Influence of working conditions in agricultural enterprises on fatigue and labor productivity

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Abstract. The article summarizes the results of studying the influence of harmful production factors on the fatigue of agricultural workers and labor productivity. The purpose of the study: to determine the possibilities of improving work efficiency and productivity by improving the sanitary and hygienic conditions in the workplace. The relevance of the work is determined by the fact that in the coming years, we can expect an increase in labor productivity of no more than 3% at a given 5-6%, which requires a search for options for changing the trend. The research methodology is based on the study of published works and the identification of the degree of influence of harmful factors in the workplace on human performance and labor productivity. In conclusion, we offer options for solving the problem. The first is to bring jobs to regulatory requirements by known methods, which in most cases does not require significant financial costs, but will significantly affect the growth of labor productivity, bringing this figure to 7%. The second is the exclusion of a person from the zone of harmful factors due to remote control systems with instrument control and video surveillance of technological processes, full automation of production processes and the transition to neural network control systems, robotics.

1 Introduction

Economic development in the modern world is based on the growth of labor productivity [1-5]. It is the productivity of labor to a greater extent than any other factor that determines the level of economic efficiency of the economic complex.. Increasing labor productivity is one of the key tasks of successful economic and social development [6-9]. In Russia, the task is to boost labor productivity by at least 5-6% per year. Hence the goal of the national project "Labor Productivity and employment support", which has been in effect since October 2019, – the growth rate of labor productivity in medium and large enterprises of basic non-raw materials sectors of the economy should be at least 5% per year by 2024.

The purpose of the study is to identify opportunities to improve working capacity and labor productivity by improving sanitary and hygienic conditions in the workplace.

The relevance of the work is determined by the fact that, given the current trends, in the coming years, we can expect an increase in labor productivity of no more than 3% at the

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specified 5-6%. This is confirmed by the experts of the Federation Council and the HSE : in the first quarter, taking into account the change in the number of jobs replaced and the dynamics of GDP, the increase in labor productivity was only 1.7%ording to their forecasts, in the coming years, the expected growth is no more than 3%.

Moreover, this level may not be reached due to the expected increase in the share of age-related employees due to the increase in the retirement age. If we assume that the working capacity of a person reaches a maximum at the age of 20 to 30 years, decreases by almost 30 % by 50-60 years, and at the age of 60-65 years falls by 40% and more (Fig. 1)[10-14]. then due to the increase in the retirement age and the increase in the share of workers aged 60-65 years by 6-7 million. with the total number of employed people in the Russian economy of 72.3 million people, we can expect a decrease in labor productivity indicators in the country as a whole by about 3%. That is, the projected growth in labor productivity of 3%, while maintaining the current trends, can be offset by an increase in the share of age-related workers and a decrease in their working capacity. Therefore, it is necessary to use all possible reserves of improving efficiency in order to ensure the necessary increase in labor productivity of at least 5% per year. Among these reserves: replacement of physically and morally obsolete equipment, modernization of production, introduction of the best available technologies, improvement of the level of labor organization and management of production processes. But these natural areas of productivity improvement require significant investment and time to implement them. There are other reserves. In particular, it increases the efficiency of employees 15-16].

Fig. 1. Age dynamics of professional performance (Cherednichenko I. P.).

The research methodology is based on the study of the materials of published works and the identification of the degree of influence of sanitary and hygienic conditions in the workplace on human performance and labor productivity. We have analyzed the impact of harmful production factors on the working capacity and productivity of a person and identified the possibilities of increasing labor productivity through their normalization.

2 Working conditions in agricultural enterprises

Efficiency depends on many reasons, but one of the most influential and at the same time manageable are harmful production factors in the workplace. It is difficult to ensure the efficiency and increase in labor productivity, if, according to official data (Rosstat), in 2016, almost 39% of the population of the total number of employed workers in the economic sphere of the Russian Federation (that is, tens of millions of people) worked in conditions that do not meet sanitary and hygienic requirements. Statistics of these indicators in 2017-2018. it is better, but many people attribute this not to the improvement of working conditions, but to the underestimated indicators when conducting a special assessment of workplaces on working conditions.

