Original Article

Improving the safety of hospital complexes in modern conditions

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Abstract

Background: The article presents the results of a study of ensuring fire safety in medical and preventive institutions (LPI) on the example of the central city hospital. **Objectives:** Research is aimed at improving the fire safety of hospital complexes and hospitals in modern conditions. ***Materials and Methods:*** The study used the methods of system analysis of scientific research and statistical data on ensuring fire safety, methods of structural analysis of the practice of ensuring fire safety of hospital complexes, mathematical methods for calculating the evacuation of people from a building and the spread of a fire in a building, methods for calculating the economic efficiency of means of support fire safety. ***Results and Discussion:*** Based on the analysis of fire statistics in healthcare facilities in Russia, it is concluded that it is advisable to improve the fire safety of hospitals and hospital complexes in modern conditions. The point of view is expressed that along with the fact that fire safety in hospitals is observed, the analysis indicates the existing problems in the practice of implementation. ***Conclusion:*** In order to increase the level of fire safety, it is possible to introduce: a modern fire alarm system; video of control systems and monitoring of safety of objects on the territory of the medical facility; installation of automatic fire extinguishing systems in fire-hazardous premises; installation of additional emergency lighting and reflectors indicating the direction of evacuation in case of fire and smoke; carrying out organizational and practical measures to ensure the safety of patients in a medical institution in an emergency situation (ES), namely, it is proposed to develop a memo of actions for patients in the hospital complex on inpatient treatment in case of an emergency with a list in the instruction log; provision of medical facilities with individual rescue equipment and provision of hospitals and hospital complexes with high-rise buildings with modern evacuation means.

Keywords: fire safety system, improving the fire safety of hospitals and hospital complexes in modern conditions, fire alarm system, video control and monitoring system for the safety of facilities, automatic fire extinguishing system in fire-hazardous premises, individual rescue equipment, modern means evacuation.

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Introduction. According to the statistics of the Ministry of civil defense, emergencies and elimination of consequences of natural disasters of the Russian Federation for 2012-2016, an average of 140 fires occurred in medical and preventive institutions per year [1]. Data analysis shows that every 2nd fire in a health facility occurs in stationary facilities. The first cause of fires is the "human factor".

On average, about 3 million people are treated in hospital every day in 8400 hospitals, 1502 polyclinics, 106 clinics of research institutes and universities and other medical institutions in our country, and about 130 thousand patients are treated in day hospitals. Up to 250 thousand patients a day in the country are being treated in hospitals in a helpless state for health reasons, add to this figure patients in nursing homes and

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boarding schools. The main share of fires (58%) falls on medical and preventive institutions (LPU). At the same time, characteristic conditions that contribute to the death of people in fires are: a state of alcoholic intoxication (53%), a state of sleep (18%) and non-transportability of victims (14%). The most common causes of fires at these facilities were: careless handling of fire (30%), violation of the rules for the installation and operation of electrical equipment and household appliances (24%) and carelessness when Smoking (16%) [2]. These facts are evidence of the relevance of considering the issue of improving fire safety in health care facilities in modern conditions.

Modern medical facilities are equipped with a large number of complex diagnostic equipment, which increases the risk of fire and fire load on the premises. In operating rooms, in addition to a large amount of electronic equipment, oxygen is also provided, which will accelerate the development of a fire and may lead to an explosion.

Thus, in all the above cases, a fire can occur in almost any room of the health care facility where people can be located-from wards to utility rooms. Therefore, any medical facility is an object of increased fire danger – and this danger is combined with the constant presence of a large number of people. The combination of dangerous factors and fire conditions requires improvement of the fire safety system [3]. This approach is the basis for searching for solutions to a scientific problem.

Materials and methods.

Experimental method. The study used methods of system analysis research and statistics on fire safety, methods of structural analysis practices ensuring fire safety of hospital complexes, mathematical methods of calculation of evacuation of people from buildings and spread of fire in the building, methods of calculation of economic efficiency of means of maintenance of fire security.

Results

Theoretical foundations (theory and calculations). It should be noted that from the point of view of the law, fire safety of medical institutions ensures their work, but there are a number of features that require detailed consideration from the point of view of practice.

The analysis of fire safety on the example of the medical institution of the SBU "syzranskaya TSGB" shows that as shown by the calculations, the main building structures meet the requirements of regulatory documents on fire resistance indicators. However, the examination of the internal layout of the hospital buildings has significant drawbacks.

