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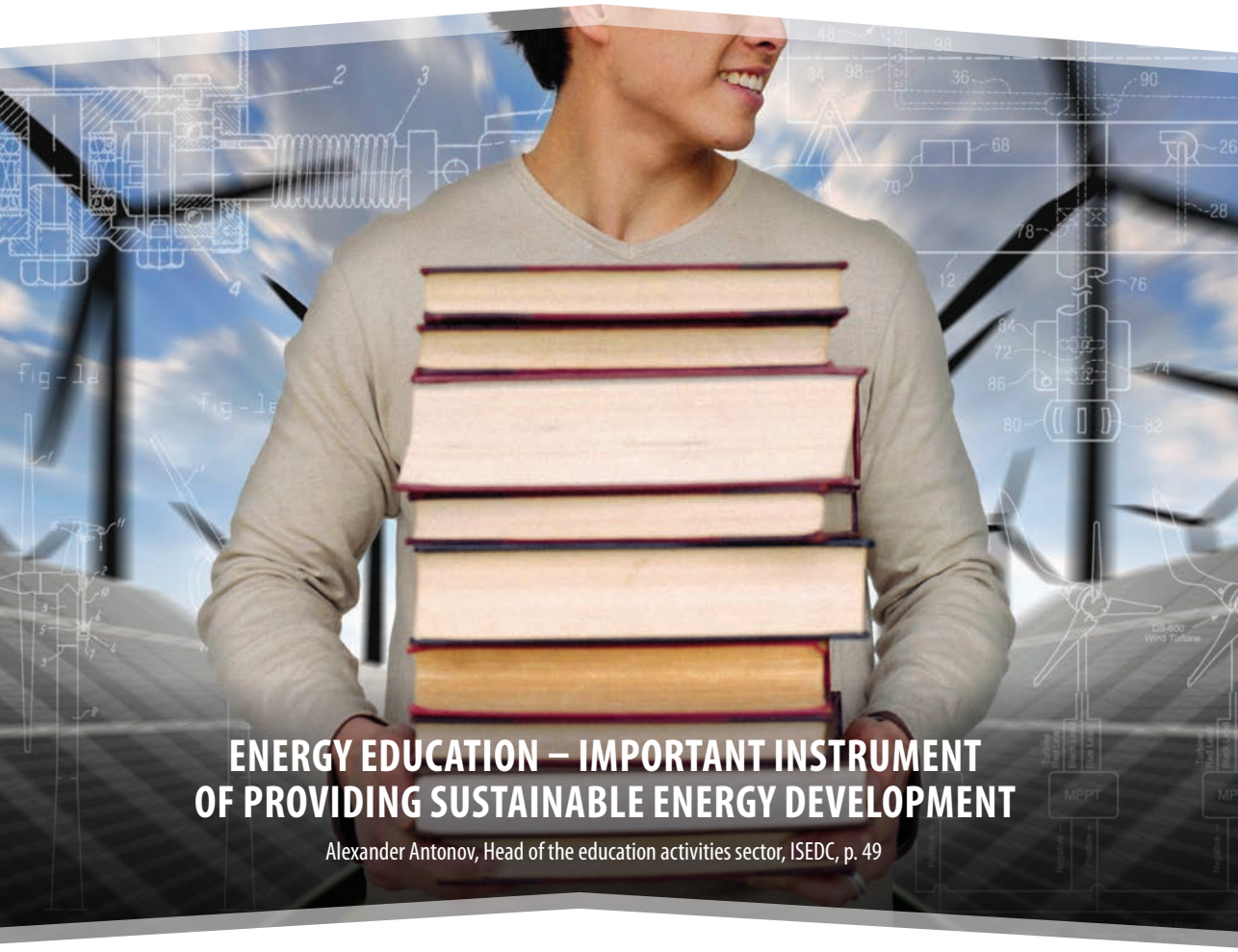

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Modern Lighting in Schools

Galina Fedyukina,
Lead Researcher,
Russian Lighting Research Institute (VNISI)

The Russian Lighting Research Institute named after S.I.Vavilov (VNISI) is Russia's leading lighting research centre dealing with theoretical issues, methods, technology and standardisation of lighting, as well as specialising in the development of high performance lighting and irradiation equipment/systems for the agriculture, defence and space industries.

