UDC 616–057:622.874

Hygienic characteristics of labor conditions for main occupations in the asbestos cement industry of the Ukraine

Украина асбестцементті өндірісіндегі негізгі кәсіби мамандардың еңбек әрекетінің гигиеналық сипаттамасы

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Мақала авторлары Украина асбестцементті өндірісіндегі негізгі кәсіби мамандардың еңбек әрекетінің сипатын және еңбек жағдайын зерттеді. Сондай-ақ ауа жағдайын сипаттайтын, микроклиматтық жағдай, шу деңгейі, вибрациялық жүктеме және еңбек процесінің ауырлығы мен еңбек қауырттылығы бойынша көрсеткіштерді анықтады.

На основе изучения условий труда и характера трудовой деятельности рабочих основных профессий асбестоцементных предприятий Украины представлены показатели, характеризующие состояние воздушной среды, микроклиматические условия, уровни шумовой, вибрационной нагрузки, тяжесть и напряженность трудового процесса.

The issue of asbestos use is a critical world problem [1–3]. It has been long debated and being primarily a medical problem it has also acquired an economic and political nature. The presence of a certain risk of asbestosis, a specific fibrosis of lung tissue, and of a blastomogenic process (bronchial carcinoma, pleural and peritoneal mesothelioma) in workers occupationally exposed to asbestos raises no doubt [4–8]. However the body of evidence showing that asbestosis and specifically lung cancer are related to the uncontrolled use of amphibole asbestos has been increasing recently [9, 10]. Thus, the ban of this type of asbestos is perfectly substantiated today [11, 12]. As for chrysotile asbestos accounting for almost 95 % of all asbestos mined in the world, there appear more and more convincing data in the world literature proving that this type of asbestos is low aggressive and can be safer for human health than its substitutes, the number of which exceeds 20, in case of its controlled use [13, 14]. At least at the moment there exist no epidemiologic studies giving evidence of a higher health risk of chrysotile compared to its substitutes.

According to some researchers (Yu.I.Kundiyev, E.P.Krasnyuk, A.A.Dobrovolsky [15]) the problem of the continued use of chrysotile asbestos must be solved by improving the control of its concentrations in workplace air. Russian researchers E.I.Likhachev et al. [16] also note that in modern conditions of the chrysotile mining and milling with low asbestos dust concentrations the average duration of dust exposure of workers until the development of asbestosis increases to 20.5 years; the progression of fibrous changes in lungs prolongs, too. One of the ways of a safe and controlled industrial use of chrysotile asbestos is the estimation of exposure doses of dust on respiratory organs of workers (personal dust loads). Based on data obtained by a team of researchers of the RAMS Institute of Occupational Medicine, a «critical value» of the dust burden for the whole period of exposure to asbestos-containing dust has been substantiated; it can help effectively prevent the development of dust-related diseases [17].

In the Ukraine there is no medical statistics that gives evidence of a high health risk of the use of chrysotile asbestos in the production of asbestos cement. Only 18 cases of asbestosis have been registered in the Ukraine for the last 25 years of monitoring of occupational diseases; cases of occupational cancer (pleural mesothelioma, lung cancer, etc.) have not been registered at all.

One of the a priori explanations of the situation is the circumstance that asbestos is not mined in the Ukraine and 11 asbestos-cement factories working with the imported raw (chrysotile asbestos) deal with bound asbestos in the form of an asbestos-cement mixture. Yet, in some shops (a preparation department) a direct contact of workers with chrysotile fibers is possible. Besides, fine asbestos dust, especially in dry weather conditions, can move freely in the air of most industrial premises. It can be found as airborne dust at workplaces with no sources of chrysotile emissions.

The effect of the dust factor is certainly related to the dust load, which, in its turn, is determined not only by dust concentrations in workplace air but also by the duration of dust exposure, the respiration depth and rate. The latter depends on the severity of work and microclimate at workplace.

Thus, there are grounds for a complex approach to the dose evaluation of dust loads affecting workers of the asbestos-cement production with account for the duration, severity and conditions of the microclimate. And, finally, when the task is set to study the heath risk of workers exposed to adverse occupational factors, the most important provision of the methodology of the occupational risk assessment is the consideration of the whole complex of adverse factors at the workplace.

This study on the hygienic evaluation of occupational conditions at the main asbestos cement enterprises of the Ukraine was conducted from these positions. Similar studies have never been conducted in the Ukraine before.

