Hygienic and Ecological Justification of Natural Light Transportation System in the City of Tyumen

G A Sukarnaeva\textsuperscript{1,a}, I D Sulkarnaeva\textsuperscript{2,b}, E V Bulgakova\textsuperscript{3,c}

\textsuperscript{1,3}FSBEI HE «Tyumen Industrial University», Tyumen, Russia (625000, Tyumen, Volodarsky str., 38)

\textsuperscript{1,2,3}FSBEI HE «Tyumen State Medical University», Tyumen, Russia (62500, Tyumen, Odesskaya str.,54)

\textsuperscript{2}FSAEI HE «University of Tyumen», Tyumen, Russia (625023, Tyumen, Volodarsky str.,6)

E-mail: \textsuperscript{a}gas200768@mail.ru, \textsuperscript{b}l.d.sulkarnaeva@utmn.ru, \textsuperscript{c}elena-bulgakova-00@mail.ru

Abstract. This paper performs the assessment of the effectiveness of organization of natural light transportation in Tyumen Region, describes the primary natural light transportation systems: light lanterns, solar tents, glass roofs, Solarspot systems, light wells; determinates advantages and disadvantages of natural light transportation systems implementation, analyses the results of simulation of upper, lateral and combined lightning and measurements and assessment of the illumination and the coefficient of natural illumination, as well as studies on the light transmission ability of corrugated glass under the open sky; using hygienic and ecological arguments, justifies the usage of natural light transportation for the city of Tyumen; considers the possibility of the installation of mirrors for Tura River embankment.

1. Introduction
Activation of metabolism, impact on the synthesis of hormones and positive psychological effect by natural light and solar insolation are examples of their great importance for the human body.

Favourable lightning tones, improve one’s mood and the main processes of higher nervous activity. Lack of solar (natural) light leads to decreasing of human’s organism resistance to hostile environment, stress, strain and stamina and the development of anaemia.

The Relevance of this Research is connected to variable benefit humans gain from natural lightning: health and comfort of eyes, decreasing of energy consumption and related money saving, improvement of the exterior of the building. The strong demand for natural lighting in the interior room leads to the increasing importance of natural transportation into closed spaces.

The Main Objectives of the Study:
- To figure out the central systems of light transporting, to point put their main advantages and disadvantages;
- To assess the effectiveness of the organisation of natural light in the Tyumen Region;
- To analyse the results of simulation of upper, lateral and combined lightning and;
- To study the light transmission of glass with different corrugation;
- To give an ecological and a hygienic justification of usage of natural light transport system in the city of Tyumen;
- To recommend the ways of improvement of insolation of the Tura river embankment.

2. Theoretical Part

Glass roofs are constructions made of glass. Due to their shape (pyramid, arc, dome, horizontal surface), glass roofs provide maximal usage of natural light. This fact is useful to fulfill the demands of the current requirements of energy efficiency. The central demand for the material of the roofs are translucency and durability. The glass must prevent overheating of the rooms in sunny weather and reduce the heat emission during the winter time.

The material of the glass roof must withstand snow and wind loads, as well as repairs carried out. Such methods as tempered glass, a double-glazed window, triplex, reinforced glass with a metal grid that preserves its integrity in case of fracture are used to increase the durability of a glass roof [1].

The double-glazed window represents a design from two or several glasses which are hermetically connected on a frame.

The space between the panels can be filled with an inert gas to improve the noise and thermal insulation properties of the double-glazed window. For the manufacturing of roofing glass, all types of glass are used, but to ensure the durability and safety of glass, it is essential to use tempered glass and triplex. Triplex (laminated glass) consists of two or more sheets of ordinary glass bonded to each other with a specific film. This film does not allow the glass to break up into fragments when it is destroyed and increases its resistance. Moreover, such glasses characterized by satisfying thermal and noise insulation as well as resistance to temperature extremes. Properly designed and well-mounted glass roof is durable and reliable. It is able to level the penetration of ultraviolet radiation into the building, and also does not allow dust, smoke and harmful emissions into the room.

The disadvantages of a glass roof include: the ability to heat up from the sun rays to a high temperature in the summer period (to solve this problem, insulating materials are used to reduce the heating level of the glass surface, as well as a ventilation or air-conditioning system); the high cost of impact-resistant glass, which increases the durability of the roof structure; large amount of dust and pollution accumulates on the roof surfaces it is necessary to provide an access for cleaning workers to the roof [2].

Light well is a kind of equipment for lighting rooms with natural light. It is a pipe that transmits sunlight to the room. The top of the light well is located on the roof of the building. It collects sunlight with the help of various collectors, reflectors and other devices. The shape of the light well is very important for the transmission of sunlight. A straight and short well is the most effective conductor of natural light. On the other hand, a well with corners, turns, or a long one contributes to the dispersion of part of the light. Transparent materials with high reflectivity (for example, fiber) are used to reduce the loss of sunlight. The bottom of the well is displayed in the room. It has devices for dispersing sunlight.

The advantages of using light wells: these devices prevent the penetration of infrared and ultraviolet rays into the room; they do not allow hot air in summer and cold in winter penetrate the room; have a long service life (up to 30 years); reduce energy costs [3].

Light reflectors and mirrors. The Canadian company Sun Central offers the Solar Canopy system. The basis of this design is a frame with a set of small light mirrors, deviating horizontally and vertically to follow the sun. These mirrors direct light to two pairs of parabolic mirrors that compress the light flux and throw it into the mouth of the lightbox, which from the inside is covered with a mirror film. In the lower part of the box, there is a prismatic diffuser, forwarding light running down the box to the room. Inside the box, there are also fluorescent lamps that illuminate the room at night or in cloudy weather [4].