Introduction

Experience shows that there is a correlation between pupil performance on the one hand, and the physical environment in schools, on the other. That is why improving the learning environment in schools means investment in the future. Artificial lighting of school buildings is essential for successfully implementing educational programmes, providing adequate visibility for pupils solving complex visual tasks, as well as for improving the energy efficiency of lighting. One of the main issues here is eyesight health, because children and young people in Russia are increasingly suffering from eyesight problems. According to statistics, 22-25 per cent of young people who leave school have impaired vision, the number of vision defects increasing 2.4-2.5 times during school years. It is primarily the development of nearsightedness (or myopia). Among the causes of myopia are poor natural light and the lack of artificial lighting. This is proved by the fact that the overall rate of myopia in pupils depends on the area of residence. For instance, research studies conducted in our country from 1978 to 1982 reported the rate of myopia to be 11-39% in the north and 5-8% in the south. Researchers attribute the prevalence of myopia in pupils living in the northern regions to a number of reasons, chief among them being specific light conditions and poor lighting in schools. Inadequate or poor-quality lighting is known to trigger the development of myopia due to incorrect posture caused by bringing objects too close to eyes to see, which results in eye strain when reading, writing and drawing. This sets particularly high requirements for lighting in schools, since not only do school children actively develop their visual skills, but their eyes continue to grow and the eye's refraction continues to change until the age of 18-24 years, depending on climatic conditions and ethnic background.

Lighting surveys of schools regularly carried out in Russia's urban and rural areas in the early 1980s and in the 2000s reveal that not even half of lighting requirements have been complied with since the surveys began. What is worse is that, in general, lighting conditions in schools are constantly deteriorating. Even in Moscow schools the average illuminance on the white-board/blackboard surfaces is 130-140 lux, with the required level being 500 lux. The average illuminance in classrooms varies from 50-100 lux

to 250-260 lux on the working plane, though it is required that this illuminance should not fall below 400 lux. Most school buildings are lit with outdated fluorescent lamps, and as a result the luminance flicker frequency is 2.5-3 times higher than the maximum allowed. Despite the fact that a number of regulations adopted in 2003 prohibit the use of incandescent light bulbs to light classrooms, they are still used in many schools equipped with outdated and inefficient lamps, which means that 35% to 40% of excess energy consumption can be saved, thus offering great potential for cost reduction.

Hence there is an urgent need to provide adequate lighting in schools, which requires compliance with relevant requirements for lighting when using new technologies.

Basic lighting requirements

Lighting requirements include health, environmental and energy aspects. In addition, lighting conditions should be comfortable. The health aspect includes standardising lighting parameters that ensure best practice visual performance and prevent fatigue. The environmental and energy aspects are related to the use of energy efficient light sources and lighting control systems for reduced energy consumption. This, in turn, reduces harmful emissions into the atmosphere, thus preventing pollution of the environment. It should be noted that environmental education has already been integrated into the school curriculum, so it is necessary to raise awareness amongst school children about some practical issues of lighting and energy saving (e.g. the need to turn off unused lights), which may have a positive impact on the future of mankind. How comfortable lightning is has practical importance, because this exerts a background influence on standardised parameters for lighting and provides the correct lighting environment.

The values of recommended lighting parameters depend on many factors: the purpose and physical characteristics of rooms; the type, complexity and duration of visual tasks to be carried out in a room.

In accordance with the modern concept of the general education system, all schools are supposed to act as centres for meeting the educational needs of communities, so, ideally, schools are viewed as full day educational institutions providing pupils with the opportunity to acquire knowledge and learn new skills, do homework, practise sports, join special interest clubs, have fun and eat out. To manage, organise, facilitate and control the educational process, various teaching aids and equipment are expected to be widely used.

In this context, architectural and planning solutions, the design of buildings and technological equipment are to meet the requirements of the educational process. In addition, professionals involved in designing lighting schemes for school buildings should have extensive knowledge of lighting equipment.

In Russia, primary documents used in engineering design are health and construction regulations based on international standards.

It is worth noting that the new health standards for educational institutions, which came into force on 1 September 2011, include up-to-date requirements for lighting.

Lighting indicators

An important characteristic of light is illuminance on the working plane and, according to Russian regulations, it is understood to be the minimum illuminance. Normalised values of illuminance are set depending on the type and complexity of visual tasks to be performed, and on the levels of fatigue to be assessed by the amount of time spent entirely on visual work when the eye's line-of-sight is directed to the working surface. Reading and writing require an illuminance of 400 lux on the working plane (desks). As for sketching and drawing, there must be a maintained illuminance on the working plane (whiteboard/blackboard) of not less than 500 lux. Illuminance can be horizontal, vertical or spatial (cylindrical).

