Working conditions of housing and communal services system and innovative technology to minimize occupational hazards for plumbers of emergency repair services

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Abstract. This article presents the result of studies of occupational hazards in housing and communal services of Irkutsk region. It identifies harmful and dangerous factors that may affect the employees of enterprises "Vodokanal" of the cities of Irkutsk and Usoye-Sibirskoe. The assessment of working conditions for plumbers of emergency repair services is carried out in accordance with the special method of assessment of working conditions and includes tool measurement of the actual characteristics of the working environment. Particular attention is paid to studying the effects of the chemical factor – gas discharge, primarily hydrogen sulfide, on employees when working in manholes. The actual level of professional risk in emergency repair services during the performance of plumbers’ duties in sewer networks and facilities was determined. An innovative device for sewer flusher, aimed at reducing the effects of chemical and biological factors on humans during the operation of sewer networks, is presented.

1. Introduction

Nowadays housing and communal services (HCS) is a basic sector of the economy and is a combination of enterprises, services and farms providing comfortable living to the population through providing housing and utility services that meet modern quality standards. Typical housing and communal services are heating, hot and cold water supply, water disposal, gas and energy supply, improvement and maintenance of clean urban (township) and yard areas, timely removal of household waste.

The recent reforms at the state level in the housing and utilities system have significantly improved the situation, including in Irkutsk region. In particular, the state program “Development of housing and communal services of Irkutsk region” for 2014–2020 has been successfully implemented in Irkutsk region (approved by the Government of Irkutsk region on October 24, 2013, No. 446). This program includes such subprograms as: "Modernization of municipal infrastructure facilities", "Gasification", "Clean water", "Energy saving and energy efficiency increase", "Overhaul of apartment buildings", "Ensuring a balanced and stable policy in the state regulation of prices (tariffs)".
2. Overview of the communal complex

Housing and communal services are available in all municipalities. The largest number of the services is concentrated in cities where about 80% of the population of Irkutsk region lives. The housing and utilities sector in the region is represented by 2 thousand enterprises and organizations of various forms of ownership, and about 45 thousand people work there. A feature of the housing and utilities sector of Irkutsk region is the need to function in a sharply continental climate, extremely uneven settlement and in terms of the economic development of a vast territory. With a high concentration of the population in a number of cities with a large energy potential, its low density is observed on the rest of the territory. Many unsolved problems that are caused by the obsolescence and wear and tear of heat, water and sewer networks, heat sources, etc., remain in housing and communal services. According to [1], utility network wear reaches 62%, leakage and unaccounted utilization of utility resources reaches 40% in plumbing and sanitary system and 50% in heat supply.

2.1. The main problems of the utility complex of Irkutsk region are:

- unsatisfactory technical condition of communal infrastructure facilities: high wear of life-support facilities and inefficient configuration of communal infrastructure facilities in certain territories of Irkutsk region;
- technological obsolescence of the used equipment and technologies that technically limit the increase in the efficiency of the functioning of the communal infrastructure;
- shortage of life-support objects, including water intake and water treatment facilities, facilities for utilization and waste disposal (landfills or plants replacing them for processing or burning waste);
- high energy intensity of communal infrastructure facilities [2].

Emergencies constantly arise, and the key personnel involved in the liquidation process are plumbers of emergency repair services (plumber ERS), who often have to work under extreme conditions, are exposed to harmful and hazardous production factors, and occupational hazards.

The purpose of this work was to assess the occupational hazards of a plumber ERS, to develop and test a device that would minimize these risks.

3. Objects and methods of research.

The research represents the analysis based on data of Municipal unitary enterprise Vodokanal, Irkutsk, and Municipal unitary enterprise Vodokanal, Usolye-Sibirskoye.

The methodological approaches, used in the research, provided the assessment of factors of the working environment and the work process in terms of emergency repair operations as required by the methodology for special assessment of working conditions and job descriptions [3,4].

3.1. A plumber ERS performs the following duties.

Canals and pits excavation and lining them; repair of water supply networks; disinfection with chlorine compounds; emergency repair of pipelines under pressure, sock and laying of pipes and fittings; work on manual drainage mechanisms; pipeline heating; pipe cutting of all diameters with a hydraulic tool; sewer networks cleaning with hydrodynamic and mechanical methods at a depth of up to 8 m; servicing various valves on main pipelines and more.

