Risk Assessment for Stonecutting Enterprises

A J Aleksandrova¹, and S S Timofeeva²
¹Master, National Research Irkutsk Technical University, Irkutsk, Russia.
²Professor, National Research Irkutsk Technical University, Irkutsk, Russia.
E-mail: aleksandrova.angelina1993@yandex.ru

Abstract. Working conditions at enterprises and artisanal workshops for the processing of jewelry and ornamental stones were considered. The main stages of the technological process for processing of stone raw materials were shown; dangerous processes in the extraction of stone and its processing were identified. The characteristic of harmful and dangerous production factors affecting stonecutters is given. It was revealed that the most dangerous are the increased level of noise and vibration, as well as chemical reagents. The results of a special assessment of the working conditions of stone-cutting plant workers are studied. Professions with high professional risk were identified; an analysis of occupational risks and occupational injuries was carried out. Risk assessment was produced by several methods; professions with high and medium risk indicators were identified by results of the evaluation. The application of risk assessment methods was given the possibility to justify rational measures reducing risks to the lowest possible level. The received quantitative indicators of risk of workers of the stone-cutting enterprises are the result of this work.

1. Introduction
Our humanity has been aware of natural stones for a long time. They have been connected with everyday life of human beings since the very first stages of human civilization development. There are good grounds for a prolonged and ancient stage of the humanity history to have been called the Stone Age. At those times people appreciated the role of stones and started using them to make tools, primitive household articles and arms. In the process of mineral properties perception, selection and dressing the humanity accumulated information about stones. Stones were specific in their hardness, colour specifications and the form of appearance. Natural stone had been subjected to a long period of development before it was discovered in carving forms which they were supplied with foremen lapidary. At present, the development of carving art has been extended to different corners of the world, the traditions of stone dressing keeping on their development and opening new orientations.

The art of stone-carving is one of the most ancient expressions of art. Stone products made of ornamental stones are products intended for dressing the interior of living rooms, executive function offices, institutions, etc. The ornaments of stone can beautify a human being as semi-precious stone products also belong to jewellery [1]. For clarity, stones can be divided into practical – decorative ones covering the objects of everyday life, writing sets, pen stands, ashtrays, jewel-boxes, desk-lamps and jewellery and purely decorative ones covering vases, pictures of stone, mosaics, indoor sculpture, etc. [2]. In the interior, the products of stone are most often exhibited on special mounts, display facilities and supports. They can also be displayed on book-shelves, writing tables and as decorations and possess a certain decorative function.
At present there is a great number of enterprises and craft shops engaged into gem dressing on the territory of the Russian Federation. The enterprises famous for being large in the European part of Russia are the open joint-stock companies of “Moscow Stone Dressing Industrial Complex”, “Uralkamen” in Chelyabinsk region in the Urals, “Kolyvan Stone Carving Works” in the region of Altai and the open joint stock company of “Baikalkvarts’samotsvety” in Irkutsk region. Each of these plants started its activities as a small shop where each of the products was carved in a manual way. The process of workpieces production from natural stones is quite labour intensive and complicated. All the technological processes in the above field are inherent in great labour inputs.

2. The aspect of technologies
To find out the way that a stone turns into a subject of admiration one should give consideration to the technological aspect of items production from the stone and understand the risks and problems occurring in the process.

As a matter of fact, searching and prospecting of a stone deposit is the starting stage of exploration. The extraction of gem stones calls for substantially different technological processes and equipment as compared with the extraction of other mineral resources and needs an absolutely different execution order and sequence of mining operations within an open-pit field [3]. Some special variations of stripping and development systems are determined by the above difference. Extraction of the stone is carried out mainly as a result of open-pit operations. Drilling and blasting operations are used to develop stripping [4]. The process of stone raw material extraction substantially affects the enterprise engaged people and is negative for their health.

The open-cut mining of mineral resources is inherent in the following dangers:
- explosive deflagration resulting in no explosion;
- unauthorized explosions during blasting operations en masse;
- water breakthrough or mined rock watering of surface opencast workings, overflowing the area of operations and equipment location;
- collapse of mined rock and steps;
- workers being traumatized and bruised along with getting other somatic injuries when they happen to be trapped in a zone of devices in motion, and some other dangers.

After the extraction, stone blocks are delivered to a stone cut production. This is followed by four production stages: saw cutting, generation of geometry, debugging and polishing.

The technological process of gem items production at a stone dressing enterprise consists of the following operations:

1) Saw cutting is a process of cutting great stone boulders into smaller pieces. Boulders being delivered to the works from a stone deposit cannot be used for direct processing if they are not cut into rather small pieces. To prepare the raw material for dressing stoncutters use different sorts of diamond impregnated saws. They fix them on a corresponding machine-tool with the construction inherent in the sizes of the stones being cut and the specific purpose of cutting. The greatest boulders are cut into thin plates or blocks which are followed by the blocks being cut into smaller work pieces and undercuts (Figure 1a). Precious material is cut with small saws to minimize the wastes [5].