Depreciation factor. Normalised values are the values below which the average illuminance should not fall during the use of equipment. Therefore, it is required that a depreciation factor of 1.4 should be applied for school buildings used under normal conditions, and that normalised values should be multiplied by the depreciation factor.

Non-uniformity of illuminance. An illuminance level is determined for a particular work area. And in order to avoid brightness fluctuations within the field of view, it is necessary to

standardise illuminance conditions in immediate surroundings, with the illuminance in this case having a lower value.

Limitation of glare. One of the undesirable effects of illumination is direct and reflected glare, which hinders vision and is the result of excessive contrast between bright and dark areas in the field of view. It can also be caused by directly viewing a light source. According to the latest edition of national standards and regulations, the psychological direct glare is evaluated and limited using the UGR method (Unified Glare Rating), which is well-established as an international index. This method calculates the glare of the entire lighting installation at a defined observer position. Normalised UGR values for school buildings intended for different purposes are 14-25.

Shadow formation. To enhance the visual perception of three-dimensional objects it is necessary to strike the right balance between light and shade which is achieved by maintaining a certain ratio between horizontal and cylindrical illuminance. The optimum ratio of Eh to Ec is 1.6-3.0.

Spectral composition of light sources. To create a physically and psychologically comfortable environment in premises, it is necessary to select light sources, taking account of their colour characteristics: colour temperature (Tc) and colour rendering index (Ra). Classrooms and facilities where children interact with each other (canteens, playrooms, gyms) and where it is necessary to maintain adequate visibility of faces and hands should be fitted with light sources with a colour temperature (Tc) of 3000_4500 K (neutral white and warm white) and with a colour rendering index Ra > 80. Painting rooms require light sources with a colour temperature of at least 5000 K.

Limitation of luminance flicker frequency. The luminous flux of light sources supplied with a power current produce flicker with a frequency of 100 Hz. Despite not being perceived visually, such flicker has a negative effect on the biological activity of the brain. It can cause eye strain, fatigue and headache. Flicker characteristics can be defined using a flicker coefficient which should not exceed 10% for the majority of school buildings. As for computer laboratories, the flicker coefficient should be 5%. The main measure to prevent flicker involves converting the current supplied to lamps into a high-frequency current, i.e., it means using electronic devices. Standardised lighting parameters for particular types of school buildings are set out in the normative documents [1_5].

Energy consumption indicators

When designing school buildings, particular attention should be paid to the energy efficiency of lighting. The main parameters used to monitor the energy efficiency of artificial lighting are power density required to provide an illuminance of 100 lux (W/m2/100 lux) and the luminous efficacy of light sources used (lm/W). Depending on the required level of illuminance and room indices, maximum permissible values for the majority of school buildings are 25-35 according to national standards, which is more than is required by international standards (17-25 W/m^2).

The luminous efficacy of light sources used for internal lighting should be not less than 70 lm/W. The optimum energy performance of lighting and, therefore, the energy efficiency of lighting systems in schools along with environmental improvement can be achieved by using modern light sources, luminaires and lighting control systems.

Light sources

Lighting systems in the majority of school buildings should be fitted with triphosphor fluorescent lamps with a high luminous efficacy (75-100 lm/W), good colour rendering (Ra = 80-90) and long service life (16-20 thousand hours). The most effective are T5 triphosphor fluorescent lamps with a tube diameter of 16 mm and with associated electronic control gear, which completely eliminates flicker. In the case of utility rooms it is advisable to use compact fluorescent lamps with a relatively high luminous efficacy (55-75 lm/W), good colour rendering (Ra = 80-90) and long service life (8-12 thousand hours). Innovative LED technology is being increasingly used as a very effective lighting solution. Due to their high environmental performance (free of mercury), long service life (up to 50 thousand hours), good impact resistance and the absence of UV or IR radiation, LEDs are likely to have promising applications in the near future, especially for accent lighting, and for the lighting of conference halls, stages, utility rooms and hard to reach areas. It is also possible to use other innovative light sources.

Lighting control systems

Lighting control systems provide additional opportunities to save energy. They make lighting installations more efficient and economical so that lamps and luminaires can be optimally controlled and maintained in order to create the most comfortable lighting levels possible. Automatic lighting controls with presence detectors monitor occupancy or movement of people and automatically switch off lighting when the area is unoccupied. Daylight detectors with associated dimming controllers monitor daylight availability, and automatically dim artificial lighting by reducing its power consumption to the level needed to sufficiently illuminate the area. These systems combined with Venetian blinds, which can be used to let daylight into the interior space, create energy saving potential for schools and other educational establishments. The use of presence detectors and daylight detectors, which adjust lighting levels according to the level of daylight the room is receiving, provide energy savings of up to 65%.

