable fibres at individual miner's workplaces exceeded 2.7 times the norms suggested by the American National Institute for Occupational Safety and Health for all asbestos species −0.1 f/cm^3[3, 10]. All identified fibres in dust samples were chrysotile asbestos and no amphibole minerals were detected in the phase contract optical microscopy (PCM) or scanning electron microscopy (SEM) samples[11, 12]. Nonfibrous dust particles were mostly composed of serpentine minerals. The quartz concentration was below 1.0% as determined by X-ray diffractometry in the ore and dust samples[9].

Table 2. Phase contract fiber count concentration in quarry (f/cm^3)

Working place. Operation	Variance	Average
Excavator operator	0.11–0.27 (0.12)*	0.17 (0.16)**
Driller operator	0.06–0.09 (0.02)*	0.07 (0.06)**
Bulldozer	0.05–0.20 (0.04)*	0.11 (0.11)**
Truck operator	0.20	—
Locomotive operator	0.05–0.15 (0.07)*	0.09 (0.09)**
Maintenance/Electrician	0.01–0.03	0.02
Railway fitter	0.05	—
Background	0.01–0.08 (0.004–0.03)*	0.03 (0.03)**

*Samples taken by the Center's collaborators, **average concentration with the account of samples taken by the Center's collaborators.

The degree of dispersion of dust in the pit, studied by PCM and SEM methods, is rather homogeneous (Table 3). The dust consists mainly of granular particles (90.1–98.3%) up to 5 μm (81.5–95.6%)[13]. The fibrous particles range from 1.7% (drilling machine cab in the process of drilling) to 9.9% (excavator cab in ore reloading), in which respirable fraction fibres at different miner's workplaces are from 40.1% (unloaders position in the ore reloading base) to 90.0% (excavator cab in the ore reloading base).

Medical Examinations

No medical examinations of the mining shop miners have been carried out for a long time, as only brawny men with robust health went to work in the quarry[14, 15]. When the miners were medically examined for the first time in 1952, 8.0% of those examined had a diagnosis of asbestosis, of them 7.3 per cent—asbestosis stage I, and 0.7%—asbestosis stage II (Fig. 3)[8]. In 1954 five per cent of the miners

Table 3. Size and morphological composition of the airborne dust in workplaces in quarry (%)[13]

Working place. Operation	Particles, μm					
	grains			fibers		
	all	up to 5	>5	all	up to 5	>5
Excavator cab:						
– ore and rock loading	92.6	95.6	4.4	7.4	54.2	45.8
– ore reloading	90.1	87.9	12.1	9.9	10.0	90.0
– rock reloading	95.9	87.3	12.7	4.1	41.8	58.2
Woman-piler's working place:						
– ore reloading base	93.7	90.9	9.1	6.3	37.9	62.1
– rock reloading base	97.9	90.9	9.1	2.1	59.9	40.1
Drilling machine cab:						
– hole drilling	98.3	91.3	8.7	1.7	36.4	63.6
Drillers working place:						
– oversized lumps drilling	96.9	81.5	18.5	3.1	48.7	51.3
Dump truck cab:						
– ore and rock transportation	94.1	91.6	8.4	5.9	67.8	32.2

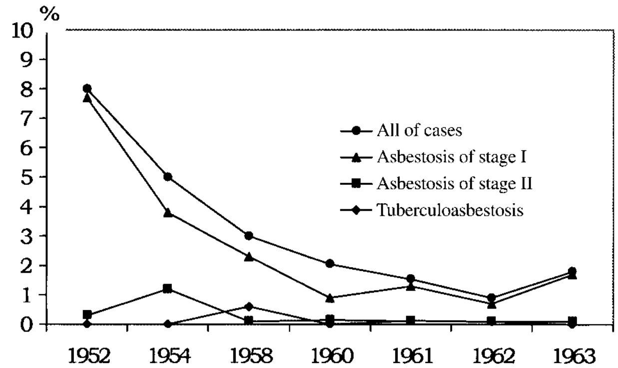

Fig. 3. Diagnosticate of the new occurences of asbestosis (1952–1963).

examined were diagnosed with asbestosis, including 3.8% stage I; and 1.2% with asbestos stage II. To 1958 the number of asbestosis cases newly diagnosed decreased to 2.4%, and at that time 0.6 % of asbestosis cases were complicated with tuberculosis. For the period 1960–1963 the number of newly diagnosed asbestosis cases was within 0.9–1.8% of the miners examined, mainly diagnosed with asbestosis stage I[16]. All the asbestosis cases were diagnosed among the hand-labor miners with 15 years of service under dusty working conditions and working without respirators. During 1964–1996 only three new cases of category-I asbestosis among all the miners working in the pit was diagnosed[11]. Asbestosis was diagnosed among the drillers of oversized lumps and women-pilers. For the whole period of surveillance among the excavator operators in the quarry no asbestosis case was detected. Higher noise and vibration levels generated by the mining equipment are the causes of all the occupational diseases among the miners.

The malignant tumor epidemiology investigated among the miners engaged in asbestos mining (1948–1991) shows that, for the period of 1968–1979 in comparison with 1948–1967, the index of risk of development of cancer in all locations among men was reduced from 3.3 to 2.7; and that of pulmonary cancer was reduced from 3.9 to 2.9[17]. As far as women are concerned for the same period, the cancer-risk index in all locations increased from 2.1 to 3.9 and that of pulmonary cancer, from 3.9 to 9.4 in those occupational groups in which there were chrysotile ore pickers who were taken to work there after the chosen ore hand-labor mining had come to an end. For the period 1987–1991 a further study showed a reduction in the cancer at all locations: beside men previously 1.6, and woman's previously 1.5, pulmonary cancer previously 1.5 and 1.2.

Conclusion

Thus, according to the materials submitted, all the technological operations in asbestos ore mining in the Bazhenovskoye chrysotile-asbestos deposit quarry are accompanied by the formation of high-disperse asbestos-contained aerosols characterized by disintegration of various intensities. All the identified fibres belonged to chrysotile asbestos. No amphibole asbestos, such as tremolite asbestos, has been identified.

The analysis of dust content at the miners' working places has proved that the concentration at the absolute majority of the miner's workplaces for the last 30 years (1970–2000), as a rule, was at the level or below Russian $MACs_{m.s.}$ (4.0 mg/m^3). The seasonal precipitation amount in the deposit area causes a rise in dust content at certain times of the years. Maximum number density of asbestos respirable fibres at individual miner's workplaces exceeded 2.7 times the norms suggested by the American National Institute for Occupational Safety and Health for all asbestos species — 0.1 f/cm^3.

The study of occupational diseases and malignant tumor occurrence demonstrates that as to the miners, occupational diseases are mainly diagnosed where there is a high level of noise and vibration. An excessive dust level remains, despite the dust content level decrease, at the workplaces of oversized lumps drillers and unloaders, and oncopathologically heightened risk remains in these occupational groups as a result.

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