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FEATURES OF ESTABLISHING AND OPERATING A MEDICAL SERVICE AT REMOTE HIGH-ALTITUDE SITES: A REVIEW

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Introduction. The development of a system for organizing health protection for workers at remote industrial sites (including high-altitude ones) is a relevant priority for both the Russian Federation and the Kyrgyz Republic. Due to the absence of unified standards in the remote health-care system, a priority is the analysis of principles and approaches in organizing an adequate and effective model of medical care delivery for personnel in these industrial production sectors.

Objective. Analysis and synthesis of data on the organization of medical care at remote industrial sites (RIS) in extreme high-altitude conditions.

Discussion. Labor activity at RIS in high-altitude conditions involves the impact on workers' health of extreme climatic and geographic factors, adverse socio-psychological factors, as well as harmful and dangerous factors of the industrial environment, which necessitates the implementation of a specialized medical support system for workers. Medical care for RIS workers may be provided by the company's own medical service or by hired medical service providers (outsourcing). In the Kyrgyz Republic, all mining enterprises have their own medical services. The medical service at a high-altitude RIS consists of two units: the main medical station of the RIS (paramedic or physician-staffed) and a medical station at the central check-point. A distinctive feature of the medical station's work in high-altitude conditions is the high number of patient visits for acute mountain sickness (AMS). For example, among shift workers at a mining enterprise in the Kyrgyz Republic at an altitude of 3800 m, the AMS incidence was 25%. The main approaches to AMS preventing in the general worker population are altitude acclimatization, pharmacological support, rehydration, prevention of electrolyte imbalances, protection against light-induced eye and skin damage, and prevention of cold injury. For further medical care provision to workers with AMS, a two-stage evacuation system is used when the RIS is located at an altitude above 3500 m and at a significant distance from populated areas, which involves establishing an intermediate medical station at an altitude of 1700–1800 m above sea level.

Conclusions. Medical support for shift workers in extreme high-altitude conditions is part of a developing field — remote healthcare. The issues of organizing medical care at remote industrial sites in mountainous areas are relevant due to the intensive development of the mining industry in the Kyrgyz Republic. The need is shown for special training of medical personnel in remote healthcare, improvement of the regulatory framework governing the procedures and algorithms for providing medical care to RIS workers, in order to enable the construction of a new model of medical support that complies with unified standards of medical care, including through the introduction of telemedicine and mobile components.

Keywords: remote healthcare; mountain medicine; healthcare organization; industrial medicine; remote industrial sites; medical education; shift work; medical evacuation

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ОСОБЕННОСТИ СОЗДАНИЯ И ФУНКЦИОНИРОВАНИЯ МЕДИЦИНСКОЙ СЛУЖБЫ НА УДАЛЕННЫХ ОБЪЕКТАХ В УСЛОВИЯХ ВЫСОКОГОРЬЯ: ОБЗОР

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Введение. Развитие системы организации охраны здоровья работников удаленных промышленных объектов (в том числе высокогорных) является актуальным направлением как для Российской Федерации, так и для Кыргызской Республики. Ввиду отсутствия единых стандартов в системе удаленного здравоохранения приоритетным является анализ принципов и подходов в организации адекватной и эффективной модели оказания медицинской помощи персоналу этих отраслей промышленного производства.

Цель. Анализ и обобщение данных по организации медицинской помощи на удаленных промышленных объектах (УПО) в экстремальных условиях высокогорья.

Обсуждение. Трудовая деятельность на УПО в условиях высокогорья сопровождается влиянием на здоровье работающих экстремальных климатогеографических, неблагоприятных социально-психологических, а также вредных и опасных факторов производственной среды, что диктует необходимость внедрения специализированной системы медицинского обеспечения работников. Медицинская помощь работникам на УПО может оказываться собственной медицинской службой компании или нанятыми провайдерами медицинских услуг (аутсорсинг). В Кыргызской Республике все горнодобывающие предприятия имеют собственные медицинские службы. Медицинская служба на УПО в высокогорье состоит из двух подразделений: главного медицинского пункта УПО (фельдшерского или врачебного) и медицинского пункта на центральном контрольно-пропускном пункте. Особенностью работы медицинского пункта в условиях высокогорья является большое количество обращений больных с острой горной болезнью (ОГБ):

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так, у вахтовых рабочих на горнодобывающем предприятии в Кыргызской Республике на высоте 3800 м частота возникновения ОГБ составила 25%. Основными подходами к профилактике ОГБ в общей популяции работников являются высотная акклиматизация, фармакологическая поддержка, регидратация и предупреждение нарушений электролитного обмена, защита от светового поражения глаз и кожных покровов, предупреждение холодовой травмы. Для дальнейшего оказания медицинской помощи работникам с ОГБ применяют двухэтапную систему эвакуации при нахождении УПО на высоте более 3500 м и значительном расстоянии от населенных пунктов, предусматривающую создание промежуточного медицинского пункта на высоте 1700–1800 м над уровнем моря.

Выводы. Медицинское обеспечение вахтовых рабочих в экстремальных условиях высокогорья является частью развивающегося направления — удаленного здравоохранения. Вопросы организации медицинской помощи на удаленных промышленных объектах в горной местности актуальны в связи с интенсивным развитием горнодобывающей промышленности в Кыргызской Республике. Показана необходимость специальной подготовки медицинского персонала по вопросам удаленного здравоохранения, совершенствования нормативной базы, регламентирующей порядок и алгоритмы оказания медицинской помощи работникам на УПО, для возможности построения новой модели медицинского обеспечения с соблюдением единых стандартов медицинской помощи, в том числе при введении телемедицинского и мобильного компонентов.

Ключевые слова: удаленное здравоохранение; горная медицина; организация здравоохранения; промышленная медицина; удаленные промышленные объекты; медицинское образование; вахтовый метод; медицинская эвакуация

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INTRODUCTION

In recent years, there has been a growing interest in the Russian Federation in the topic of remote healthcare, encompassing regulatory frameworks, approaches to organizing medical care, and the development of medical infrastructure, logistics, and communications at remote industrial sites (RIS).

In the Russian Federation, hard-to-reach industrial sites located at a significant distance from cities are identified: at oil fields in Eastern Siberia, in the Arctic shelf region, or in the arid zones of the Caspian Lowland; however, production sites with a permanent workforce located under high-altitude conditions are absent [1, 2].

Currently, in the Kyrgyz Republic, there are more than ten actively operating mining enterprises located at an altitude of 3000–4000 m above sea level, which requires attracting a significant number of shift workers, the number of whom can reach up to 1,000 people per shift. The leading mining enterprises are Jerooy and Kumtor. The Jerooy gold deposit is located at an altitude of 2500–3800 m above sea level in the Talas region, with a shift camp for workers at an altitude of 2500 m. The Kumtor deposit is located at an altitude of 3800–4200 m above sea level in the Issyk-Kul region, with a shift camp for workers at an altitude of 3800 m.

Workers in the mining industry under high-altitude conditions are exposed to a combination of extreme climatic, geographic, occupational, and socio-domestic factors, while living and working at an altitude of 3800–4200 m above sea level is accompanied by significant strain on human adaptive mechanisms [3].

Extreme natural-climatic factors include low oxygen content in the ambient air, reduced atmospheric pressure, low air temperature and its significant daily

fluctuations, increased solar radiation, and many others. All these factors are collectively referred to as the “mountain complex”, and according to the classification of vertical mountain zonation, the altitude of 3500–4500 m above sea level is classified as uninhabitable highlands or ultra-highlands.

Under the influence of low atmospheric temperatures and strong winds, acute inflammatory diseases of the respiratory system (rhinitis, pharyngitis, tracheitis, bronchitis, pneumonia, sinusitis), musculoskeletal system (myalgia), nerve endings (neuritis, radicular radiculopathy), blood vessels (arteritis), eyes (blepharitis, conjunctivitis, keratitis), as well as cold injuries: hypothermia and frostbite (most often of the extremities) occur more frequently. Moreover, in the mountains, the clinical course of chronic diseases becomes more severe, and traumatic injuries are more often complicated by shock [4]. Increased insolation intensity (predominance of the ultraviolet part of the spectrum), the simultaneous exposure to direct solar radiation and diffuse radiation up to 96% (resulting from the scattering of part of the direct solar radiation flux in the atmosphere due to reflection from mountain slopes and snow cover), and the rarefied atmosphere can contribute to the occurrence of skin burns (wings of the nose, lips, chin, neck, dorsum of the hands) and eye burns [5].

When organizing labor at RIS in high-altitude regions, workers live at sea level during the inter-shift period; however, after arriving at the production site in the mountains, the main factor significantly reducing their work capacity is exogenous hypoxia. Signs of hypoxia are observed in workers starting at an altitude of 2500–3000 m above sea level, and in most individuals at an altitude of 3500 m. At altitudes above 3800 m above sea level, workers may develop life-threatening syndromes: acute mountain sickness,

high-altitude pulmonary edema, and high-altitude cerebral edema, which require immediate treatment and descent to low altitudes [6, 7]. Hypercatabolism also plays an important role in the development of “mountain pathology.” For example, total daily energy expenditure of the body under mid-altitude conditions averages 3900–4100 kcal, and at high altitude — 4300–4500 kcal. Against the background of increased energy expenditure, reaching up to 5000 kcal per day at high altitudes, phenomena of nutritional exhaustion may occur during movement, prolonged and heavy physical labor in the mountains [8].