Lighting recommendations for different areas of school buildings

Classrooms. In Russia, classroom desks are normally placed in a standard arrangement. The line-of-sight is directed mainly towards the blackboard/whiteboard, with desks arranged in a line along windows. Since teachers and students interact with each other, it is required to provide adequate horizontal and vertical illuminance, as well as a favourable light environment (basic lighting requirements are set out in the normative documents [1_5]). The general lighting system (400 lux) is most commonly used. For general lighting, it is recommended to use light sources and predominantly direct light sources with fluorescent lamps (Fig. 1, a_b).

Special attention should be paid to the lighting of whiteboards/blackboards (500 lux). It is recommended to use luminaires for fluorescent lamps which produce an asymmetric light distribution in the lateral plane. They should be installed in a line parallel to the plane of the blackboard/whiteboard. Other lighting options are also possible: luminaires with direct light output, which are installed at an angle. In any case, to provide uniform illumination it is necessary to relate the height at which the luminaire will be installed to its distance from the plane of the board (Fig. 1, c). Interactive whiteboards, which are increasingly used in schools, do not require special lighting.

Normally, classrooms receive good levels of daylight. To reduce energy consumption, it is required to use lighting control systems, namely luminaires fitted with daylight detectors, which switch on lights and adjust lighting levels, taking into account the natural light contribution from the windows during daylight hours. To provide lighting for wall-mounted visual aids, it is necessary to use luminaires for display and accent lighting because they help highlight display areas and achieve the required level of light intensity in a room.

Computer laboratories. The rapid computerisation of Russian schools has led to the provision of computer laboratories, which require special lighting design, the requirements for which are distinctly different from those for the lighting of general purpose classrooms. Health requirements specified in the relevant regulations [1_4] not only determine standard specifications, but also set maximum permissible levels of luminance of light sources emitting light which can be reflected in the computer screen (Table 1).

Great attention should be given to the elimination of direct and reflected glare, which is achieved by adhering to the following guiding principles: a luminaire with direct light output should be sited on one side of a computer workstation; alternatively, it is possible to use reflected light luminaires to be mounted above workstations (Figure 2). Combined lighting installations are another option. In this case, to ensure adequate lighting over a desk it is necessary to use luminaires with opaque reflectors with a shielding angle of at least 40 degrees.

Table 1. Maximum permissible luminance of light sources when using different types of displays

Display types (as defined by ISO)	I	II	III
Display quality	Good	Average	Bad
Maximum permissible average luminance of light sources	<1000 cd/m^2		<200 cd/m^2

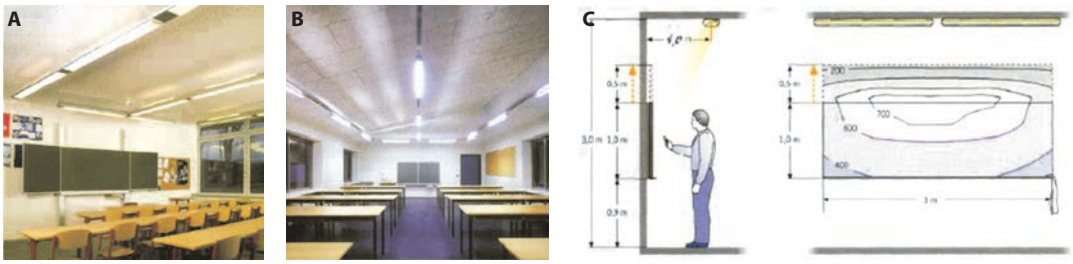

Figure 1. Suspended fluorescent luminaires used for classroom lighting:
a – fluorescent luminaires installed in a line, b – luminaires mounted on fixturing system ceiling bus bar;
c – blackboard lighting using fluorescent luminaires with asymmetric reflectors
(producing an asymmetric light distribution in the lateral plane)

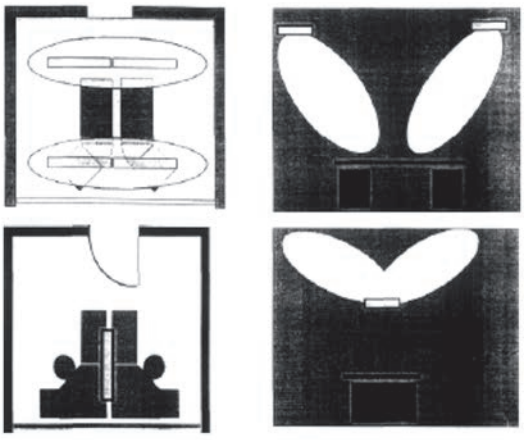

Figure 2. Illustration of luminaire layout:
Top – luminaires with reflectors 1 ´ 58 W and direct light output, with two luminaires mounted on either side of the desk; bottom – reflected light luminaires 2 ´ 55 W mounted above the workstation.