Most of all, non-compliance of real working conditions with sanitary and hygienic requirements was revealed in agriculture and related sectors of the economy-34%, utilities - 33.5%, processing types of production-33.3%. About 28% of jobs do not meet the regulatory requirements in mining, energy, and construction. Moreover, workers employed in workplaces with non-compliance with sanitary and hygienic working conditions, in 17.7% of cases, are exposed to significant effects of acoustic vibrations: noise, ultrasound, infrasound; at 6.6 % of workplaces, there are discrepancies in the light environment, 5.3 % - the microclimate, 5.1% exceeded the permissible level of vibration (Ministry of Labor of the Russian Federation, 2018).

Machine operators are in the first place in terms of the risk of accidents and occupational diseases. As established in the process of conducting a special assessment of workplaces on working conditions (SOUT), which was completed in the Russian Federation in December 2018, machine operators are exposed to a complex of unfavorable production factors, such as unfavorable microclimatic conditions, dusty air, increased noise and vibration levels, contact with fuels and lubricants, high physical activity, irrational work and rest conditions, and nervous and emotional stress. Each of these factors, individually or in combination, has a harmful effect on the body of machine operators and, as a result, on its health.

According to the results of the assessment of workplaces by working conditions, it can be concluded that the working conditions of workers in the profession of "tractor driver" on traditional machines (MTZ-80) in terms of the severity and intensity of the labor process are harmful (class 3). Among the most significant parameters for assessing the work of a machine operator as harmful of the 3rd class of the 2nd degree, the degree of risk to one's own life and the degree of responsibility for the safety of other persons should be noted (Table).

At SOUT, the highest class of harmfulness is noted according to the indicators from the group "emotional loads", due to the fact that the mechanic is responsible for the functional quality of the main work and failure to perform it entails corrections due to additional efforts of the entire team. In addition, during the performance of work, there is a risk to the operator's own life, and there is also a share of responsibility for the safety of others.

However, even without an additional psycho-emotional load, working conditions on agricultural machinery are assessed as stressful according to the factor of perception of signals (information), since they require the perception of signals with a subsequent comprehensive assessment of all production parameters (information) that characterize not only actions to control the equipment as a vehicle, but also actions to maintain the specified parameters of the technological process.

Therefore, when conducting a special assessment of the tractor driver's workplace, it is necessary to assess the nature of the work performed on agricultural machinery as strenuous work of the first degree - work in conditions of time shortage, since sowing and harvesting take place in a short time frame.

Table 1. Sample from the protocols of the special assessment of workplaces on the working conditions of the tractor driver.

Indicators of the severity of the labor process	The actual value of the indicator	Class of working conditions
4.1 Intelligent loads		
4.1.1 Content of the	Solving simple tasks according to the instructions	2nd class
4.1.2 Perception of signals (information) and their evaluation	Perception of signals with subsequent correction of actions and operations.	2nd class
4.1.3 Distribution of functions according to the degree of complexity of the task	Processing, completing, and verifying a task	2nd class
4.1.4 Nature of the work performed	Work on a set schedule with the possibility of its correction in the course of activity	2nd class
4.2 Sensor loads		
4.2.1 Duration of concentrated observation (in % of shift time)	75	2nd class
4.2.1 Duration of concentrated observation (in % of shift time)	102	2nd class
4.3 Emotional stress		
4.3.1 The degree of responsibility for the result of its own activities. Significance of errors	Is responsible for the functional quality of auxiliary work (tasks). Entails additional efforts on the part of the higher management	2nd class

When assessing sensory loads, it should be taken into account that labor activity when working on agricultural machinery is characterized by significant concentration and switching of attention and the load on the analyzer functions. The levels of such indicators of the intensity of sensory loads as the duration of concentrated observation, the density of signals, the number of production objects of simultaneous observation can vary depending on the type of work performed and the brand of equipment.

In the process of working on mobile agricultural machinery, workers experience a load on the hearing aid when it is necessary to perceive signals and sound information about the operation of the equipment and the progress of the technological process. Increased noise levels in the cabins are a hindrance to their perception, which increases the intensity of work.

With the transition to modern technology, the nature of work and the type of loads changes. Most of the listed factors of harm and danger (noise, vibration, dust, gas, microclimate parameters) are sharply reduced to acceptable levels when using tractors and combines of foreign production.