Intense physical exertion during work in the mountains leads to increased sweating even under relatively cold weather conditions and is accompanied by dehydration (due to increased fluid excretion from the body in urine), which slows down the recovery of a person’s work capacity and worsens the AMS course. Under conditions of low partial pressure of oxygen against a background of dehydration, conditions are created for the growth of bacterial microflora even with minor damage to the skin, mucous membranes, and injuries. Hypoxia and dehydration cause disturbances in mineral metabolism, which significantly affects the function of the gastrointestinal tract (suppression of gastric juice, pepsin, bile secretion, and disorders of intestinal motor-evacuatory function) [9].

At mining enterprises, when assessing the impact of occupational factors, it has been established that workers are exposed to a combination of adverse occupational factors: psycho-emotional, physical (noise, vibration, unsatisfactory microclimate parameters), chemical (dust, contamination with various chemical compounds), biological factors, the levels of which often exceed hygienic standards [10].

The atmospheric air of open-pit mines at the production site during open-pit ore mining and its chemical processing at a gold recovery plant is polluted with dust and toxic substances (sodium cyanide (NaCN), alkalis (CaO, NaOH), hydrochloric acid (HCl), nitric acid (HNO₃)). The main sources of hazardous gas emissions are blasting operations, the operation of vehicles, scrapers, and bulldozers. All processes of crushing, grinding, loading, and transporting ore are accompanied by dust formation. During the warm season, dust concentrations at workstations where machinery is used increase sharply and can reach 25–30 mg/m³. In open-pit mines of Siberia and the Far North, higher dust content is observed due to low efficiency or absence of dust control measures. In addition, the air of the work zone contains components of exhaust gases from internal combustion engines (nitrogen oxides, acrolein, formaldehyde, etc.), the levels of which can exceed permissible values by 2–3 times. The operation of various types of drilling machines and other equipment is accompanied by elevated levels of noise and vibration at workstations;

as a rule, workers are exposed to a combined effect of noise and vibration [11].

The shift method of labor organization at RIS imposes high demands on a person’s adaptive capabilities and is accompanied by significant physiological changes in the body: the quality of life of workers objectively decreases, which manifests in the deterioration of the health of shift personnel due to abrupt changes in climatic conditions, time zones, diet, psycho-emotional stress, and occupational workload, with shifts lasting from two weeks to several months. Professional activity at RIS involves high intensity of the labor process, longer work shifts, reduced rest between shifts, minimal social and domestic support, and pronounced prolonged exposure to factors of chronic social stress [12, 13]. Daily high-intensity occupational workload, night shift work, limited access to social infrastructure facilities, and abrupt changes in living conditions can lead to psycho-emotional tension, the development of anxiety, depression, and frustration in shift workers [14]. Living in a confined space in a shift camp can lead to the rapid spread of infectious diseases transmitted by airborne droplets, which necessitates constant sanitary-epidemiological monitoring of all visitors to production sites.

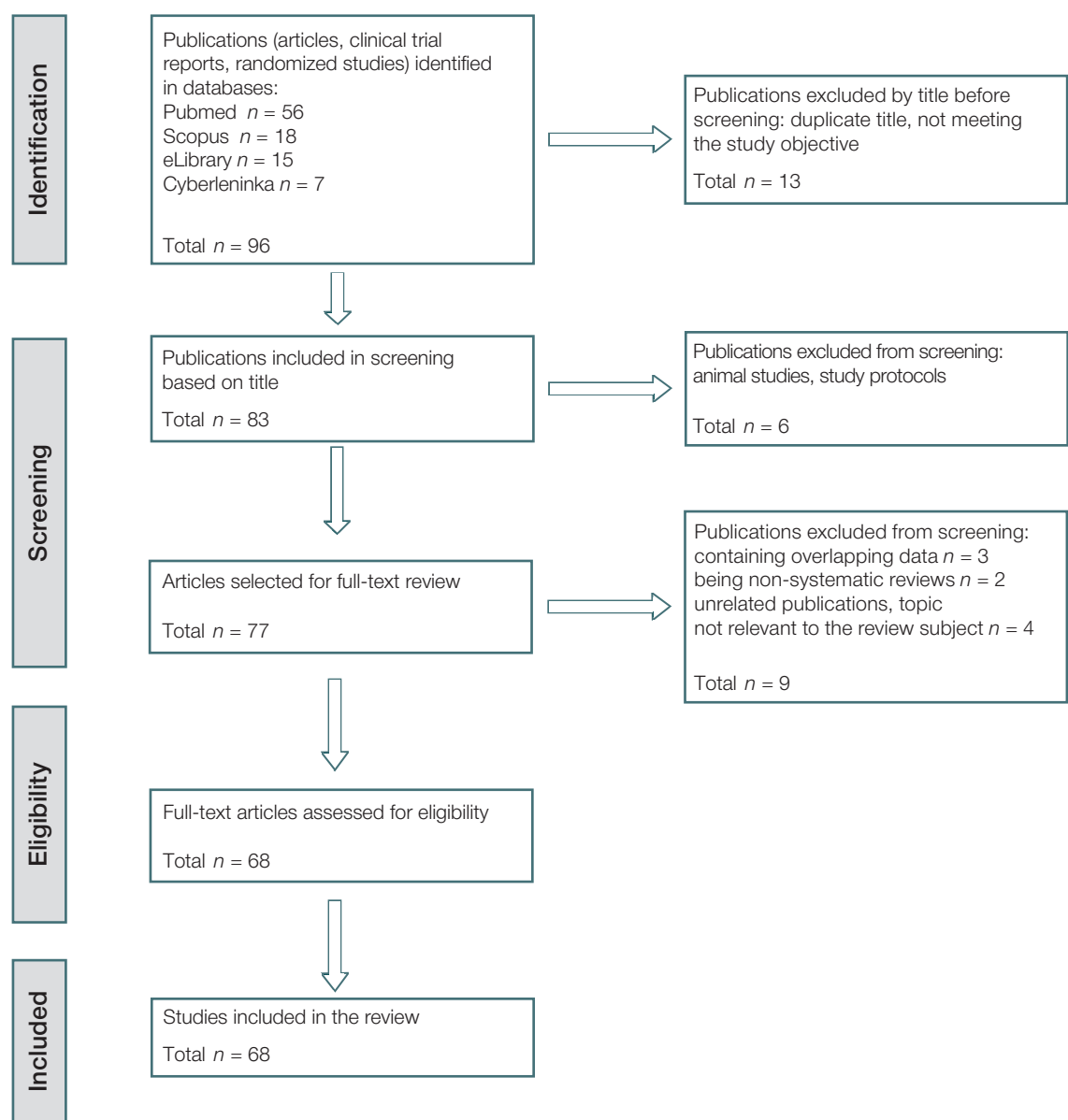
Given the need for careful monitoring of the health status of RIS workers to preserve their health and ensure safe working conditions, high demands are placed on the organization of the medical service.

The aim of the study is to analyze and synthesize data on the organization of medical care delivery at remote industrial sites located in extreme high-altitude conditions.

An analysis of scientific literature for the period 2015–2025 on the features of medical support for shift workers under high-altitude conditions was conducted in the electronic databases PubMed, Elibrary, Cochrane; on the websites of the International Society for Mountain Medicine (ISMM)¹ and the International Commission for Alpine Rescue (Internationale Kommission für Alpine Rettung, ICAR)². The analysis included sources containing information on the types of medical care organization at RIS located in the regions of Eastern Siberia, the Arctic, and the Far East of the Russian Federation, as well as at high-altitude RIS in the Kyrgyz Republic. Excluded were: articles without full text, duplicate publications, those not related to the field of medical care organization under high-altitude conditions, and those focused on recreational climbers. The following keywords were used: remote healthcare, mountain medicine, industrial medicine, remote industrial sites, healthcare organization, shift work, medical evacuation. In the search process, 96 publications were selected; after screening, 68 publications were included in the review. The study scheme is presented in Figure 1.

¹ International Society for Mountain Medicine. <https://ismm.org/>

² International Commission for Alpine Rescue. <https://www.alpine-rescue.org/>



The figure is prepared by the authors

Fig. 1. Study flow diagram

MAIN BODY

Production activity in adverse and extreme climatic conditions can contribute to the emergence and growth of occupational pathology, which necessitates a more in-depth assessment of the health status of people temporarily residing in such areas.

According to the data of the statistical committee³ for 2025, based on the results of periodic medical examinations and medical visits, in the structure of morbidity among shift workers at high-altitude RIS, the top three places in descending order are occupied by diseases of the respiratory system, cardiovascular system, and musculoskeletal system. At the same time,

the proportion of diseases associated with exposure to high altitude in the morbidity structure accounts for up to 10% (Table 1).