Technical drawing and painting classrooms. More demanding visual tasks result in much higher requirements for lighting – 500 lux. Particular attention should be paid to correct colour rendering, so it is only necessary to use light sources with a colour temperature (Tc) of 5000–6000 K and with a colour rendering index (Ra) of not less than 80. The general lighting system is normally employed, with luminaires being the same as for classrooms.

Metalwork- and woodwork- rooms. There should be adequate lighting in the work area, which is achieved by maintaining high levels of illuminance through combined lighting installations. It is essential to avoid glare and ensure adequate contrast, sharp shadows being totally unacceptable, especially where dangerous tools and equipment are used. When working with rotating parts, it is required to use luminaires with electronic control gear in order to avoid stroboscopic effect.

All the recommended specifications are given in [5].

Conference halls may be used for various purposes, which is why it is crucial to provide for the installation of lighting control systems and stage lighting systems. High levels of vertical illuminance on stage allow a better view of the speaker. The general lighting system (200 lux) is normally comprised of rows of fluorescent lights. It is also possible to use compact fluorescent lamps, halogen ceiling lights (Fig. 4), and reflected light sources.

In addition, if a conference room can accommodate up to 100 students, it is required that illuminated exit signs be provided above all exit doors and connected to an evacuation lighting system.

Gyms. The main purpose of lighting in gyms is to provide a safe and well-lit environment with an adequate level of vertical illuminance and with minimum glare. It is advisable to use fluorescent luminaires mounted on the ceiling along the side walls or at an angle on the side walls. Each luminaire should be fitted with a protective grille which can withstand the effect of ball impact during games. The minimum illuminance should be 200 lux at floor level.

In the case of indoor swimming pools, the most commonly used are luminaires with direct light output. As a general rule, they are mounted on the ceiling or walls above side aisles for ease of maintenance. Reflected light sources (reflect-

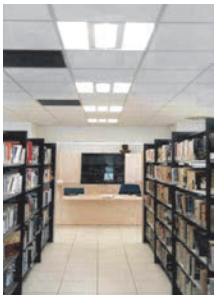

Figure 3. Example of lighting in the books storage area of a library

Figure 4. Conference hall lighting example

Figure 5. Lighting of staffroom

ing light from walls onto the ceiling) are also useful for swimming pools and gyms.

Staffrooms. Teachers' common rooms, head-teacher's rooms and secretary's offices are designed for multiple purposes and require a maintained illuminance level of 300 lux. In these rooms the lighting has the following role: to light teachers' desks and workstations, which is why it is important to prevent glare on screens. In meeting spaces it is necessary to use luminaires capable of providing sufficient levels of cylindrical illuminance (Fig. 5).

Recreation areas, staircases. Well-lit corridors and staircases prevent injuries and create a feeling of confidence and security. Light-coloured walls and ceilings are most preferable. Modern LED signs in stairs, together with luminaires installed in walls to light stairs, can increase safety. Naked lights should not be seen when looking up and down. It is necessary to provide for an evacuation lighting system. Lighting in recreation areas is exemplified in Figure 6.

Exterior lighting of schools. To prevent accidents, areas around schools should be well lit, and all the luminaires should be architecturally compatible with school buildings and the surrounding landscape. To save energy when employing outdoor lighting systems, it is advisable to use dimming technology as well as selective switching (switching off selected lights) at nighttime. Facade lighting can help to protect school buildings from being hit by burglars or vandals.

Conclusion

Currently, there are favourable conditions for the design of lighting systems for school buildings in Russia in line with the latest technological developments. Relevant health and construction regulations have been developed and brought into effect to set requirements for lighting that will provide healthy environment for children and teenagers.

Modern types of lamps and luminaires contribute to energy saving, whilst improving the quality of lighting. The use of electronic control gear reduces power loss and eliminates flicker. Modern reflective materials used in lighting equipment improve luminaire efficiency and the shielding of light sources.

Daylight detectors with associated dimming controllers monitor daylight availability and automatically dim lighting to the level needed. Presence detectors automatically switch off lights in unoccupied areas. All this reduces power consumption, thus improving the environment.

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