The presence of on-board computers significantly facilitates the operator functions of the tractor driver (Fig. 2), but the role of the "human factor", i.e., the psycho-physiological properties of the tractor driver, only increases. This is due to the continuous monitoring of parameters(states), the output of which exceeds the optimal limits (transition to unacceptable states) significantly reduces the resource of the main units and components (for example, clogging of filter elements) with an indication of the need to change the operating modes or conduct extraordinary maintenance;

taking into account the operating time of the tractor from the moment of the last maintenance with an indication of the value of the permissible operating time to the next planned maintenance (for a given periodicity of maintenance). And the use of autopilots

(satellite driving systems) removes the burden on the operator to maintain an ideal route, so that other phases of work can be performed even more efficiently.

Fig. 2. Workplace of a modern computerized tractor.

It should be borne in mind that the introduction of satellite driving increases the monotony of the production environment, the monotony of stimuli and a small number of elements (techniques) for switching controls and maintaining the progress of the technological process.

Moreover, the working day of the machine operator significantly exceeds the standard 8 hours and reaches 12-14 hours without days off during peak periods. I.e., it is not possible to restore the accumulated fatigue, attention, and efficiency: it is impossible to allow breaks for intra-shift rest due to the threat of soil moisture loss during sowing or grain shedding during harvesting. Not only is the working day of the machine operator significantly increased, but it also has a very high density: according to the results of time studies – up to 95%.

As a result, when switching to modern equipment, new types of risks arise due to the combination of the traditional tension of the tractor driver with the tension of the dispatcher and the PC operator.

No less difficult is the situation with the working conditions of livestock workers, especially milkmaids. Despite significant progress in the robotization of milking processes, which allows to exclude (or significantly minimize) the influence of the human factor both on the milking process and on the occurrence of risks of accidents with milkmaids (operators of machine milking), in Russia, according to VNIIMZH, 95% of farms still operate with tethered maintenance and milking in a bucket, milk pipeline or unbound maintenance and milking of cows on installations such as "Herringbone", "Tandem" or "Carousel" (Fig.3). In the context of a shortage of personnel, when older people leave and young people almost do not go to farms, because this work is not very attractive, it is necessary to create conditions to increase the attractiveness of the profession, improving working conditions and reducing the likelihood of occupational diseases and the risk of accidents.

The most responsible and time — consuming process in dairy farming is milking cows. And in this process, there is the closest contact between a person and an animal, on which the process of breast-feeding depends, and hence the economic efficiency of the enterprise.

All costs for the formation of the herd, the maintenance of animals, the preparation and preparation of feed may be in vain due to the human factor. The human factor: fatigue, decreased performance, impaired attention, etc. leads to violations of the milking technology, in particular, violation (reduction) of the udder massage time, delay in the vacuum connection time, etc.

Fig. 3. Workplace of the machine milking operator.

This is because the milk that fills the alveoli and small milk ducts of the cow's udder (alveolar milk) can be milked only when the milk-giving reflex occurs – a complex act that includes a change in the tone of the muscles of the milk ducts and the cisterns of the gland, the tone of the blood vessels, the contraction of the alveoli, relaxation of the nipple sphincter, etc. The hormone oxytocin plays a special role in breast delivery. It is formed in the pituitary gland, located in the brain, under the influence of nerve excitation during the preparation of the cow for milking. Oxytocin is absorbed into the blood and enters the mammary gland, where it causes a contraction of myoepithelial cells, as a result of which the milk is removed (squeezed) from the alveoli into the ducts, and from them into the udder cistern, from where it is milked. Oxytocin only works for 4-6 minutes, and during this time you need to milk the cow. Then the hormone is destroyed, and the milk-giving reflex is extinguished, which leads to the cessation of squeezing milk, regardless of whether it is milked or not. The milk remaining in the alveoli and small milk ducts cannot be extracted by ordinary milking. If this is repeated regularly, then the cow's milk formation process will be disrupted, which will lead to a decrease in milk productivity, and then a premature start.

Fatigue, poor health are caused by the influence of many unfavorable factors on the milkmaid: the state of the air environment of the premises, the peculiarities of the microclimate, noise, animal behavior, etc.