The AMS incidence among shift workers in high-altitude regions is variable, ranging 25–80% of cases depending on conditions, ascent rate, and altitude level. Farias et al. showed that the AMS incidence of among shift workers at a mining enterprise in Chile at an altitude of 4200 m reached 52% of all medical visit cases [15]. Among shift workers at a mining enterprise in the Kyrgyz Republic at an altitude of 3800 m, the AMS incidence was 25% [16]; Wu et al. noted that when working at altitudes of 3500–5000 m in China, the prevalence rate of AMS was 56% [17]. According

³ National Statistical Committee of the Kyrgyz Republic. <https://stat.gov.kg/ru/>

Table 1. Morbidity structure among shift workers at high-altitude facilities in Kyrgyzstan

No.	Cause (ICD-10 code)	Proportion, %	Main nosologies	Risk factors
1	Respiratory diseases (J00–J98)	30–40	Pneumoconiosis, chronic obstructive pulmonary disease (COPD), bronchitis	Dust, low atmospheric temperature, hypoxia
2	Cardiovascular diseases (I00–I99)	15–25	Hypertension, coronary artery disease (CAD), cor pulmonale	Hypoxia, intense physical exertion
3	Musculoskeletal diseases (M00–M99)	10–15	Osteochondrosis, radiculopathy	General/local vibration, heavy physical labor
4	Nervous system diseases (G00–G98)	5–10	Asthenia, encephalopathy	Hypoxia
5	Injuries, poisonings, and certain other consequences of external causes (S00–T98)	3–8	Poisoning by metals, gases	Chemical factors
6	Effects of high altitude (T70.2)	≤10	Acute and chronic mountain sickness	Altitude above sea level exceeding 3500 m

Table compiled by the authors based on data from an internet source⁴

to Forster et al., among shift workers operating a telescope in Hawaii at an altitude of 4200 m, the AMS prevalence was 80% [18].

In the structure of injuries among shift workers at high-altitude RIS facilities in Kyrgyzstan, mechanical injuries predominate, resulting from technical malfunctions, falls, and rockfalls. The most common types of injuries with severe consequences are falls from height, impacts from moving, flying, rotating objects, parts, machines, and mechanisms, and transport accidents. Meanwhile, occupational injuries from physical and chemical factors account for about 15–20% (Table 2).

In the mortality structure among shift workers at high-altitude facilities in Kyrgyzstan, accidents and injuries occupy the first rank, followed by mortality from cardiovascular diseases and complications of respiratory diseases (10–15% of cases); mortality from intoxications accounts for 5–10% (Table 3).

Medical care for RIS workers may be provided by the company's own medical service or by hired medical service providers (outsourcing). When outsourcing medical services, all types of medical interventions are performed: provision of primary medical and emergency care, implementation of treatment and preventive measures, conducting periodic medical examinations and vaccinations, maintaining statistical records of diseases, introducing telemedicine technologies for medical support, and performing emergency medical evacuation of patients [19].

When organizing medical care through the industrial enterprise's own resources, it is necessary to establish departmental medical services, which requires the development of own standard operating procedures, adherence to continuity in diagnosis, treatment, disease prevention, recording of all morbidity data, and preservation of medical records of RIS workers for further analysis and monitoring of the health status of the enterprise's employees [20].

In the Kyrgyz Republic, all mining enterprises have their own medical service. The method of outsourcing medical services at remote sites is not used due to the imperfection and incompleteness of the regulatory and legal framework in this area and the low level of development of private medicine in the country.

The structure of the medical service organization at RIS, developed at the Siberian State Medical University, tested at many RIS in the Russian Federation and in mountainous areas in the Kyrgyz Republic, includes the following stages:

- organization of medical station infrastructure, logistics, and communications in high-altitude conditions;
- organization of treatment and preventive work under high-altitude conditions;
- training and preparation of medical specialists and shift workers for work in extreme high-altitude conditions;
- organization of document flow, which also includes work with medical information systems, telemedicine issues, conducting audits, etc.

⁴ National Statistical Committee of the Kyrgyz Republic. <https://stat.gov.kg/ru/>

Table 2. Injury structure among shift workers at high-altitude facilities in Kyrgyzstan

No.	Injury type	Proportion, %	Incident characteristics
1	Mechanical injuries	50–70	Falls, rockfalls, technical malfunctions
2	Occupational injuries: - exposure to physical factors - exposure to chemical factors	10-20 10–15 5–10	Explosions, collapses Frostbite, hypothermia Gas poisoning

Table compiled by the authors based on data from an internet source⁵

Table 3. Mortality structure among shift workers at high-altitude facilities in Kyrgyzstan

No.	Cause of mortality	Proportion, %	Incident characteristics
1	Accidents and injuries	40–60	Accidents, collapses
2	Cardiovascular diseases	20–30	Acute coronary syndrome and other acute pathological conditions
3	Respiratory complications	10–15	Pulmonary edema, respiratory failure
4	Intoxications	5–10	Carbon monoxide, industrial gases
5	Other	≤5	Hypothermia

Table compiled by the authors based on data from an internet source⁶

Organization of medical station infrastructure, communications, and logistics in high-altitude conditions

At the stage of feasibility study of a mining project, the technical specifications include the organization of a medical service at the production site in high-altitude conditions, specifying the regulations on the medical service, the scope and type of medical services, staffing schedule, job responsibilities of personnel, lists of necessary medications, consumables and equipment, premises, and other conditions required for the functioning of the medical service.

The main principles of organizing and operating a medical station (MS) at an RIS located in high-altitude conditions are: selection of the site for the station (consideration of terrain and degree of ruggedness, proximity to transport links); calculation of the number of medical personnel; equipping with medical equipment, consumables, and medicines depending on the size of the working population; organization of communication for the MS at the RIS (implementation of telemedicine technologies, use of satellite communication channels, and connection to a 24/7 support medical center system); logistics activities at the RIS (ensuring uninterrupted control of material assets and information flows, taking into account the specifics of RIS operations, seasonality of transport links, route

durations, communication features; development of a long-term strategy for the development of the logistics system and short-term operational plans to achieve set goals) [21].

The choice of medical service format depends on the level of risks and the number of working personnel at the RIS. The medical service may operate as a paramedic station for facilities with a small number of employees (50–60 people) and low risk; when the number of employees at the enterprise exceeds 500 people, medical care is provided at a medical station with a physician’s office, treatment room, medication storage, isolation room, and other auxiliary rooms.

The medical service at an RIS in mountainous areas consists of several (at least two) units: the main MS of the RIS (paramedic or physician-staffed) and an MS at the central checkpoint. At the MS located in the shift camp, medical care, including emergency care, is provided to the population on demand; medical examinations, patient treatment, and vaccine prophylaxis are conducted; medical evacuations (scheduled or emergency) are organized; and continuous monitoring of the health status of workers, collection and processing of statistical data, and preparation of reports are carried out.

The medical station at the central checkpoint is located at the entrance to the production site and is equipped with basic medical equipment for monitoring

⁵ National Statistical Committee of the Kyrgyz Republic. <https://stat.gov.kg/ru/>

⁶ Ibid.

vital signs: clinical laboratory equipment and rapid testers for detecting narcotic substances, alcohol, and various prohibited drugs in biological fluids. The main task of this medical station is screening all shift workers and contractors entering the production site [22].

If there are additional production facilities located at a distance from the shift camp and the main production site, it is possible to create an additional MS directly near the production site territory, which should also be equipped with basic medical equipment for checking vital signs, a necessary supply of essential medications, including those for treating emergency conditions, and an antidote kit. The main tasks of the additional medical station are conducting morning professional examinations of workers using hardware-software complexes, as well as conducting first aid training for shift workers [23].

A distinctive feature of the operation of an MS under high-altitude conditions is the large number of worker visits for AMS; therefore, the equipment list must include oxygen sources (oxygen cylinders, oxygen concentrators) and a hyperbaric chamber for the treatment of acute mountain disorders [24, 25].

To equip an MS with equipment, medications, and consumables, guidelines from international organizations developed for the operation of medical services located in remote locations can be used. Also, a good practice is to include a pharmacist on the staff of the medical team, whose tasks include interaction with medication suppliers, regular inventory of medications and equipment, procurement of medications, and their shipment to the production site [26].

The primary means of communication among all RIS, including the medical service, is telephone communication. The medical service must be equipped with all types of communication (internet, radio, cellular, and satellite communication). Through satellite technologies, remote diagnostics and consultations are implemented, and prompt access to patients' electronic records for reviewing medical history is ensured, which is particularly important for RIS workers [27, 28].

Logistical support at an RIS includes ambulance vehicles for timely evacuation of workers with serious illnesses and injuries from the RIS in mountainous areas to the nearest specialized medical facility. At an RIS, it is necessary to have at least two ambulances (EMT vehicles) operating on gasoline engines with a 4 × 4 wheel drive; drivers must be relieved from other duties and be ready to perform emergency medical evacuation. Ambulances must be equipped with all necessary medical equipment (mechanical ventilator, automatic oxygen delivery system, electrocardiograph, defibrillator, infusion pump for controlled drug administration, etc.), be in working condition, and be permanently housed in a heated garage. Additionally, ambulance transport must be equipped with radio communication and a map indicating reception zones

and corresponding radio channels along the route, and the use of GPS during its movement is necessary to maintain constant communication with the evacuation transport [29]. Other available transport means may include air ambulance (helicopter). In these cases, the organization of a helipad or airstrip must be considered.

With the development of digital technologies, the experience of using telemedicine technologies at RIS has significantly increased. The study by Smal et al. presents the results of an analysis of the frequency and nature of discrepancies in diagnostic decisions when describing X-ray images by a local physician (remote residential areas) and by experts using remote medical service technologies. The most common types of diagnostic errors were identified, and the quality of X-ray description was assessed [30].

The possibility of constructing a new model of medical support that complies with unified standards of medical care through the introduction of telemedicine and mobile components was demonstrated by Levanov et al.: new elements of the system may include re-equipping RIS medical stations with medical and telecommunication equipment and connecting them to medical information systems; implementing medical information exchange systems; using patient-oriented personal hardware-software complexes for prevention, treatment monitoring, and rehabilitation of workers; using mobile telemedicine complexes; increasing the material, technical, and human resource capacity of emergency medical care and medical evacuation services; and developing digital communication systems between primary healthcare units, emergency medical services, air ambulance services, and specialized and high-tech care centers [31]. Other authors presented information on the use of telemedicine technologies at oil-producing companies in the Far North regions [32].