Since the building OF the SBU "syzranskaya TSGB" was designed and built in 1977, it is necessary to improve the fire extinguishing system, evacuation signs, fire evacuation signs, doors with expanded passageways, alarm systems and video surveillance systems that meet modern requirements.

The modern fire protection system should no longer be focused on the elimination of the intended focus and should become adaptive. The implementation of this approach is the use of a modular wireless fire extinguishing system that interacts with the heat field of the fire [4]. In the domestic industry, several types of wireless fire extinguishing systems are produced: "GARANT-R" and "TRV-GARANT-R" [5] .

It is possible to note the advantages of this alarm system: extinguishing a fire in the initial period is much easier and cheaper; the problem of extinguishing spills of liquids is eliminated; the reliability of the automated fire protection system is significantly increased; the effectiveness of the automatic extinguishing system is monitored. Analysis of fire statistics at such facilities indicates that the rapid spread of fire over the area of the building, the average annual damage is quite large. Therefore, the possibility of introducing a wireless fire extinguishing system can reduce damage and is economically feasible.

We will justify the approach by calculating two options for protecting premises: the first, without BSPT, when the object is protected by outdated fire protection equipment; the second option, when there is a BSPT to the existing protection. The main performance indicators are: capital investment K_1 and K_2, rub.; operating expenses C_1 and C_2, rub. / year; fire damage Y_1 and Y_2, rub. / year. Analysis of fire statistics for 5 years on 40 existing similar institutions (N=40) that are not equipped with BSPT (table 1).

Table 1: Distribution of the number of fires and damage by year [6]

Years T_i	Number of fires n_i	Damage Y_i,, thousand rubles
2013	223	(14885340) 3920283
2014	192	(18246565) 347419
2015	171	(22461847) 294012
2016	153	(13418423) 510372
2017	164	(13767378) 513751
2018	211	(15517156) 89231

Based on the method of calculating the damage assessment[7], the calculation of direct fire damage over six years is:

$$\text{ó}_{\text{и}} = \frac{\sum_{i=1}^{n} Y_i}{\left(\sum_{i=1}^{n} T_i\right) N} = 5675068 \text{ тыс.руб./ } 1114 = 5094 \text{ thousand rubles / year (1)}$$

Calculations also show[8] that the average fire damage for building structures is 17.5 thousand rubles., and for equipment 82.5 thousand rubles. Thus,

$$Y_{\text{п.э}} = 0{,}12 \cdot 17{,}5 + 0{,}15 \cdot 82{,}5 = 14{,}47 \text{ thousand rubles (2)}$$

The total average annual damage for the first option will be

$$Y_I = 5094 + 14.47 = 425{,}73 \text{ thousand rubles / year. (3)}$$

Calculations of indicators for the second option indicate that the capital investment for the BSPT device is approximately K_2 = 25 thousand rubles.

We will determine the economic effect of the options, in accordance with the standard methodology.

We determine the listed costs by options:

$$\text{I var. } P_1 = Y_{I/cp} = Y_I = 19 \text{ thousand rubles / year, (4)}$$

$$\text{II var. } P_2 = K_2 E_N + C_2 + Y_2 = 25 \cdot 0{,}15 + 2{,}825 + 6{,}24 = 12{,}815 \text{ thousand rubles / year. (5)}$$

The annual economic effect of using a wireless fire extinguishing system at one facility will be 412.9 thousand rubles, which indicates the feasibility of implementing a new fire extinguishing system.

The evacuation system also needs to be improved. For example, "SBUZ SO syzranskaya TSGB" has 736 round-the-clock beds in 34 profiles, 2 polyclinic therapeutic departments with a capacity of 375 visits per shift, a women's consultation for 200 visits per shift, a trauma center and oncological Department of the clinic, diagnostic, paraclinical and auxiliary units. The hospital staff consists of 1,172 employees, including: 160 doctors, 549 average medical workers, 258 Junior doctors, and 205 others. More than 25,000 patients are treated in our hospital's inpatient beds every year. 85% of them are emergency patients. The obstetric observational Department and the neonatal Department are equipped with modern equipment purchased after reconstruction and received within the framework of the PRP "Health". Every year, the maternity hospital accepts about 2500 deliveries[9].

In the event of a fire, fire extinguishing actions are organized simultaneously with the evacuation of people and the protection of escape routes.