2) Generation of geometry. The process of geometry generation results in the work pieces acquiring their final forms following the surface dressing. Different methods can be used to provide the work pieces with final forms depending on the kind of raw material subjected to dressing and what kind of end product is to be resulting. Each stone is peculiar in its own way, so a special approach is to be used with regard to each one in the process of geometry generation (Figure 1b). At the given stage the product acquires its primary outlook of a designed item with the assistance of such instruments as drilling tools, abrasive tools, miniature cutting saws, manual abrasives and other auxiliary devices. On imparting a sketchy outlook to a product it is directed to be debugged.

3) Debugging. The operation being considered is an intermediate one between the generation of geometry and polishing. It is the last stage of stone dressing in the process of geometry generating prior polishing. The debugging process is not complicated: all you need is to rub the stone against a
flat plate having some abrasive material put on it. This mode is always applied for when an even surface is to be obtained on a flat cut or on thin parts of a product (Figure 2). Debugging usually starts from using some coarse grain abrasive and is finished by using the finest of it [6].

4) Polishing. The final dressing of a product covers making a stone surface fully brilliant and smooth [7]. The quality of this kind stone dressing depends on the previous stages of geometry generation and debugging. Dazzling and smooth surfaces that are usual for polished stones result from the surface contact with a rotating soft material such as felt, leather, fabric or wood (Figure 2b). The materials are loaded with polishing pastes and contribute to stone polishing. Sticks made of hard wood can be used to dress hard-to-reach spots. They are fixed in a collet holder of a drilling tool and overdoned with the paste enriched in a micropowder.

![Figure 1](image-url)

**Figure 1.** The operations of stone-cutting production, where a is the process of stone cutting, b is the process of formation.

3. Risk analysis

Professional risks occur at each stage of stone material dressing. They are a number of physical, chemical, psychophysical factors that are dangerous and impregnated with a harmful effect for human health. The workers are exposed to such dangers as those of moving products and semiproducts of stones, dust in the process of cutting and polishing the stone, the temperature of the stone surfaces being dressed, moving devices and mechanisms, cutting waste from metallic tools cutting the stone, etc. Modern output of stonecutting products is characteristic for the use of equipment with dangerous technological parameters in the processing [8] (noise, vibration, air dustiness, moving tools) and a sufficient level of different chemicals.

A number of professions characterized by high professional risks were revealed on investigating and analyzing the resulting data of special estimating the working conditions of workers for stone-cutting productions and a shop engaged in raw gemstones dressing which is a production shop of jewellery. The professions of this kind are as follows: a grinder, a polisher of stone products, a stone cutter, a jeweller-assembler, a jeweler – integrator, a carver of stones [9].

Several methods were used to assess professional risks for most dangerous professions: predictive assessment of professional risks, determination of an individual professional risk for a worker, evaluation of professional risks on the official place of work resulting from questionnaire. The methods of predictive assessment and determination of an individual professional risk are objective ones as they are based on the results of official place of work assessment performed at an enterprise, whereas professional risk assessment on the official place of work based on questionnaire is a subjective one as it results from workers interrogation. The results of professional risk assessment based on these methods revealed that every worker of a stone cutting production has to be employed in
some operation environment conditions which make a negative effect on their health.

**Figure 2.** The operations of stone-cutting production, where a is the process of polishing stone; b is stone polishing process.

With regard to safety, stone cutting industry is one of the dangerous productions [10] and leads to feedback effects influencing the workers’ health in the course of performing technological operations. It means that before we admire the art of stone carving a great number of complicated stages and operations are to be completed to extract and dress stone material.

The present paper deals with the assessment of professional risks resulting from stone dressing and jewelry making having taken the open joint-stock company of “Baikalkvarts’samotsvety” located in Irkutsk region of the Russian Federation as an example.

Unsalutary production factors were revealed as a result of instrumental measurements. The used measuring instruments were the ones that had been exposed to a state control and their metrological data were certified in the prescribed procedure.

The presence of steady sources of an intense noise was found to be a specific peculiarity of the stone-dressing industry, manufacture of carved stone products including: production machinery, stone carving tools (the sound of hydro-abrasive machinery and ultrasound found in the operation environment, vibration perceived at every stage of production), fans and exhaust plants.

Noise measurements were performed in accordance with the authorized test procedure [11]. The results obtained are presented in Table 1.

**Table 1.** The results of noise level evaluation on the official work places.

| The indication of a work place | MAL, [dBA] | Real level of work environment factor, [dBA] | Working conditions class |
|-------------------------------|-----------|---------------------------------------------|-------------------------|
| Grinder-polisher              | 70        | 74.4                                        | 3.1                     |
| Stone sawer                   | 70        | 74.4                                        | 3.1                     |
| Jeweller-assembler            | 70        | 74.4                                        | 3.1                     |
| Jeweller-integrator           | 70        | 74.4                                        | 3.1                     |
| Carver of stone               | 70        | 74.4                                        | 3.1                     |

As follows from the data represented in Table 1, the indices of noise level on all the official work places exceed authorized level limits. This is indicative of the fact that the labor condition class for noise level at these places is harmful (Class 3.1). The excess of noise level at the official work places
is conditioned by the workers being in a close proximity to the production machinery which is a source of noise affecting the functional state of a worker’s organism.