Martinelli et al. noted the increasing role of telemedicine consultations in the operation of MSs located in mountainous areas. Data were presented on the testing of the European project e-Rés@MONT (Interreg ALCOTRA), within which a temporary videoconferencing system was developed for dynamic medical monitoring of diseases occurring at high altitude (such as AMS, high-altitude pulmonary and cerebral edema). During the project implementation, 702 teleconsultations were conducted: 333 (47%) individuals were referred to specialized doctors, 356 (51%) were monitored remotely by physicians, and 13 (2%) patients required immediate interventions. In the cases presented, the use of telemedicine technologies allowed the avoidance of 30 unnecessary interventions: 18 ambulance trips, 12 air ambulance flights, and consequently, associated hospitalizations to emergency and specialized care units, as well as achieving financial savings of € 75,489 [33].

The study by Zhou et al. provided information on the implementation of telemedicine ultrasound examination

of 708 patients in remote areas of China, involving a remote expert and using the tele-HHUS system (STOCK, Chengdu, China), which allowed 75% of patients to receive the service at their place of residence without visiting a medical clinic [34].

Some publications present data on conducting tele-education of personnel [35], teleconsultations, and telemonitoring of morbidity dynamics in patients with chronic pathology [36, 37]. However, the widespread implementation of telemedicine technologies into the daily practice of remote healthcare requires a significant increase in funding for the basic equipping of medical stations, technical support, coordination of this activity, and the training of relevant specialists [38].

Organization of treatment and preventive work under high-altitude conditions

Treatment and preventive work consists of providing primary and emergency care to patients with mountain pathology, injuries, and acute surgical conditions, in full or reduced scope depending on medical capabilities, stabilization of the patient's condition, and, if necessary, their evacuation to a specialized medical facility. The list and volume of medication and consumable supplies depend on the location of the facility, the number of employees, and the specifics of production activities; currently, there is no single approved list intended for MSs located in high-altitude conditions. As a template, the list of medications recommended by the WHO Model List of Essential Medicines⁷ and Order⁸ No. 617 of 07.12.2011 is used, which contains 136 items and is intended for providing medical care to shift workers numbering no more than 500 people. Such lists are not strictly regulated and can be adapted according to the needs of the medical station at the RIS, taking into account the operating terrain: antimalarial drugs — in tropical countries, drugs for acclimatization to high altitude (acetazolamide, dexamethasone, etc.) — in high-altitude regions.

Medical personnel also perform sanitary-hygienic and preventive measures at the production site: medical examinations of workers, monitoring of water and food quality, and others.

In the study by Badmaeva⁹, a scheme of organizational technology for improving the delivery of medical care to RIS workers based on a paramedic/physician MS is presented. It is recommended to be included in a common information system with access to and presentation of information in databases based on the results of periodic medical examinations and medical evacuations. Also, MSs at RIS should maintain round-the-clock communication with contact centers

coordinating the work of RIS; specialists of the RIS medical service can receive telemedicine consultations from specialist physicians and receive training through educational programs in remote healthcare.

The organization of general therapeutic care for workers under mid- and high-altitude conditions consists of the sequential implementation of preventive measures (altitude acclimatization, pharmacological prevention of mountain sickness, adequate rehydration and prevention of electrolyte imbalances, protection against light-induced eye and skin damage, prevention of cold injury), treatment of early manifestations of AMS and prevention of its complications, and provision of therapeutic care for decompensation of somatic diseases [39].

The main approaches to the AMS prevention in the general worker population include staged acclimatization, which involves: gradual altitude gain (an ascent of no more than 300–500 m per day is recommended after reaching 3000 m, with rest days for every 1000 m of altitude gain); making an ascent to a higher altitude during the day followed by descending to a lower altitude for sleep; starting from 3000 m, the altitude of each subsequent sleeping location should not exceed the previous one by more than 300–500 m; staged ascent with mandatory one-day stops for adaptation, which reduces the AMS risk; adherence to a drinking regimen and monitoring of the main physiological systems.

When ascending to an altitude of 2500–3000 m for recreational climbers, it is recommended to spend one day for adaptation at 2500 m; then, when ascending to 3000–4000 m, every 1000 m of ascent should be interrupted by one day of rest at an intermediate altitude. Two independent studies found that staying for 6–7 days at a moderate altitude ($\approx$ 2200–3000 m) or a two-day stay at 3000 m before moving to a high altitude (4300 m) (so-called “staged/gradual ascent”) reduced the AMS risk, improved pulmonary ventilation and oxygenation, and reduced pulmonary artery pressure [40, 41]. The study [42] demonstrated the feasibility of short stays at intermediate altitudes (around 1500 m) from a physiological perspective to reduce the AMS risk.

Due to the constant presence of shift workers under high-altitude conditions and the continuous production process, staged acclimatization is practically impossible for them. Shift workers ascend to the production site in a single day from sea level to an altitude of 3800–4200 m.

Pharmacological support for adaptation and prevention of AMS involves the use of acetazolamide, dexamethasone, ibuprofen, nifedipine, tadalafil, sildenafil (Table 4).

⁷ Model List of Essential Medicines. <https://www.who.int/groups/expert-committee-on-selection-and-use-of-essential-medicines/essential-medicines-lists?ysclid=mnrg1jc38e497785540>

⁸ Order of the Ministry of Health of the Kyrgyz Republic No. 617 of December 7, 2011, «On measures to improve emergency (ambulance) medical care for the population of the Kyrgyz Republic».

⁹ Badmaeva ER. Improvement of the organization of medical care for workers at remote industrial sites: author's abstract of diss. Cand. Sci. (Med.). N.A. Semashko National Research Institute of Public Health; Moscow, 2023.

Table 4. Recommended doses of medications used for the prevention and treatment of various forms of acute mountain sickness

Medication	Indication	Route of administration and dosing regimen
Acetazolamide (Diacarb®, Diamox)	Prevention of AMS, HACE	Orally 125 mg every 12 h ^{a,b} In children: 1.25 mg/kg b.w. every 12 h (maximum single dose 125 mg)
	AMS treatment ^c	Orally 250 mg every 12 h In children: 2.5 mg/kg b.w. every 12 h (maximum single dose 250 mg)
Dexamethasone	Prevention of AMS, HACE	Orally 2 mg every 6 h or 4 mg every 12 h ^a In children: do not use for prophylaxis
	Prevention of AMS, HACE	Orally, intravenously/intramuscularly AMS: 4 mg every 6 h HACE: 8 mg once, then 4 mg every 6 h In children: 0.15 mg/kg b.w. every 6 h (maximum single dose 4 mg)
Ibuprofen	Headache	Orally 600 mg every 8 h
Nifedipine (slow-release)	HAPE prevention	Orally 30 mg every 12 h or 20 mg every 8 h ^d
	HAPE treatment	Orally 30 mg every 12 h or 20 mg every 8 h ^d
Tadalafil	HAPE prevention	Orally 10 mg every 12 h ^d
Sildenafil	HAPE prevention	Orally 50 mg every 12 h ^d

Table compiled by the authors based on data from the source¹⁰

Note. b.w. — body weight; AMS — acute mountain sickness; HACE — high-altitude cerebral edema; HAPE — high-altitude pulmonary edema; a — for individuals ascending to a given altitude and remaining there after reaching the target elevation, continue medication for 2 days (for those adhering to the recommended ascent rate) and 2–4 days (for those ascending faster than the recommended rate); b — dose applicable for low- and moderate-risk ascent profiles (for high-risk ascent profiles, 250 mg twice daily is recommended); c — acetazolamide may also be used at this dosage as an adjunct to dexamethasone in the treatment of HACE, although dexamethasone remains the first-line drug; d — for prevention of HAPE in individuals ascending to a given altitude and remaining there, continue medication after reaching altitude: for 4 days (when adhering to the recommended ascent rate) and 4–7 days when exceeding the recommended ascent rate.

Acetazolamide is a sulfonamide-group drug; the recommended dose for AMS prevention in adults is 125 mg every 12 h. The mechanism of action of acetazolamide in the AMS treatment is based on its ability to accelerate physiological acclimatization by affecting acid-base balance and respiration. Acetazolamide blocks the enzyme carbonic anhydrase in the kidneys and other tissues, which reduces bicarbonate reabsorption and increases its excretion in the urine. Bicarbonate loss leads to mild metabolic acidosis, a decrease in blood pH, stimulation of respiration with an increase in minute ventilation, which contributes to an increase in alveolar and arterial pO₂. Due to enhanced respiration, blood oxygen saturation increases and the symptom complex of hypoxia — a key factor in the AMS development — is reduced.

McIntosh et al. [43] noted that when taking the drug at a dose of 62.5 mg every 12 h, no reduction in pharmacological effect was observed. At the same time, Lipman et al. [44] showed in a randomized controlled trial that the use of acetazolamide at a dose of 62.5 mg is less effective in AMS preventing than

125 mg, and higher doses (250 mg every 12 h) may be recommended only when ascending to altitudes up to 5000 m under high-risk conditions, although no direct comparisons of dosing regimens have been conducted. The recommended dose of acetazolamide for children is 1.25 mg/kg b.w. (maximum — 125 mg) every 12 h. However, this drug has adverse reactions: increased diuresis (which in high-altitude conditions may contribute to additional dehydration and electrolyte imbalance), paresthesias, allergic reactions, anaphylaxis. The presence of any type of allergic reactions caused by sulfonamide drugs, or a history of Stevens–Johnson syndrome, are contraindications to the use of acetazolamide, and with long-term use, leukopenia, thrombocytopenia, and aplastic anemia may develop [45].