Weather conditions in the cowsheds in winter are characterized by low temperature, high relative humidity and moderate air velocity. Air pollution in cowsheds occurs due to the accumulation of carbon dioxide, ammonia and hydrogen sulfide. The concentrations of ammonia and hydrogen sulfide in most cases do not exceed the permissible according to

GOST 12.1.005-76 (ammonia - 20 mg/m³, hydrogen sulfide - 10 mg/m³). Concentrations of carbon dioxide in ventilated areas are non-toxic, they in most cases do not exceed 0.3 %. But, as studies of a number of institutes have shown, such a concentration significantly affects a person's well-being, and with prolonged exposure can provoke serious occupational diseases. The greatest amount of gases is detected in the morning hours in winter, when all openings and doors are closed.

When serving animals in cowsheds and feedstocks, workers are exposed to dust of mixed composition (inorganic and organic), as well as microbial flora. In the air of the working rooms of farms and complexes, an increased dust content is determined when distributing dry concentrated feed and cleaning the premises, in feed shops-when processing and loading coarse and bulk feed into feed dispensers. The composition of the dust is heterogeneous and unstable. It may contain particles of soil, plants, mineral fertilizers, pesticides, all components of animal feed, including various additives (trace elements, vitamins, antibiotics, hormones, etc.), animal waste products (wool, dandruff, epidermis, manure, etc.), microorganisms and fungi. The qualitative composition of the dust determines the degree of its allergenicity and, under certain conditions, can cause the development of allergic diseases in livestock breeders.

3 Influence of sanitary and hygienic working conditions on working capacity and labor productivity

Due to unfavorable conditions, labor productivity indicators are significantly reduced. If about 5.0 million people work under the influence of significant levels of acoustic vibrations: noise, infrasound, ultrasound (as noted above, this discrepancy with sanitary and hygienic requirements was revealed in 17.7% of workplaces with harmful working conditions), then we must take into account the fact that their performance indicators can not even come close to the potential maximum [6,7].

Studies show that acoustic impacts that exceed sanitary and hygienic standards reduce performance and productivity by up to 66%, and the number of errors in design work increases by more than 50%. Ultrasound and infrasound present in technological processes², ³and affecting workers not only increase fatigue, but also cause drowsiness, dizziness and other disorders that reduce performance and increase the risk of accidents and accidents [8,9]. As noted above, 6.6% of workplaces with harmful working conditions also violate the norms of the light environment. Research of the Research Institute of Labor has shown that the creation of rational artificial lighting increases labor productivity by up to 13%, and natural lighting (through window openings) – up to 10%. Under normal lighting conditions, the probability of injury to employees due to accidents is also significantly reduced. And injuries are, as a rule, a long-term departure of an employee from the production process, which most directly reduces the labor productivity indicator and distracts from work for an average of 50.4 days (Rosstat, 2020).

Excessively bright light is also harmful: it blinds, reduces visual functions, leads to overexcitation of the nervous system, reduces efficiency. The passion of recent years for energy saving and environmental safety has led to the mass replacement of incandescent and gas-discharge mercury lamps with LED ones. Most of the LED light sources used in industrial lighting systems are based on blue crystals. In the course of research, it was revealed that the excess volume of blue color in the spectrum of LEDs created on the basis of a blue crystal negatively affects the physiological processes in the human body, increasing fatigue and reducing performance. At the same time, the production of the hormone melatonin, which adjusts the human body to rest and sleep at the end of the day, is disrupted. I.e., its deficiency prevents the recovery of strength in the inter-shift period,

which leads to an increase in the period of workability and does not allow to achieve maximum productivity during the period of stable performance.

Through the visual apparatus, a person receives about 90 % of the information. Sufficient lighting has a tonic effect, improves the flow of the main processes of nervous activity, stimulates metabolic and immunobiological processes, affects the daily rhythm of the physiological functions of the human body. The generalized patterns of the influence of workplace illumination on some important production parameters are shown in Fig. 4

Fig. 4. Generalized dependence of some production parameters on the illumination of the workplace (Kipin, Razuvaev).

Practice shows that only by improving lighting in the workplace, it was possible to achieve an increase in labor productivity from 1.5 to 15%. Rational lighting with the use of light sources that give a radiation spectrum close to the sun, and do not create an abnormal depth of pulsation of the luminous flux, provides psychological comfort, helps to reduce visual and general fatigue, reduces the risk of occupational injuries [8]. Moreover, the solution to the problem of optimizing the lighting of workplaces does not require large costs, but can immediately give an effect in improving efficiency and increasing labor productivity.