Materials and methods. Measurements and hygienic evaluation of factors of occupational environment and work processes were performed at the following enterprises: «Kievsky Slate Factory, Ltd.», «Balakleysky Slate Combine, Ltd.», «Kramatorsky Shifer, Ltd.», a subsidiary of private company «Kryazh» Krasnogvardeysky Slate Factory, «Techprom, Ltd.» Amvrosiyevka, JSC «Zaporozhsky Factory of Asbestos Cement Products», «Firm «Delta Boug, Ltd.».

Dust concentrations in workplace air were measured in accordance with Method Guidelines of the Ministry of Health of the USSR № 4436–87, *Measuring concentrations of aerosols with a predominantly fibrogenic effect.*

Air sampling was performed using aspirators «Typhoon» R-20–2 on filters AFA-VP-10. Then the filters were weighed using the analytical balance VLR-200. The duration of measuring maximum concentrations was 30 minutes with the volume velocity of sampling 20 l/min. At some workplaces the volume of pumped air was increased to 2,000 liters.

Dust concentrations were calculated as follows (1):

$$V_N = \frac{V(273+20)(P-P_N \cdot f)}{(273+t^{\circ})(760-P_0)}, \tag{1}$$

Where, V_N is a normalized air volume, dm; P is the shift average atmospheric pressure at the site, gPa; P_N is the pressure of the saturated steam at a certain temperature, gPa; f is the relative air humidity at the site, fractions; $t°$ is the average air temperature at the site, °C; P_0 is the pressure of water vapors at 20 °C and air humidity of 50 % (this value is constant and equal to 8.7 mm Hg or 1,160 Pa).

The air volume is calculated as (2):

$$V = gt, \tag{2}$$

Where, g is air flow for 1 minute and t is the time of measurements in minutes.

For a quantitative determination of asbestos concentrations in the airborne dust we conducted an X-ray structural analysis in accordance with Guidelines for measuring a mass portion of chrysotile in samples by a quantitative X-ray phase analysis developed by the Asbestos Research Institute («NIIprojectasbest»), 2004, Asbest (Russia) [18].

To establish the number of asbestos fibers in the airborne dust we applied a counting method in accordance with the Methods of establishing the fiber count in ambient and workplace air developed by «NIIprojectasbest» in 2001, Asbest, Russia [19]. The measurements were conducted during sequential sampling (during at least 75 % of the work shift with the coverage of all basic work operations), the duration of sampling — 30 minutes per sample, the minimum number of samples — 3.

Measurements of noise and total vibration were conducted according to acting normative and method documents (GOST 12.1.050–86, *SSBT (Systems of Standards in Occupational Safety). Methods of measuring noise at workplaces*, DSN 3.3.6.037–99, *Ukrainian State Sanitary Norms of Occupational Noise, Ultrasound and Infrasound*; GOST 12.1.012–90, *SSBT. Vibration Safety — General Requirements*, DSN 3.3.6.039–99, *State Sanitary Norms of Occupational Total and Local Vibration*») using a sound level meter and spectre analyzer «Oktava-101 A», a noise measurer VSV-003-M2 with vibropacks (DN-3, DN-4).

The noise exposure was assessed based on the equivalent level of noise in acoustic decibels and the vibration exposure — by the equivalent adjusted level of vibration acceleration of total vibration in decibels.

Microclimate parameters (temperature, relative humidity, and air velocity) were measured in the beginning, in the middle and in the end of the work shift, 0.5–1.0 m above the floor if the worker sits and 1.5 m above the floor if he stands most of the work shift.

The air temperature was measured by an aspiration psychrometer «Assmana»; the air velocity was measured using a flowmeter IS-02 in warm seasons at constant workplaces.

The evaluation of microclimate parameters was performed in accordance with requirements of GOST 12.1.005–88, *General Sanitary and Hygienic Requirements for Workplace Air*; DSN 3.3.6.042–99, *State Sanitary Norms for the Microclimate of Workplaces*.

The study of the severity of labor was based on indices of the dynamic work, the mass of the lifted and transferred load, static load, the number of routine movements of hands and fingers, and the work posture.

Labor intensity was assessed by indices of the attention function, tension of analyzing functions, emotional and intellectual tension, and indices of labor monotony.

Assessment of labor severity and intensity was performed according to criteria of the Hygienic Classification of Labor (based on indicators of hazard and risk of factors of the occupational environment, severity and intensity of the work process) No. 4137–86.

A complex assessment of labor conditions was also performed in accordance with the criteria of this classification.

Results

Our studies showed that the technological process of manufacturing asbestos-cement products in all factories is similar. Its main stages include asbestos batching, mixing it with Portland cement and preparing an asbestos cement mixture (Portland cement — 80-90 %, chrysotile asbestos — 10–20 %, water), forming asbestos cement products in sheet forming machines, drying and moving them to the warehouse of finished products.