In some studies, the use of inhaled budesonide at a dose of 200 µg twice daily in the AMS prevention was studied compared to placebo. Although a clear mechanism of preventive action against AMS could not be established, improvements in spirometry parameters and oxygen saturation were noted [46, 47].

¹⁰ Wilderness Medical Society Clinical Practice Guidelines for the Prevention, Diagnosis, and Treatment of Acute Altitude Illness: 2024 Update. *Wilderness & Environmental Medicine*. 2024;35(1):2S–19S. <https://doi.org/10.1016/j.wem.2023.05.013>

When AMS develops directly at the production site, treatment is aimed at reducing physical exertion and meeting the body's oxygen demand (oxygen inhalation), as well as prophylactic administration of acetazolamide at a dose of 250 mg/day every 12 h for two to three days. In severe AMS (10–12 points on the Lake Louise Scale) [48] and in the development of high-altitude pulmonary edema, the worker must be urgently evacuated down to the lowlands.

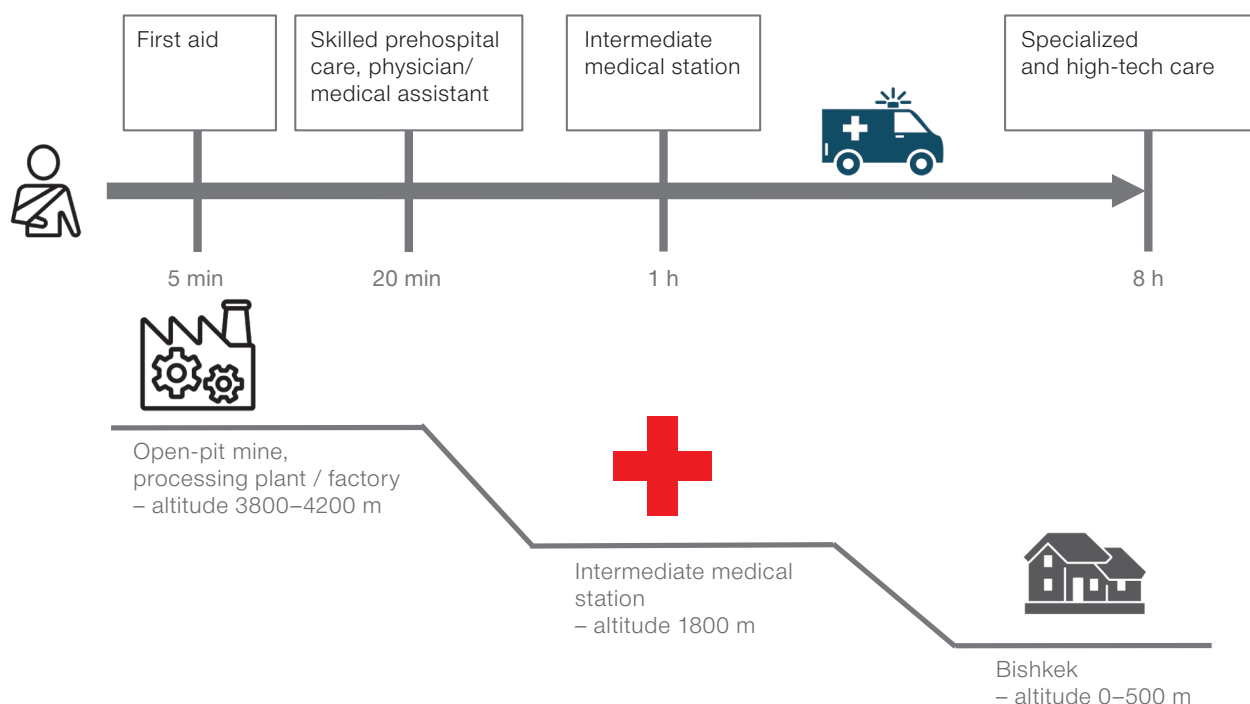
When carrying out production activities in the mountains, planned or emergency evacuation is carried out along pre-developed evacuation routes, for each of which sufficient medical forces and resources must be available. In some cases, such directions may be isolated and separated by tens of kilometers. Features of transporting patients from an RIS under high-altitude conditions include evacuation from hard-to-reach areas with an underdeveloped road network, abrupt changes in weather conditions, and short daylight hours.

Features of medical evacuation (ME) using air ambulance in mountainous areas — short daylight hours, often unfavorable weather conditions, and high financial costs. In many countries, there is no unified state service responsible for organizing and conducting ME from any facilities regardless of their purpose or departmental affiliation. The use of air ambulance for evacuating casualties from an RIS can significantly shorten the time of rescue operations in mountainous areas. Rescue helicopters must operate within the existing emergency medical care system with appropriate mountain rescue and medical personnel, as well as medical and rescue equipment on board [49].

In Europe, the USA, and Canada, there is a system for training medical teams that perform evacuation of casualties by air transport from an RIS to the receiving medical organization. Such teams ensure stabilization of the patient's condition and life support during the flight [50].

When an RIS is located at an altitude above 3500 m, a two-stage system for evacuation can be used (this scheme is used at the Kumtor company) due to the significant distance of the RIS from populated areas. For the proper organization of timely treatment and evacuation support, one of the main criteria for its correct implementation is minimizing the time from the moment of injury/illness of the victim to the provision (if necessary) of specialized and high-tech care. In a two-stage ME scheme, an intermediate MS is established (at approximately 1700–1800 m above sea level), which serves as a transit logistics hub for delivery, storage, sorting of medical supplies, staff rotation, and solving other operational tasks. The medical station at the operational base is used during the evacuation of patients (with severe mountain sickness and high-altitude pulmonary edema) who only require descent from altitude. The intermediate medical station may also be used during evacuation in poor weather conditions, at night, in cases of patient instability, transportation problems, etc. The travel time from the Kumtor mine to the intermediate medical station is one hour; the medical station is staffed by a paramedic (Fig. 2).

In some Russian studies on the ME organization of RIS personnel, an assessment of the structure of causes of all evacuations depending on age and type



The figure is adapted from [22]

Fig. 2. Scheme of a two-stage system for organizing medical evacuation under high-altitude conditions

of industrial enterprise has been conducted. For example, Karpov et al. presented an analysis of emergency MEs among RIS workers carried out during the period 2018–2020. It was found that the main causes of evacuation were: injuries and poisonings in 367 (24.5%) cases, diseases of the circulatory system — 307 (20.5%) cases, and diseases of the digestive system — 256 (17.1%). Differences in the structure of causes of emergency medical evacuations were identified: among young workers (under 40 years old), the main cause of evacuation was injuries and poisonings in 30.3% of cases; in older age groups, diseases of the circulatory system predominated — 37.4% [51].

Sometimes, urgent evacuation is impossible due to technical and weather-related reasons. In these cases, treatment in a hyperbaric chamber with increased pressure yields good temporary results. However, data on the use of hyperbaric chambers for the AMS treatment are limited due to a weak evidence base, and the use of the “simulated descent” method in the context of hyperbaric therapy is considered a temporary measure rather than a full replacement for descending the patient to low altitude. Nevertheless, the use of hyperbaric chambers is advisable.

There are two types of hyperbaric chambers for AMS treating: the first type — portable hyperbaric chambers made of polyurethane (Gamow bag); the second type — stationary hyperbaric chambers. The Gamow bag (weight 7 kg) is designed for one person and is recommended for use by all climbers ascending to high altitude [52]. Its main operating principle is the ability to increase the pressure inside the hyperbaric chamber using a pump to values corresponding to the atmospheric pressure at an altitude of 1500 m.

The therapeutic effect of the hyperbaric chamber (hyperbaric therapy) in the AMS treatment is based on the artificial increase of pressure, i.e., “simulating descent from altitude” without actually descending the patient, thereby increasing the partial pressure of oxygen in the inhaled air inside the hyperbaric chamber, as the air pressure inside it is increased using a pump. As a result, blood oxygen saturation improves, and hypoxia — the main cause of AMS symptoms — rapidly decreases.

The pressure inside the hyperbaric chamber corresponds to the atmospheric pressure at a lower altitude (1000–3000 m lower than the actual pressure), which is the key therapeutic effect, analogous to real descent. Improvement in oxygenation occurs, vasogenic tissue edema and intracranial pressure are reduced, ultimately leading to a decrease in cerebral edema. In the lungs, hemodynamics and microcirculation improve, pulmonary hypertension is reduced, and oxygen delivery to tissues is enhanced. Clinical effects develop rapidly, from several minutes to an hour [53].

In a clinical study by Kasic et al. [54], two treatment methods were compared in 24 patients with AMS, who were randomly assigned to groups: the first received

hyperbaric treatment (simulating a descent of 1432 m by placing patients in a fabric hyperbaric chamber and increasing the pressure inside the chamber to 120 mmHg (2.3 PSI) above ambient pressure), the second received oxygen inhalation therapy. Both courses lasted for 2 h. The same effect was obtained from both treatment methods: the rate of symptom reduction in AMS did not differ between the two groups, i.e., the use of a hyperbaric chamber is comparable in effectiveness to the use of oxygen inhalation for short-term relief of condition in patients with AMS.