Calculations indicate that 10 minutes after the fire occurred, the fire reached the walls of the room, will take a rectangular shape:

$$S_{\text{P2}} = a \cdot L_2 = 4 \cdot 10 = 40 \text{ m}^2 \text{ (6)}$$

1. Perimeter of a fire in a semicircular development:

$$P_{\text{P2}} = 2(a + L_2) = 2(4+10) = 28 \text{ m (7)}$$

1. The growth rate of square fire:

$$V_{s2} = S_{\text{P2}} / t_{\text{svr2}} = 40/10 = 4 \text{ m}^2 / \text{min (8)}$$

Calculations show a high level of danger to the medical facility in the event of a fire.

Various variants of calculations of smoke in the event of a fire indicate that, depending on the size of the premises and combustible materials, the room can be filled with smoke in the event of a fire from 30 seconds to 4-5 minutes in the corridors. In the event of an evacuation, the emergency exit lights located at a height of more than 2 meters may not be visible. Signs located at a height of 1.5 m in a poorly lit corridor may not be visible. At objects with a mass stay of people, the head of the organization ensures the availability of serviceable electric lights at the rate of 1 lamp for 50 people. Since patients act independently in case of fire, we suggest using photoluminescent evacuation plans. Schemes of this type have the characteristics of the material due to their physical and mechanical properties, allowing you to solve the problem of orientation as effectively as possible, even in complete darkness. They make it easier to evacuate the building at night, as well as in the presence of a dense wall of smoke.

Every year, more than 25,000 patients are treated in inpatient beds at the Syzran Central hospital. Analysis of training plans for emergency signal with evacuation of patients from the premises of the hospital complex indicates that they are held once a half-year. Quantitative analysis of the number of annual treatment of patients in hospitals of medical institutions shows that their number significantly exceeds by 6-8 times the number of hospital beds in the hospital, therefore 2-3% of the contingent of patients undergoing instruction on actions in case of emergency are not included. Therefore, it is necessary to organize the development of memos for patients and instructions on fire safety in accordance with current legal acts with a signature about familiarization in the instruction log.

The presence of a large number of patients who are not able to leave the hospital complex on their

own requires improving the means of evacuation of patients (new fire escape systems, external evacuation devices for bedridden patients, training incoming patients).

We will calculate the time of evacuation[10] from the hospital, provided that the fire occurred in the afternoon and the fire is located on the third floor in one of the wards. The building has 1 (A) main exit and 2 evacuation (B, C). the hospital Building is a three-story building of II degree of fire resistance and has dimensions in terms of 100x50m. The calculations are summarized in table 2.

Table 2: Evacuation time 250 people

Number of people	Exit	The evacuation time
170	A	5 min 21 sec
40	B	1 min 33 sec
40	C	48 seconds

Analyzing the results obtained during the calculation, it is possible to formulate a final conclusion that the estimated time of evacuation from exits A, B, and C corresponds to fire safety standards. However, a big problem is providing fire safety for people who are not mobile (people who are unable to move independently – non-transportable), unable to evacuate themselves, the number of which in hospitals reaches dozens of people.

These people include weakened elderly citizens, bedridden patients admitted to a hospital ward after surgery, as well as disabled people with musculoskeletal disorders. It is extremely difficult to carry non-mobile people on stretchers (and based on the number of medical staff and their physical capabilities), it is advisable to suggest the use of an individual means of rescue – a travois, an evacuation mattress, an evacuation pad, an evacuation chair.

Travois-used for evacuation and rescue of disabled people in hospitals and nursing homes by medical staff. They are suitable for rooms and passages with limited dimensions and hard-to-reach places. Evacuation travois are stored in a collapsed state and in the event of a fire or other emergency (emergency), they are quickly deployed[11].

The evacuation mattress is used for emergency evacuation of bedridden patients, including those with a large weight, in case of fire and emergency by medical personnel. Movement is performed by sliding on the floor and stairs. The mattress is flexible and not wide, which allows you to evacuate patients through standard doorways, corridors and fire escapes.

Evacuation substrate – safety, simplicity, economy and efficiency. it is Used for emergency evacuation of bedridden patients in case of fire and emergency by medical staff. In case of increased fire, it will be a means of rapid and simple movement of bedridden patients. Movement is performed by sliding on the floor and stairs. The mattress does not require lifting the patient, and the nylon material supports have a low degree of resistance, which allows a physically untrained person to transport the patient.

The evacuation substrate consists of a single cross-shaped web, has four slings that form two transverse belts for fixing and two slings that form longitudinal traction loops to ensure movement. In the corners diagonally located elastic straps for attaching the substrate to the mattress. On the sides there are four pockets for storing cross belts, with which the patient is fixed on the mattress. The cross belts are connected by buckles with a length adjustment function.