The study results indicate that asbestos-containing dust is the main adverse factor in the asbestos cement industry. A significant dust generation and dust emission was observed at all workplaces under study (Table).

Table

Maximum*, shift average concentrations of dust and respirable fibers*** of chrysotile asbestos in workplace air for the main occupations**

Enterprises	Concentrations of dust, mg/m^3 and respirable fibers/cm^3							
	Batching workmen		Operators of the preparation department		Operators of sheet forming machines		Operators of electric bridge cranes	
«Kievsky Slate Factory, Ltd.»	16.6–21.5* 5.2–7.0**	0.09–0.32***	1.1–1.5* 0.8–2.0**	0.09–0.12***	0.9–2.6* 0.6–1.6**	0.09–0.11***	0.8–1.5* 0.7–1.0*	0.094–0.26***
«Balakleysky Slate Combine, Ltd.»	9.8–14.3* 2.2–3.0**		6.9–8.6* 1.7–2.8**		1.7–2.9* 0.9–1.6**		0.8–1.8* 0.8–1.5**	
«Kramatorsky Shifer, Ltd.»	13.3–20.4* 1.9–2.7**		2.8–3.3* 1.9–2.9**		2.9–3.0* 1.8–2.6**		1.8–2.0* 1.4–1.7**	
A subsidiary of private company «Kryazh» Krasnogvardeysky Slate Factory	18.9–20.0* 1.5–1.6**		3.1–4,3* 1,2–1,5**		1.4–3.2* 1.1–1.8**		1.1–2.9* 1.3–2.0**	
«Techprom, Ltd.» Amvrosiyevka	9.7–11.0* 0.6–0.9**		0.7–1.8* 0.6–1.0**		1.0–2.4* 0.7–1.4**		0.5–1.9* 0.6–0.8**	
JSC «Zaporozhsky Factory of Asbestos Cement Products»	6,8–10,7* 0,6–0,8**		0.6–0.7* 0.5–0.9**		0.6–0.7* 0.6–0.7**		0.3–0.4* 0.2–0.3**	
«Firm «Delta Boug, Ltd.»	7.7–11.6* 0.7–0.9**		0.5–0.6* 0.6–0.7**		0.4–0.5* 0.5–0.6**			

Note: Maximum permissible concentrations: *Maximum — 2.0 mg/m^3 (if the percentage of asbestos in dust exceeds 20 % according to GOST 12.1.005–88, supplement 4); **Work shift average — 0.5 mg/m^3 (if the percentage of asbestos in dust exceeds 20 % according to GOST 12.1.005–88, supplement 4); ***of respirable fibers — 0.2 f/cm^3 (USA, 1986).

According to the table the excess of maximum permissible concentrations of chrysotile asbestos was noted:

• For maximum concentrations – at all workplaces of batching workmen (3.4–10.8 times); at workplaces of operators of the preparation department of the Krasnogvardeysky Slate Factory, Balakleysky Slate Combine Ltd., Kramatorsky Shifer Ltd. (1.4–4.3 times); at workplaces of operators of the sheet forming machine of the Kievsky Slate Factory, the Krasnogvardeysky Slate Factory, Balakleysky Slate Combine, Ltd., Kramatorsky Shifer Ltd., Techprom Amvrosievka Ltd. (1.2–1.6 times), at the workplace of the operator of the electric bridge crane of the Krasnogvardeysky Slate Factory — 1.5 times;

• For work shift average concentrations – at all workplaces (1.1–14.0 times);

• For the asbestos fiber count in 1 cm^3 of air – at workplaces of batching workmen and the operator of the electric bridge crane (1.6 and 1.3 times according to U.S. standards, 1986) in the Kievsky Slate Factory, Ltd.

Thus, according to the criteria of the «Hygienic Labor Classification…» No. 4137–86 labor conditions of workers of the main occupations must be attributed to Class III of hazard and risk degrees 1, 2 and 3 by the factor «Dust of predominantly fibrogenic effect».

Microclimate parameters at workplaces of the above occupations significantly depended upon meteorological conditions of the environment and technological processes. When the ambient temperature exceeded 25 °C, the temperature at workplaces was 2–6 °C higher than normative values. In some cases high levels of relative humidity and air mobility were noted.

The main sources of noise and vibration at asbestos-cement enterprises are batchers, mullers (with SM-139 and SM-874 drives), hydrofluffers, turbo mixers, ladle stirrers (SMA-159 A, SM-889), sheet forming machines (SM-943), and electric bridge cranes.