In the work by Markovic et al. [55], the experience of successful treatment of high-altitude pulmonary edema (HAPE) in a 37-year-old patient in a hyperbaric chamber at an altitude of 7060 m is described. The authors used a portable Gamow Bag hyperbaric chamber to generate a pressure of 103 mmHg without additional oxygen use, which corresponded to a “simulated descent” to an altitude of up to 4400 m. The treatment was successful, the HAPE symptoms were resolved, and subsequently the patient was descended to an altitude of 2000 m and made a full recovery.

Simanchas-Racines et al. evaluated the clinical efficacy and safety of non-pharmacological and pharmacological interventions as monotherapy for the treatment of acute altitude illness in an analysis of 13 studies and 468 participants. It was found that the use of hyperbaric oxygenation (in three studies involving 124 people) did not lead to increased mortality, but complete resolution of AMS symptoms was not achieved. In one study involving 64 people, it was found that simulating a pressure reduction to 193 mbar compared to 20 mbar could reduce symptom severity to 2.5 versus 3.1 units after 12 h of treatment (clinical assessment ranged 0–11 — worsening; a mean reduction of 0.6 points with the intervention had a low level of evidence). Furthermore, no complications were identified with the use of hyperbaric chambers compared with supplemental oxygen (one study with 29 participants).

Pharmacological treatment of AMS (dexamethasone, acetazolamide) was evaluated in 11 studies involving 375 people. Overall mortality was not reported; one publication presented data on complete resolution of HACE symptoms at 12 h and 16 h with the use of dexamethasone, while with acetazolamide the reduction in symptom severity was not significant (standardized mean difference (SMD) -1.15, 95% CI [-2.56; 0.27]). Some studies presented data on the use of gabapentin and magnesium sulfate, with the authors noting a low level of evidence and the absence of convincing advantages over other treatment methods, particularly over the use of oxygen inhalation or dexamethasone [56].

At the high-altitude Kumtor enterprise, the effectiveness of a stationary hyperbaric chamber (Fig. 3) was studied in 72 patients of both sexes aged 22–55 years at an altitude of 3800 m. After treatment, complete resolution of AMS symptoms was observed in 79% of

patients ($n = 57$); AMS relapse in the form of persistent headache and gastrointestinal disorders was recorded in 12.5% of patients ($n = 9$); no treatment effect was detected in 8.5% of patients ($n = 6$). Along with this, with the use of hyperbaric oxygenation, the total number of evacuations from the Kumtor deposit related to mountain disorders decreased by 50% per year [57].

The advantage of a stationary hyperbaric chamber is the ability to accommodate 3–4 people simultaneously, after which the pressure inside is increased using an electric pump at a rate of 10 mbar/min. The initial atmospheric pressure at an altitude of 3800 m is 630 mbar. The target pressure inside the hyperbaric chamber is 160 mbar, which corresponds to approximately 1828 m above sea level. Such pressure in the hyperbaric chamber is achieved in 16 min and is sufficient for the AMS treatment. The treatment time in the hyperbaric chamber is 3–4 h. After the treatment session ends, a gradual reduction of pressure inside the chamber begins over 30 min. Side effects during hyperbaric treatment are minimal and are limited to patients' complaints of unpleasant but transient sensations of pressure in the ears. Complications such as barotrauma of the eardrums, excessive CO_2 accumulation, and claustrophobia have not been observed.

Thus, hyperbaric chambers provide a "simulated descent" and lead to a rapid reduction in AMS symptoms; according to clinical studies, their effectiveness is comparable to oxygen therapy. Several authors emphasize that the use of a hyperbaric chamber is effective for the short-term treatment of acute mountain disorders (AMS, HAPE, HACE); however, due to the

limited evidence base, this treatment method does not replace descent to low altitude.

Training and preparation of medical specialists and shift workers for work in extreme high-altitude conditions

Medical personnel providing emergency care at RIS in hard-to-reach areas must possess a broad range of specialized medical training, experience working in extreme conditions, and organizational skills. Working at an RIS with limited diagnostic capabilities requires medical workers to have psychological resilience, the ability to make urgent independent decisions, and high-level communication, professional, and leadership competencies [58].

In the study by Sokolovich et al., when analyzing data from 75 technical specifications of the Corporate Medicine Center group of companies, it was shown that the medical worker at an RIS should be an internist or general practitioner with a broad scope of competencies, a deep understanding of general medical issues, advanced training in emergency medical care, and special skills in treating life-threatening conditions. Training in emergency medical care should include knowledge of basic and advanced resuscitation measures [59].

Logunov et al. emphasized that the training of medical personnel for work at RIS should be an important part of the strategic development of any modern company that engages workers for professional activities at RIS [60].

Bygvraa et al. believe that, despite the availability of universal knowledge in emergency medical care, there are differences in the professional training of medical personnel depending on the location of the facility. Thus, physicians working on maritime vessels must have knowledge in the fields of marine and diving medicine, occupational pathology, tropical medicine, as well as skills in risk assessment and local requirements [61].

In the work of Badmaeva et al., the necessity of special training for medical personnel in remote healthcare, improvement of the regulatory framework governing the procedures and algorithms for providing medical care to workers at RIS, the introduction of telemedicine consultations, and the development of electronic databases of RIS workers has been demonstrated [62].

Before mobilization to an RIS in high-altitude conditions, training of medical personnel should be conducted on the company's standard operating procedures, including training in the use of medical information systems at the medical station, telemedicine systems, and rapid diagnostic equipment. Additional training of medical personnel should include instruction in remote medicine and emergency medicine in the form of courses at specialized training centers, where medical personnel learn algorithms for basic and advanced cardiac life support [63].



Photo taken by the authors

Fig. 3. Stationary hyperbaric chamber in a medical clinic at a remote industrial site at an altitude of 3800 m

Some authors note an insufficient level of knowledge of mountain medicine among medical personnel working in high-altitude conditions; therefore, it is advisable, when training medical specialists for work in mountainous areas, to have constant and systematic updating of skills and professional competencies in the field of prehospital emergency care in mountain conditions. The latter includes ensuring upper airway patency, performing mechanical ventilation, bleeding control, limb immobilization, treatment of shock of various etiologies, establishing intravenous access and performing infusion therapy, thrombolysis, medical triage, and others [64, 65].

The theoretical knowledge and skills required for medical specialists at an RIS in mountainous areas include the management of emergency conditions according to the basic and advanced cardiac life support algorithms of the National Resuscitation Council of the Russian Federation¹¹, the European Resuscitation Council¹², the American Heart Association¹³; knowledge of the guidelines of the International Commission for Alpine Rescue for emergency medical care in acute mountain pathology¹⁴; and knowledge of the fundamentals of occupational diseases, epidemiology, and hygiene. Table 5 lists the theoretical knowledge and practical

skills required for medical specialists at remote industrial sites in mountainous areas.

In both the Russian Federation and the Kyrgyz Republic, according to the Labor Code, mining companies must organize training for shift workers in first aid algorithms and form groups of assistants whose task is to assist emergency services in the event of natural or man-made emergencies. To train shift workers, training sessions may be organized involving private companies or government organizations that offer first aid courses [66].

Document flow in the medical service of an RIS is carried out according to the nomenclature and in accordance with the regulatory requirements of government bodies. An important functional duty of the medical worker is to conduct regular audits and inspections of equipment and documentation.

To facilitate document flow at the medical station, medical information systems (MIS) are widely used. The Russian company Nobilis has implemented the TouchMED information system at remote enterprises of Russian Railways (RZD), GazProm TransGaz NN, Rosseti SZ, and UdmurtAvtodor [67].

At the Kumtor deposit, the Jonoke MIS from the Canadian company Jonoke Software Development

Table 5. Theoretical knowledge and skills required for medical specialists at remote industrial sites in mountainous areas

No.	Competency domain	Required knowledge	Practical skills
1	Emergency medicine	Algorithms for the management of major emergency conditions: shock, acute coronary syndrome, acute cerebrovascular accident, etc.	Cardiopulmonary resuscitation, defibrillation, tracheal intubation, intravenous access, medical evacuation, etc.
2	Traumatology	Management of injuries, burns, hypothermia, poisonings; use of splints and immobilization, etc.	Immobilization, bleeding control, primary surgical wound debridement, suturing, medical evacuation, etc.
3	Mountain medicine	Acute mountain sickness, high-altitude pulmonary edema and high-altitude cerebral edema, hypothermia, frostbite	Treatment in a hyperbaric chamber, oxygen therapy
4	Disaster medicine	Basics of casualty management in mass casualties, triage of casualties	Triage of mass casualties, medical evacuation, etc.
5	Infectious diseases, sanitation and hygiene	Basics of infection control and sanitary-hygienic measures	Screening and organization of isolation procedures, early disease prevention
6	Occupational diseases	Basics of protective measures against occupational factors: dust, noise, vibration, use of chemical substances	Screening, risk assessment, and organization of procedures for early prevention of occupational diseases

Table compiled by the authors using data from references¹⁵

¹¹ National Council for Reanimation of the Russian Federation. <https://rusnrc.ru/>

¹² European Resuscitation Council. <https://www.erc.edu/>

¹³ American Heart Association. <https://www.heart.org/>

¹⁴ ICAR Med Com. <https://www.icar-med.com/>

¹⁵ Patients protocol manual. International SOS. <https://www.internationalsos.com/>

is used. This system allows for maintaining medical records, inputting information on ongoing treatment and examination results, generating reports, analyzing patient visits and the nature of pathologies, and conducting inventory of medical supplies and equipment [68].