The Solarspot system is a natural lighting system using hollow tubular light guides [5]. The Solarspot system consists of three parts: the light receiving, light transporting, and light distributing. The light receiving device is a transparent acrylic dome located on the roof or facade, the design of
which includes an optical element that receives sunlight and diffused light of the sky and redirects them inside the light guide.

Advantages of the Solarspot system: energy saving; long service life; low sunlight losses; exclusion of overheating of premises during the summer period of the year and lack of heat losses in the winter; no need for constant maintenance; uniform distribution of luminous flux, which provides visual comfort in the illuminated room; possibility of combining with installations of artificial lighting [6].

Light lanterns consist of a dome made of polycarbonate and acrylic and a metal base. Two- and three-layer domes are used to increase the durability [7].

3. Practical Significance
According to results of hygienic assessment of different light transporting system using impact on human sight as a criteria and analyses of such parameters as energy consumption, energy costs, efficiency of its usage during winter time and effectiveness of its usage in the city of Tyumen, the most effective system for transporting natural light is light lanterns and a light well. These systems have a minimum cost and energy costs, while energy savings and efficiency of use in the winter are high.

Glass roofs are the most expensive system for transporting natural light, as they have high energy consumption and create the need for a heating system that prevents the accumulation of snow in the roof.

Also, for a hygienic assessment of the efficiency of light transportation, we experimented. We simulated upper, side, and combined natural lighting using an installation designed as a room. We used a box with a height of 30 cm, a length of 38 cm, and a width of 25.5 cm as a model. The floor inside the box covered with brown paper, the walls were beige, and the ceiling was white. In the roof of the box, there was a hole imitating a lantern with a size of 15.5x7.5 cm, as well as a side opening of the same size.

Natural illumination was measured using a TU 4215-003-16796024-04 “TKA-PKM” luxmeter (registered in the register of measuring instruments 24248-04, certified according to GOST R ISO 9001-2001) [8] in various positions: 1 - the top hole was covered with glass, the side was closed with a thick cardboard (in beige colour); 2 - side hole was covered with glass, the top was covered with a thick cardboard (in white colour); 3 - both holes are covered with glass.

The experiment was conducted outdoors, in the open air, in June, in sunny weather. The illuminance was measured on a non-shaded horizontal surface, as well as inside the box in the various above options.

The results of the experiment: Option 1 - illumination of 361 lx, KEO (coefficient of natural light) - 4.31%; Option 2 - illumination of 234 lx, KEO - 2.79%; 3 option - illumination of 428 lx, KEO - 5.11%.

Modelling and measured illuminance and KEO showed that the upper light transport is more efficient than the lateral one. Combined natural lighting (top and side together) give the best results for light and KEO.

Also, on the same model, we investigated the light transmission ability of corrugated glass. The difference in illumination inside the model without glass and with its use was estimated. The results of this study are presented in Table 1.

Analysis of the data in Table 1 showed that the largest light transmittance has glass in a large cell, with corrugation upwards. Reinforced glass has the lowest light transmittance.

A review of international experience in the transportation of light revealed the effective use of mirrors. In India, mirrors located at an angle on the opposite wall are used to increase the natural light in rooms with side windows.

There is a quite unusual experience of using mirrors outdoors. In Italy, in the village of Viganella (for a long time was in a dark area) mounted on a mountain mirror measuring 8 × 5 meters, allowed to reflect sunlight and illuminate the space in this village. Inspired by this Italian project, Norwegian engineer and entrepreneur Sam Eide and artist Martin Andersen got down to business. It took those
five years to create and coordinate the project of installing a system of mirrors in the Norwegian town of Rjukan (before there was no sun for six months a year, from September to March). October 18, 2013 mirrors with an area of 51 square meters were installed, which allowed illuminating the main square of the city with reflected light [9].

Table 1. The results of the study of light transmission ability of corrugated glass.

| Type of light-conducting material | The difference in illumination E, lx |
|----------------------------------|-------------------------------------|
| Glass with a smooth surface      | 34                                  |
| Corrugated glass with a ribbed surface: |
| ribbed up                        | 26                                  |
| ribbed down                      | 33                                  |
| Glass fluted in a large cell:    |
| ribbed up                        | 22                                  |
| ribbed down                      | 34                                  |
| Glass fluted with a surface in a small cell: |
| ribbed up                        | 34                                  |
| ribbed down                      | 35                                  |
| Glass reinforced                 | 76                                  |

In the city of Tyumen in the afternoon, the Tura River Embankment is also in the shadow. In the summer, this circumstance may have a positive effect on Tyumen’s rest on hot days, but for other seasons the possibility of illuminating with reflected light from the mirrors installed on the opposite bank of the Tura river will have a tonic effect on people. Using the above-described experience of using mirrors, it is possible to implement this idea, which can be modernized, by adjusting these mirrors (closing or opening with roller blinds of durable non-wetted material) closing in the morning and opportunity in the second.

4. Summary

Thus, we believe that the best light transportation system for the city of Tyumen on the premises is the installation of light lanterns and a light well. The overhead transportation of natural light is more efficient than the side one. Glass with large cells corrugation, directed upwards, has a higher light transmittance. Indicated the possibility of transporting light to improve insolation in the afternoon of the Embankment of the Tura River with the help of mirrors.

The hygienic justification for the use of natural light transportation systems in the city of Tyumen lies in the fact that it has a beneficial effect on the health, visual comfort of a person, in contrast to artificial light. The environmental justification for the use of these systems is to save energy; there is no need to dispose of lamps, as well as to improve video-ecological indicators.

5. References

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