Chemicals in the production of stone-cut workpieces are represented as harmful substances and belong to 1-4 Classes of danger. They are characterized by having different effects on the organism, some of them possessing a delayed and slow aftereffect. To calculate the concentration the methodology of photometric makeup estimation was used for each of the substances available in the work zone [12].

The production workers of such professions as jeweler-assembler, stuff-setter, polisher are commonly exposed to chemicals effect.

Table 2 shows the readings of chemicals in the work zone air of the professions being investigated.

| Indication of chemicals (in the work zone) | Real value | Standard value | Danger class | Working conditions class | Exposure time |
|------------------------------------------|------------|----------------|--------------|-------------------------|---------------|
| Phthalic anhydride, mg/m³                | 0.29       | 1              | 2            | 2                       | 70            |
| Acetone, mg/m³                            | 15         | 200            | 4            | 2                       | 60            |
| Formaldehyde, mg/m³                       | 0.012      | 0.5            | 2            | 2                       | 50            |
| Hexamethylenediamine, mg/m³              | 0.71       | 1              | 2            | 2                       | 85            |

**Time weighted averages of concentrations (TWA)**

| Indication of chemicals (in the work zone) | Real value | Standard value | Danger class | Working conditions class |
|------------------------------------------|------------|----------------|--------------|-------------------------|
| Phthalic anhydride, mg/m³                | 0.07       | 1              | 2            |                         |
| Acetone, mg/m³                            | 13         | 200            | 2            |                         |
| Formaldehyde, mg/m³                       | 0.007      | 0.5            | 2            |                         |
| Hexamethylenediamine, mg/m³              | 0.64       | 1              | 2            |                         |

Basing on the results of experimental measurements a calculation of professional risks was performed. It was found that the risk tended to be the medium one. Besides, special attention should be paid to psychophysiological factors of production, such as hearing and eyesight tension, considerable physical loading, limited, single-type movements of hands and special sets of fingers, prolonged, tense, inconvenient working posture, steady loads.

4. Conclusion

A stone-cutting industry is a potentially dangerous field for the workers engaged. A group of unfavourable factors characteristic for the operational environment (vibration, noise, a chemical factor) is formed by peculiarities of the technological process, the equipment used in it, mechanization and automatization levels of stone-cutting workpieces production.

In spite of the fact of a negative effect in the working conditions of stone-cutting production being proved the number of its workers does not become less. From the data obtained in literature it is clear that the production under consideration belongs to the category of dangerous production objects resulting in the number of people exposed to professional, accidental and ecological risk growing from year to year.

That was the reason of assessing the risks of disability for workers engaged in the stone-cutting production, the state of working conditions being paid special attention to as they exert influence on formatting professional risks, criteria of industrial security and the development of possible events oriented at risk minimization. As a result of the assessment, noise and chemicals were revealed to be the most unfavourable factors of risk.

The probability of a professional risk realization can be found at any industrial object. Therefore, the application of the methodology assessing the risk of dangers allows to reason some rational
measures that allow to make the risks as low as possible. The methodology of predictive risk assessment can be objective and subjective. The paper under consideration deals with the risk assessment in a stone-cutting production which is the identification of dangers typical for the given field, determination of danger dimensions in regard to a worker’s health and their possible after-effects.

Thus, the investigations performed allow to assess the risk for the health of production workers.

References
[1] Alexandrova A Yu and Timofeeva S S 2016 Proc. of “Technosphere Safety in XXI Century” 24–32 (in Russian)
[2] Jerrard R et al 2007 Design management: Exploring fieldwork and applications 5 102–121 (London: Routledge)
[3] Bordunov S V and Galtseva O V 2016 J. Phys.: Conf. Series 671(1) 012009 DOI: 10.1088/1742-6596/671/1/012009
[4] Mining encyclopedia Retrieved from http://www.mining-enc.ru (in Russian)
[5] Robleda A S et al 2010 DYNE (Colombia) 77(161) 77–87 ISSN: 00127353
[6] Konstanty J 2002 J. Mater. Process. Technol. 123(1) 146–154 DOI: 10.1016/S0924-0136(02)00071-7
[7] Sinkankas J 1989 Guidelines for the Processing of Precious and Semiprecious Stones (Moscow: Mir) (in Russian)
[8] Dorofee A J et al 1996 Continuous Risk Management Guidebook (Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University)
[9] Alexandrova A Yu 2016 Proc. of “Security Problems of the modern World” 7–8 (in Russian)
[10] Encyclopedia of Safety Retrieved from http://survincity.com/2012/04/stone-cutting-art-cultural-richness-of-the-country/
[11] GOST (State Standard) R ISO 9612-2013 Acoustics. Noise measurements for the evaluation of its effects on humans. Measuring method workplace (Moscow: Standartinform) (in Russian)
[12] Chemical Encyclopedia Retrieved from http://www.xumuk.ru/encyklopedia/ (in Russian)