Of great importance is the interaction of mining companies with local authorities and health agencies, as well as with medical institutions in the capital of the Kyrgyz Republic. All mining companies must enter into contracts for medical services with highly specialized medical institutions in the field of mountain medicine.

CONCLUSIONS

The main principles of organizing and operating a medical station at an RIS located in high-altitude conditions are: creation of medical infrastructure (depending on the size of the working population), organization of a treatment and preventive work system, development of a logistics system strategy, organization of communication and evacuation measures.

References

1. Karpov AB, ed. *Remote Healthcare*. Moscow: GEOTAR-Media; 2024 (In Russ.).
2. Munir S. Comprehensive approach to remote healthcare in Arctic zones of the Russian Federation. *The Journal of the Institute of Remote Healthcare*. 2016;7(2):31–3.
3. Korneeva YaA, Simonova NN. Assessment of extreme factors of shift work in Arctic conditions by workers with different regulatory processes. *Hygiene and Sanitation*. 2016;95(4):381–6 (In Russ.).
EDN: [VZVZON](#)
4. Luks AM, McIntosh SE, Grissom CK, Auerbach PS, Rodway GW, Schoene RB, et al. Wilderness Medical Society practice guidelines for the prevention and treatment of acute altitude illness: 2014 update. *Wilderness & Environmental Medicine*. 2014;25(4 Suppl):S4–14.
<https://doi.org/10.1016/j.wem.2014.06.017>
5. Stream JO, Luks AM, Grissom CK. Lung disease at high altitude. *Expert Review of Respiratory Medicine*. 2009;3(6):635–50.
<https://doi.org/10.1586/ers.09.51>
6. Macholz F, Sareban M, Berger MM. Diagnosing acute mountain sickness. *JAMA*. 2018;319(14):1509.
<https://doi.org/10.1001/jama.2018.0220>
7. Cameron H, McDevitt M, Kayser B, Kutz C, Dawadi S, Hawley A. Risk Determinants of Acute Mountain Sickness in Trekkers in the Nepali Himalaya: A 36-Year Follow-Up. *High Altitude Medicine & Biology*. 2026;27(1):17–22.
<https://doi.org/10.1177/15578682251382432>
8. Viscor G, Corominas J, Carceller A. Nutrition and Hydration for High-Altitude Alpinism: A Narrative Review. *International Journal of Environmental Research and Public Health*. 2023;20(4):3186.
<https://doi.org/10.3390/ijerph20043186>
9. Savioli G, Ceresa IF, Gori G, Fumoso F, Gri N, Floris V, et al. Pathophysiology and Therapy of High-Altitude Sickness: Practical Approach in Emergency and Critical Care. *Journal of Clinical Medicine*. 2022;11(14):3937.
<https://doi.org/10.3390/jcm11143937>
10. Bukhtiyarov IV, Golovkova NP, Chebotarev AG, Salnikov AA. Working conditions and occupational diseases at open-pit mining enterprises. *Occupational Medicine and Industrial Ecology*. 2017;5:44–9 (In Russ.).
EDN: [YNUNHR](#)
11. Izmerov NF, Chebotarev AG. Results of the Institute's research and development objectives on occupational health issues in the mining industries of Russia. *Mining Industry*. 2013;2(108):34–8 (In Russ.).
EDN: [QYOKVT](#)
12. Bayanova AE, Zhdanova EV, Lukyanova EG. Criteria for the stress of adaptation mechanisms in healthy men working on a rotational basis in the Far North. *Journal of Medical and Biological Research*. 2023;11(4):462–70 (In Russ.).
<https://doi.org/10.37482/2687-1491-Z167>
13. Akimov AM. Some factors of chronic social stress in men engaged in expeditionary-shift work in the Arctic territories of the Tyumen region (pilot study). *Siberian Scientific Medical Journal*. 2023;43(3):104–12 (In Russ.).
<https://doi.org/10.18699/SSMJ20230313>
14. Matamala PJ, Aguayo F. Mental health in mine workers: a literature review. *Industrial Health*. 2021;59(6):343–70.
<https://doi.org/10.2486/indhealth.2020-0178>

15. Farias JG, Jimenez D, Osorio J, Zepeda AB, Figueroa CA, Pulgar VM. Acclimatization to chronic intermittent hypoxia in mine workers: a challenge to mountain medicine in Chile. *Biological Research*. 2013;46(1):59–67.
<https://doi.org/10.4067/S0716-97602013000100009>
16. Ashyrbaev AA, Tolbashieva GU. Frequency of acute mountain sickness and factors influencing it. *KRSU Bulletin*. 2019;19(1):65–7 (In Russ.).
EDN: [ZALGSL](#)
17. Wu TY, Ding SQ, Liu JL, Jia JH, Chai ZC, Dai RC. Who are more at risk for acute mountain sickness: a prospective study in Qinghai-Tibet railroad construction workers on Mt. Tanggula. *Chinese Medical Journal*. 2012;8:1393–400.
18. Forster PJG. Reproducibility of individual response to exposure to high altitude. *BMJ*. 1984;289(6454):1269.
19. Kalendzhyan SO, Ermakova SE, Izmalkov NS. Analysis of the main features of outsourcing in healthcare. *Russian Journal of Entrepreneurship*. 2016;17(8):981–8 (In Russ.).
<https://doi.org/10.18334/rp.17.8.35118>
20. Perevezentsev EA. Features of morbidity and medical support systems for workers in the gas industry. *Medical Almanac*. 2017;6(51):12–6 (In Russ.).
EDN: [ZSMOAZ](#)
21. Lentz T, Genty S, Gergereau A, Descatha A. Health Support for a Remote Industrial Site. *Frontiers in Public Health*. 2019;7:180.
<https://doi.org/10.3389/fpubh.2019.00180>
22. Ashyrbaev AA. An Effective Model for Organizing Medical Services in the context of remote healthcare in the Kyrgyz Republic. *KRSU Bulletin*. 2026;26(1):179–86 (In Russ.).
EDN: [WKUZQF](#)
23. Kobayakova OS, Deev IA, Boykov VA, Perfil'eva DYU, Shibalkov IP, Antipov SA, et al. Some organizational technologies for providing medical care in small and hard-to-reach settlements. Healthcare organization and public health. *Siberian Journal of Clinical and Experimental Medicine*. 2025;40(3):194–204 (In Russ.).
<https://doi.org/10.29001/2073-8552-2025-40-3-194-204>
24. Simancas-Racines D, Arevalo-Rodriguez I, Osorio D, Franco JVA, Xu Y, Hidalgo R. Interventions for treating acute high altitude illness. *Cochrane Database of Systematic Reviews* 2018,6:CD009567.
<https://doi.org/10.1002/14651858.CD009567.pub2>
25. Samoilov AS, Rylova NV, Bolshakov IV, Kazakov VF. Prevention and treatment of altitude sickness. *Disaster Medicine*. 2021;2:55–8 (In Russ.).
<https://doi.org/10.33266/2070-1004-2021-2-55-58>
26. Ashyrbaev AA, Bebezov BK. Organization of emergency medical care in the context of remote medicine. In: *Selected issues of anesthesiology, resuscitation, and emergency medical care*. Bishkek: KRSU; 2023 (In Russ.).
EDN: [LGWYQS](#)
27. Khadonova SV. Use of GLONASS technology in providing emergency medical care. *Healthcare*. 2011;10:64–9 (In Russ.).
EDN: [QBJZWL](#)
28. Satenova GA, Satenov ZhK, Netalieva DP. Innovative technologies in the service of the ambulance station of Aktobe. *Medical Journal of Western Kazakhstan*. 2014;4(44):31–3 (In Russ.).
EDN: [UIQALT](#)
29. Radushkevich VL, Bartashevich BI. Providing emergency care in remote and hard-to-reach areas. *Emergency Medical Care*. 2011;12(4):41–8 (In Russ.).
EDN: [RLOHCN](#)
30. Smal TS, Zavadovskaya VD, Deev IA. Application of telemedicine technology in radiation diagnostics for organizing medical services in areas with low population density. *Social Aspects of Population Health*. 2017;1:4 (In Russ.).
<https://doi.org/10.21045/2071-5021-2017-53-1-3>
31. Levanov VM, Perevezentsev EA. Possibilities of integrated use of telemedicine technologies in the system of medical support for the working population in remote areas (literature review). *Journal of New Medical Technologies*. 2019;1:102–10 (In Russ.).
<https://doi.org/10.24411/2075-4094-2019-16233>
32. Teslya AB, Kryukova VK. Justification of the need to use telemedicine technologies for employees of enterprises located in hard-to-reach regions of the Russian Federation. *Scientific Bulletin of the Southern Institute of Management*. 2018;4:100–6 (In Russ.).
33. Martinelli M, Moroni D, Bastiani L, Mrakic-Spota S, Giardini G, Pratali L, et al. High altitude mountain medicine. *Journal of Telemedicine and Telecare*. 2022;28(2):135–45.
<https://doi.org/10.1177/1357633X20921020>
34. Zhou YJ, Guo LH, Bo XW, Sun LP, Zhang YF, Chai HH, et al. Tele-mentored handheld ultrasound system for general practitioners: A prospective, descriptive study in remote and rural communities. *Diagnostics*. 2023;13(18):2932.
<https://doi.org/10.3390/diagnostics13182932>
35. Levanov VM, Mamonova EYu, Orlov OI, Kamaev IA. Application of telemedicine technologies for distance learning of medical personnel of health centers of a large oil and gas producing company. *Medical Almanac*. 2016;1:18–21 (In Russ.).
36. Begiev VG, Andreev VB, Potapova KN, Moskvina AN. Telemedicine in improving the advisory and diagnostic care of highly specialized centers in the Far North. *Modern Trends in the Development of Science and Technology*. 2015;(1–3):6–8 (In Russ.).
EDN: [TWMIBR](#)
37. Sadykova EV, Yuldashev ZM. System for remote monitoring of health status and provision of emergency medical care to patients with chronic diseases. *Biotechnosphere*. 2017;1:2–7 (In Russ.).
EDN: [YMZDAZ](#)
38. Fedyaev DV, Fedyaeva VK, Omelyanovsky VV. Economic justification for the use of telemedicine technologies for clinical examination of the population in remote areas. Pharmacoeconomics. *Modern Pharmacoeconomics and Pharmacoeconomics*. 2014;7(3):30–5 (In Russ.).
EDN: [TIQQCN](#)
39. Jia N, Chen C, Chen Q, Liu J, Shen Z, Liu Y, et al. Acute high-altitude illness: risk factors, susceptibility prediction, and personalized prevention and treatment. *Frontiers in Medicine*. 2026;12:1735083.
<https://doi.org/10.3389/fmed.2025.1735083>