High levels of noise were mostly observed at workplaces of operators of sheet forming machines (the maximum permissible level was exceeded by 4–10 dB), operators of the preparation department (by 2–11 dB) and operators of bridge cranes (by 3–6 dB).

As for the vibration load from total vibration, then the maximum permissible level was exceeded at workplaces of operators of sheet forming machines (by 1.5–5.9 dB), operators of bridge cranes (by 1.7–4.8 dB) and at the workplace of operators of the preparation department of the Balakleysky Slate Combine — by 6 dB.

Differences in the levels of noise and vibration at similar workplaces of different factories are often related to distinctive features of organization of the technological process, the extent of the equipment wear, and the location of the workplace with regard to noise and vibration sources, which is determined by a specific design. An example is the workplace of the operator of the preparation department of the Balakleysky Slate Combine where the control panel is located on metal scaffolds close to the equipment generating noise and vibration. As a result, the operator is exposed to highest levels of noise and vibration (5–12 dB and 10–13 dB higher than in other factories, respectively).

In asbestos-cement factories the main stages of the technological process are mechanized and automated. Nevertheless, some technological operations require manual labor. Here we speak about the work of batching workmen. Their responsibilities include unpacking of the 50-kg sacks with chrysotile asbestos and emptying them into the bunker of the batcher-mixer.

Some elements of manual labor can be also found at the next stages of the technological process just like the necessity to work in a forced work posture, with often tilts, etc. These very components of physical activity mainly determine severity of labor for the described occupations. Based on criteria of the «Hygienic classification of labor…» No. 4137–86 some of them (the batching workman, for instance) should be attributed to Class III of Degree 2 of hazardous and risky labor conditions. Workers of these very job categories with high physical activity accompanied by a significant increase in the respiration depth and rate obviously experience higher dust exposure in conditions of an asbestos-cement enterprise.

Labor intensity of workers of main occupations in asbestos-cement industry is chiefly determined by levels of sensor loads and in operators of bridge cranes — also by a high level of emotional stress. Our data shows that labor intensity is very high for operators of the preparation department, operators of sheet forming machines (Class III, Degree 1) and especially for operators of bridge cranes (Class III, Degree 2).

Conclusions

1. The leading adverse industrial factor in asbestos cement production is chrysotile dust, the mass portion of which in the airborne dust at the workplace of the batching workman can be as high as 100 %; and at workplaces of the operator of the preparation department, the operator of the sheet forming machine and the operator of the electric bridge crane – over 50 %.

2. Maximum concentrations exceeded the maximum permissible concentration of chrysotile dust at all workplaces of asbestos batching workmen (3.4–10.8 times) and at workplaces of operators of the preparation department. Average work shift concentrations exceeded the maximum permissible concentration of chrysotile dust at all workplaces (1.1–14.0 times). Concentrations of respirable asbestos fibers in the workplace air

can vary in the wide range – from 0.09 to 0.32 f/cm^3. At the workplaces of the asbestos batching workmen and the electric bridge operator the maximum permissible concentration was exceeded by 1.6 and 1.3 times, respectively (according to U.S. regulatory values, 1986).

3. Workers of the main occupations of the asbestos cement production are exposed to a complex of adverse industrial factors such as elevated temperature and air humidity, noise (the excess of the maximum permissible level varies from 2 to 11 acoustic decibels), total vibration (the excess of the maximum permissible level varies from 1.5 to 6.0 dB based on vibration acceleration), which corresponds to Class III, Degree 1–2 of hazardous and dangerous labor conditions according to criteria of «Hygienic Labor Classification…» No. 4137–86. The occupation of the asbestos batching workman must be also attributed to the category of rough labor in asbestos cement industry (Class III, Degree 2); to the category of intensive labor — work of the operator of the preparation department and the operator of sheet forming machines (Class III, Degree 1); work of the operator of the bridge crane (Class III, Degree 2).

4. Accepting the concept of the controlled use of chrysotile-asbestos, in accordance with Convention No. 162 and Recommendations No. 172, the hygienic ensuring of labor safety on asbestos cement factories should provide for the introduction of progressive technologies with complex automation and mechanization of industrial processes, exclusion or minimization of manual labor; optimization of use of collective (during unpacking of asbestos in the first place) and personal (special work clothes, respirators) protective means; a systematic medical control of workers' health and the follow-up of accumulation of critical doses of dust loads in workers and their timely removal from occupation; safety instructions and promotion of a healthy mode of living.

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