3.2. Assessment of working conditions.

Included measurement of microclimate parameters, levels of industrial noise, local and general vibration, air pollution of the working area with aerosols and toxic substances, medium-term dust and noise-vibration dose loads in accordance with the method of special assessment of working conditions. The measurements were carried out with the help of portable equipment of the industrial and fire safety laboratory and the East-Siberian center for collective use "Technosphere safety" of the Irkutsk
State Technical University. In this research, we used an IKP-5 dust counter to measure the mass concentration of dust and its fine fraction in air, while monitoring the excess of maximum permissible concentrations in the air of the working area, with a relative error of ± 20%. Also we used OKA-T gas analyzer, designed to monitor toxic gases in the air of the working area, with a relative error of ± 25%; Vibroacoustic multichannel high-frequency "Ecophysics" meter, set of "EcoMaxima-2011" (noise, infrasound, ultrasound, vibration, electromagnetic radiation, light environment, microclimate), with relative error limits ± 2%.

The research was focused on the assessment of chemical and biological factors, since it is the presence of hydrogen sulfide; carbon monoxide leads to accidents during the work of plumbers ERS.

4. Results and discussion
The first step in assessing occupational hazards is the identification of hazards. It was established that during the working process the following dangerous and harmful industrial factors may affect a plumber ERS: moving machines and mechanisms; moving parts of industrial equipment; danger of bruises when opening and closing manholes covers, falls during descent into wells; danger of exposure to sewage streams in wells; danger of soil collapse in trenches; possibility of objects falling down in the open hatches on those, who work in the wells; increased gas pollution of wells, chambers, and rooms of underground pumping stations, which can lead to explosions, burns and poisoning of workers; dampness in wells and chambers; sanitary hazard in contact with waste liquid; adverse weather conditions; high temperature of surfaces of the equipment; increased or decreased air temperature, air humidity, air velocity (drafts); insufficient illumination of the working area; infrared radiation during metals welding and cutting, industrial noise, local and general vibration.

The most serious problems, which cause the occupational risk of a plumber ERS, are the effects of a chemical factor – gas emissions, primarily hydrogen sulfide. Failure to comply with safety requirements can lead to acute or chronic intoxication and as a consequence – death. A plumber ERS can develop chronic occupational bronchitis of mixed etiology, as well as diseases of the musculoskeletal system [5,6].

In judicial practice, including in Irkutsk region, are cases of poisoning with hydrogen sulfide and carbon monoxide gas. For example, at the beginning of July 2013, while carrying out repair work on the valve of the sewage treatment plant in the village of Nizhneye Yarkeyevo, Ilishevsky district, three employees of LLC Aquarius died. The 42-year-old plumber of emergency repair services when working in the sewer well lost his consciousness, and the 48-year-old master of the site and the 30-year-old plumber ERS died while assisting him. The commission conducted the investigation determined the main cause of the accident – the unsatisfactory organization of the work environment, there was no order clearance to do a work of heightened danger. Valve repair was started without checking the air environment for gas contamination. The necessary devices as a gas analyzer or gas alarm were absent at the work site. The working process in the sewer well was carried out without use of personal protective equipment and without a safety belt with a safety rope [7]. In Bashkortostan in the period from 2010 to 2016, 5 cases of acute hydrogen sulfide poisoning among emergency plumbers happened [8].

On October 23, 2017, in one of the sewage wells on Zarechnaya Street of the city of Schelkovo, the bodies of two men, 39 years old and 68 years old, were discovered. They were employees of the enterprise "Inter-district Schelkovsky Vodokanal". During the rescue operation, a 34-year-old rescuer was poisoned with hydrogen sulfide.

On October 25, 2017, in the well of a water conduit along Leninskaya Street in the village of Bolshoy Lug, the bodies of men 54 and 59 years old were found. Two plumbers of one of the enterprises of Irkutsk region independently were fixing the leakage by pumping out water from the well. Going down, they turned on a water pump that emitted carbon monoxide. Men died from carbon monoxide poisoning [9].

Such poisoning is far from being unusual, especially in the hot summer season, when high temperatures in the sewer wells produce emissions of decay of waste products – hydrogen sulfide.
Under normal conditions, hydrogen sulfide is a colorless gas with an unpleasant smell of rotten eggs. Very poisonous: acute poisoning of a person occurs already at concentrations of 0.2–0.3 mg/l, concentrations above 1 mg/l are fatal. Hydrogen sulfide is a very toxic gas that affects the nervous system directly. On a scale of danger, this gas is assigned to class 3. The lethal concentration of the gas in the air is very low – only 0.1%. This amount of hydrogen sulfide can lead to death in 10 minutes. If to increase only a little the concentration of the gas, death will occur instantly, after the first breath. For instance, in the sewer system, the concentration of hydrogen sulfide sometimes reaches 16% [10]. The death of a person occurs due to oxygen starvation, which is caused by a blockade of tissue respiration due to the inhibition of cellular redox processes. A feature of hydrogen sulfide is the ability to dull the olfactory nerve, so that a person simply ceases to distinguish the poisonous fumes surrounding him or her, and intoxication can occur suddenly.