40. Beidleman BA, Fulco CS, Muza SR, Rock PB, Staab JE, Forte VA, et al. Effect of six days of staging on physiologic adjustments and acute mountain sickness during ascent to 4300 meters. *High Altitude Medicine & Biology*. 2009;10(3):253–60.
<https://doi.org/10.1089/ham.2009.1004>
41. Staab JE, Muza SR, Fulco CS, Andrew SP, Beidleman BA. Impact of 2 days of staging at 2500–4300 m on sleep quality and quantity following subsequent exposure to 4300 m. *Physiological Reports*. 2021;9(21):e15063.
<https://doi.org/10.14814/phy2.15063>
42. Baggish AL, Fulco CS, Muza S, Rock PB, Beidleman B, Cymerman A, et al. The impact of moderate-altitude staging on pulmonary arterial hemodynamics after ascent to high altitude. *High Altitude Medicine & Biology*. 2010;11(2):139–45.
<https://doi.org/10.1089/ham.2009.1073>
43. McIntosh SE, Hemphill M, McDevitt MC, Gurung TY, Ghale M, Knott JR, et al. Reduced acetazolamide dosing in countering altitude illness: a comparison of 62.5 vs 125 mg (the RADICAL Trial). *Wilderness & Environmental Medicine*. 2019; 30(1):12–21.
<https://doi.org/10.1016/j.wem.2018.09.002>
44. Lipman GS, Jurkiewicz C, Burnier A, Marvel J, Phillips C, Lowry C, et al. A randomized controlled trial of the lowest effective dose of acetazolamide for acute mountain sickness prevention. *The American Journal of Medicine*. 2020;133(12):e706–15.
<https://doi.org/10.1016/j.amjmed.2020.05.003>
45. Nieto EVH, Molano FD, Medina R, et al. Interventions for preventing high altitude illness: Part 1. Commonly used classes of drugs. *Cochrane Database of Systematic Reviews*. 2017;6:CD009761;
<https://doi.org/10.1002/14651858.CD009761.pub2>
46. Zheng CR, Chen GZ, Yu J, Qin J, Song P, Bian SZ, et al. Inhaled budesonide and oral dexamethasone prevent acute mountain sickness. *The American Journal of Medicine*. 2014;127(10):1001–9.e2.
<https://doi.org/10.1016/j.amjmed.2014.04.012>
47. Chen GZ, Zheng CR, Qin J, Yu J, Wang H, Zhang JH, et al. Inhaled budesonide prevents acute mountain sickness in young Chinese men. *The Journal of Emergency Medicine*. 2015;48(2):197–206.
<https://doi.org/10.1016/j.jemermed.2014.07.047>
48. Roach RC, Hackett PH, Oelz O, Bartsch P, Luks AM, MacInnis MJ, et al. The 2018 Lake Louise Acute Mountain Sickness Score. *High Altitude & Medicine Biology*. 2018;19(1):4–7.
<https://doi.org/10.1089/ham.2017.0164>
49. Grissom CK, Thomas F, James B. Medical helicopters in wilderness search and rescue operations. *Air Medical Journal*. 2006;25(1):18–25.
<https://doi.org/10.1016/j.amj.2005.10.002>
50. Tomazin I, Vegnuti M, Ellerton J, Reisten O, Sumann G, Kersnik J. Factors impacting on the activation and approach times of helicopter emergency medical services in four Alpine countries. *Scandinavian Journal of Trauma, Resuscitation & Emergency Medicine*. 2012;20:56.
<https://doi.org/10.1186/1757-7241-20-56>
51. Karpov AB, Skobelsky AV, Badmaeva ER, Shibalkov IP, Mazurov RG, Antipov SA. Medical evacuation of personnel at remote industrial facilities. Problems and solutions. *Healthcare of the Russian Federation*. 2021;65(3):214–21 (In Russ.).
<https://doi.org/10.47470/0044-197X-2021-65-3-214-221>
52. Hackett P, Shlim D. High elevation travel and altitude illness. In: *CDC Yellow Book: Health Information for International Travel*. Atlanta: Centers for Disease Control and Prevention (US); 2024.
53. Rodway GW, Windsor JS, Hart ND. Supplemental oxygen and hyperbaric treatment at high altitude: cardiac and respiratory response. *Aviation, Space and Environmental Medicine*. 2007;78(6):613–7.
54. Kasic JF, Yaron M, Nickolas RA, Lickteig JA, Roach R. Treatment of acute mountain sickness: hyperbaric versus oxygen therapy. *Annals of Emergency Medicine*. 1991;20(10):1109–12.
[https://doi.org/10.1016/s0196-0644\(05\)81385-x](https://doi.org/10.1016/s0196-0644(05)81385-x)
55. Marcovic D, Kovacevic H. Recompression therapy of mountain sickness. *Arhiv za Higijenu Rada i Toksikologiju*. 2002;53(1):3–6.
56. Simancas-Racines D, Arevalo-Rodriguez I, Osorio D, Franco JVA, Xu Y, Hidalgo R. Interventions for treating acute high altitude illness. *Cochrane Database of Systematic Reviews*. 2018;6:CD009567.
<https://doi.org/10.1002/14651858.CD009567.pub2>
57. Ashyrbayev AA. Treatment of mountain sickness with a stationary hyperbaric chamber. *The Newsletter of the International Society of Mountain Medicine*. 1999;9(2):5–7.
58. Orlov OI, Mamonova EY, Romanov MA, Kalinina MY. Requirements for medical personnel providing medical care at onsite industrial facilities in the Russian Arctic continental shelf. *Extreme Medicine*. 2026; 28(1):113–22 (In Russ.).
<https://doi.org/10.47183/mes.2025-409>
59. Sokolovich EG. *Personnel of health centers at remote industrial sites*. Proceedings of the V International Conference on Remote Healthcare. Tomsk; 2025 (In Russ.).
60. Logunov KV, Antipov SA, Lepetinsky IS. Industrial healthcare in the Russian Arctic — trends and experience of recent decades. *Marine Medicine*. 2022;8(3):118–26 (In Russ.).
61. Bygvraa DA, Adhikari TB, Charalambous G. Maritime doctors' skills and competencies: A review for policy analysis. *Maritime Technology and Research*. 2019;22(1):40–51.
<https://doi.org/10.33175/mtr.2020.206375>
62. Badmaeva ER, Antipov SA. *Training personnel for the remote healthcare system. Current requirements*. Conference proceedings of the IV International scientific-practical conference “Science and education in modern society. current issues and innovative research”. Penza; 2021 (In Russ.). EDN: [GHHZIX](https://doi.org/10.47183/mes.2025-409)
63. Mumber AA. *Corporate standards of teaching medical personnel in the Group of companies Center of Corporate Medicine*. Proceedings of the V International conference on remote healthcare. Tomsk; 2025 (In Russ.).
64. Metrailler P, Greiser J, Dietrich G, Walter D, Richon J, Walliser M, et al. Swiss mountain guides: medical education, knowledge and practice. *High Altitude Medicine &*

- Biology*. 2019;20(3):251–61.
<https://doi.org/10.1089/ham.2018.0124>
65. Berendsen RR, de Vries DCAA, Steger A, Herold N, Halbertsma FJ, Norbart AF, et al. Lack of Altitude Medicine Knowledge Among Mountaineers in the Italian Alps. *High Altitude Medicine & Biology*. 2025;26(4):361–73.
<https://doi.org/10.1089/ham.2025.0028>
 66. Ashyrbaev AA. Basic life support of the workers of the gold mining company at the remote site in the Kyrgyz Republic. *Resuscitation*. 2023;192(1):S21.
 67. Chinilov SS. *Innovations in software and systems enabling medical examinations and monitoring of workers' health in situations of full or partial autonomy*. Proceedings of the V International Conference on Remote Healthcare. Tomsk; 2025 (In Russ.).
 68. Ashyrbaev AA, Kadyrov MS, Adashbaev NT, Tolbashieva GU. Training of medical personnel for work at remote industrial facilities in the Kyrgyz Republic. *Healthcare of Kyrgyzstan*. 2022;4:185–8 (In Russ.).
<https://doi.org/10.51350/zdravkg2022.4.10.26.185>

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