Evacuation chair-provides easy access to the stairs for people with limited mobility in case of fire and emergency[12]. The evacuation chair can be easily moved up the stairs. This is important for children with disabilities and people with limited mobility, who can quickly move from their strollers to a chair.

It is advisable to provide high-rise hospital complexes with modern means of evacuation. Inclined rescue sleeve[13]. This system can quickly and reliably provide a safe mass evacuation of people from buildings. A special feature is the ease of bringing the device into working condition, which allows you to use it to rescue children, women, the elderly and people with disabilities before the arrival of the rescue service or firefighters.

Discussion and conclusion

Scientists have studied various aspects of fire safety: in the works Legasov V. A., Topol's'ke N. G., H. H. Brushlinskii, A. K. Mikeev discusses the creation of a doctrine or concept of fire safety, improve the legal framework for the activities of the fire service; andresearch scientists Borodin, D. A., Yershova, K., Vasiliev V., Titkova, V., etc. – are considered fire safety as a specific fire-technical work. Rudakov P. G., Smirnova O. Ya., Khartofilakas A. C., Kamlet Kh. y., Krundyshev B. L., Stepanov V. K., Molotkova E. G. investigated the design of a comfortable and safe living

environment for the disabled and elderly.

Authors: Koshmarov Yu. a., Ryzhov Yu. a., Dekterev A. A. and others devoted their works to modeling the spread of fire hazards. These developments were used in calculating the spread of the hospital fire model.

The works of V.V. Kholshchevnikov[14], R.N. Istratov, V. M. predtechenskiy, D. A. Samoshin, E. E. kiriukhantsev, E. T. Shurin, A. B. Apakov, and others were devoted to modeling the processes of evacuation of people, including the study of evacuation of people with disabilities. The achievements were used in calculations and search for solutions to evacuate patients from a hospital building in the event of an emergency.

Foreign scientists D. Dreidel[15] and others-studied modeling of the spread of fire hazards; A. Schadschneider [16], W. Klingsch, H. Kluepfel, T. Kretz, C. Rogsch, A. Seyfried, E. Kuligowsky, D. Peacock R. and others – studied modeling of evacuation processes.

Serebrennikov E. A., Chupriyan A. P., Kopylov N.P. and others investigated fire safety and modern directions of its improvement[17]; Ivanova L.P., Sukhonina M.A., Tikhonova N.V.[18] considered the issues of fire safety in buildings of medical institutions. These aspects contributed to the definition of measures to improve fire safety in modern conditions.

Scientists Khairil Idham Ismail, Haniza Mohd Yusof, Ahmad Faidi MZ, Basri I. Have considered the importance of fatigue management for healthcare workers[19].

Scientific achievements of scientists allowed us to complete the research tasks.

Conclusion.

Thus, the analysis of the security system of the GBUZ WITH "TSGB" indicates that the existing system ensures compliance with the requirements of documents. However, practical activities require improvement. In order to improve the level of fire safety possible implementation: advanced alarm systems for fire, video monitoring system and security monitoring facilities on the territory of SBME; the installation of automatic fire suppression systems in fire areas (warehouse, laboratory, canteen, etc.); setup of external devices and evacuation of the sick; the installation of additional emergency lighting and reflectors indicating the direction of evacuation in case of fire and smoke; set individual elements of pointers on the floor covering with reflectors or lyuminestsentnym coating, which will allow you to specify the path of evacuation; conducting organizational and practical measures to ensure the safety of patients of medical institutions in emergency situations, namely, it is proposed to develop a memo of action patients located in a hospital complex for inpatient treatment in case of emergency with the painting in the journal of instruction; provision of health facilities by individual means of salvation (scrapers of various types, evacuation mattresses, evacuation of the substrate, evacuation chairs) and provision of hospitals and hospital complexes, high-rise modern means of evacuation (rescue sloping arms).

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Conflicts of Interest

"The authors state that there is no conflict of interest."

Ethical purity:

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Authors' contribution:

In the course of work on the article, the author Vaulin Vladimir Ivanovich prepared the idea of the study, reviewed the statistical materials, clarified the calculations, made conclusions, and completed the design of the article.

The author of the article Singeev Sergey Aleksandrovich checked the calculations, clarified the authors of the discourse, and detailed the conclusions. In general, the authors jointly checked the quality of the article.

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