To assess occupational hazards we selected the following methods: the scoring method, the questionnaire method and the method of assessing the level of individual professional risk (IPR), developed by the Klin Institute for Protection and Working Conditions together with the Research Institute of Occupational Medicine of the Russian Academy of Medical Sciences. To assess the risk in the construction industry in general, the method of retrospective occupational hazard was chosen [11, 12].

Based on instrumental measurements of the actual parameters of the working environment and comparing them with hygienic standards, we determined the generalized level of safety of the working environment related to the work experience by a point method. To calculate the maximum permissible level of risk, we presume that all factors of the working environment, affecting an employee in terms of his work activity, are on the best possible level. Ideally, these are classes of working conditions for each factor that are optimal or permissible, except for those factors that cannot be reduced (improved) due to the peculiarity of the technological process (for example, noise from equipment). The occupational hazards are ranked according to the scale of deviation of the actual level of occupational hazard from the maximum allowed.

It was established that the actual deviation from the maximum for a plumber is in the range of 10-30%, therefore, the risk level for all the professions studied is average.

When calculating the individual occupational risk for the professions studied, it was determined that the value of the IPR ranges from 0.13 to 0.21 and, according to the adopted scale, the risks also fall into the category of averages except for the biological factor.

In sewer wells, sewage treatment plants, the personnel is in contact with gram-positive rods and cocci, actinomycetes, mold fungi Aspergillus, Penicillium, Cladosporium, Mucor, Ruzopus. In contact with microorganisms, employees may experience:

- diseases, carrier state, intoxication, caused by microorganisms-bacteria, viruses, rickettsia, spirochetes, fungi, actinomycetes, protozoa and their metabolic products;
- sensitization of the organism caused by the microorganisms listed above [13].

Therefore, according to the biological factor, working conditions are assigned to class 3.2.

Taking into consideration the described factors, the authors of the article have proposed an innovative device for supporting and controlling the direction of movement of the high-pressure hose sewer channel sewer flushers (Figure 1) [14], which allows minimizing the impact of chemical and biological factors on plumbers ERS when working on sewer networks.

The basis of the invention is the research made by scientists of the Irkutsk National Research Technical University, and operating experience of technological equipment Municipal unitary enterprise Vodokanal, Irkutsk [15-25]. Improvements in safeness of labor of plumbers ERS are achieved due to the positioning of the working body of the sewer flusher the way that the zone of influence of chemical and biological factors is limited.
Figure 1. Device for support and control of the direction of movement of the high-pressure hose sewer channel sewer flushers.

The device consists of: metal plates (1), rigidly interconnected by metal plates (2); a conductor (3), made of a metal plate and rigidly attached to metal plates (2); metal studs (4), installed in the mounting holes of the metal plates (1); support rollers (5), made of antifriction material, mounted on metal studs (4); shell (6), made of rigidly connected longitudinal and transverse bars of a metal circle and rigidly fixed to the metal plates (1); a metal pin (7), rigidly fixed to the shell (6); a metal pin (8), rigidly fixed to the metal plate (2); rod (9), made of metal pipe and rigidly fixed to the metal plate (1); backlight (10), fixed to the rod (9), made of metal pipe and rigidly fixed to the metal plate (1); the backlight (10), fixed to the rod (9).

The device works as follows – between the metal plates 1 and the shell 6, the high-pressure hose 11 with the necessary nozzle 12 installed on it are placed in the device, so that the nozzles are located outside the pins 7 and 8. With the help of the rod 9, the device is placed in the well and fixed in the pipeline with the help of pins 7, 8 or with the help of the conductor 3, depending on the internal diameter of the pipeline. Then the rod 9, throughout the period of flushing the pipeline, holds the device. In case of weak illumination, the backlight 10, placed on the rod 9, switches on and allows improving the view in the well in low illumination. Due to the jet thrust generated by the water streams escaping from the nozzle, the high-pressure hose changes its direction of movement from vertical to horizontal. Bending in the transition zone to the pipeline is carried out along a path defined by the support rollers 5, in accordance with the required parameters. When the device performs a controlling, support function, the bending of the high-pressure hose against the edge of the pipeline is eliminated, thereby eliminating additional hydraulic resistances that adversely affect the efficiency of hydrodynamic washing. It also reduces the frictional effect on the shell of a high-pressure hose, increasing its service life [14].

This device eliminates the need for a plumber ESR to sink into the sewer well, and, therefore, contact with harmful biological and chemical factors is excluded. The use of this device, as a fundamental tool when working in sewer manholes, should be included in the work regulations and be present as the main protection device function for a plumber ESR.
5. Conclusion
In conclusion, it is worth noticing that in order to prevent industrial injuries and, therefore, to minimize economic losses, it is necessary to properly organize workplaces and implement innovative technologies to perform work processes.

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