The parameters of the microclimate also have a significant impact on a person's well-being and performance [9]. In real production, the parameters of the microclimate do not meet sanitary and hygienic standards in 5.1% of workplaces. These inconsistencies do not cause damage or health disorders, but lead to feelings of thermal discomfort, stress on the mechanisms of thermoregulation, deterioration of well-being and reduced performance. It is established that the working capacity of a person begins to fall at an air temperature of more than 24-25 °C. For example, when the temperature increases from 26 to 29 °C, labor productivity decreases by 13%, and when it increases to 33 °C, it decreases by 35%. Earlier studies showed that an increase in temperature from 25 to 30 °C in the spinning shop of the Ivanovo worsted Mill led to a decrease in labor productivity by 7 %. In the same period (1980), the Institute of Occupational Health and Occupational Diseases of the USSR Academy of Medical Sciences found that the productivity of employees of a machine-building enterprise at a temperature of 29.4 °C decreased by 13 %, and at a temperature of 33.6 °C by 35 % compared to the productivity at 26 °C.

It is experimentally established that the maximum efficiency and labor productivity take place when optimizing the heat balance due to the absence of tension in the thermoregulation system [9].

The increase in metabolic processes with a decrease in temperature by 1 oC is 10%, and with intensive cooling, it can increase by 3 times compared to the level of the ma. exchange.

Fig. 5. General regularity of the influence of temperature in the workplace on labor productivity (Mokrushina).

Further exposure to cold affects your breathing: it becomes non-rhythmic, increases the frequency and volume of inspiration, changes the carbohydrate metabolism. There is a muscle contraction (tremor), in which external work is not performed and all the energy of the muscle contraction is converted into heat. This allows you to delay the decrease in the temperature of the internal organs for some time. Cold injuries can occur due to exposure to low temperature.s

Productivity and quality of work also decrease when exposed to a factor that is present in many workplaces, such as vibration (5.1% among workplaces with harmful working conditions), as a result of which fatigue also increases, there is a real risk of serious occupational diseases.

As a result of the above, we will consider how working conditions can affect the known phases of human performance (Fig. 6):

phase I. Pre-working state-the period when the employee is set up for work, thinks about the upcoming actions;

phase II. The period of working in, getting involved in the workflow (or adapting). Labor productivity at this time is lower than the potential (line 2) and gradually increases.

Phase III. The period of stable performance. The duration of this period is usually about 70-75% of the time of the working shift. The efficiency of work during this period is maximum.

Phase IV. The period of fatigue. During this period, performance decreases, attention falls, the speed of reactions slows down, and erroneous actions appear. This period occurs earlier in the presence of unfavorable working conditions.

Fig. 6. Phases of human performance during the working day (Source: compiled by the authors).

Line 1-a horizontal line without the stages of workability and decline, shows the hypothetical performance of the robot, when there are no periods of workability and decline due to insensitivity to negative factors in the workplace.

Labor productivity is determined by the area of the polygon bounded by the time-efficiency axes and the curve of change in efficiency.

Line 3 shows the change in health in the presence of harmful factors (over a long period of srabatyvaet with insufficient rest, not the achievement of regulatory performance in phase III, with stable performance and decreased performance in phase III after the lunch break, compared with their pre-dinner period).

The area of the shaded zone is equivalent to the loss of productivity in the presence of adverse factors in the workplace that reduce efficiency.

Practice shows that, depending on the severity and intensity of the labor process, fatigue in the previous working day and the level of recovery during the inter-shift rest, the phase II period can take from a few minutes to two to three hours. Naturally, it is important to minimize this period by reducing the severity and intensity of the labor process and increasing the efficiency of inter-shift rest due to its activation: fitness, sports, etc.

The time of the phase III period should be approximated to the duration of the shift. But, depending on the presence of harmful production factors, the maximum peak of working capacity may not be reached (line 3), which actually happens in many workplaces where there are unfavorable production factors that do not meet sanitary and hygienic standards.

The sanitary and hygienic state of production in the Russian Federation should have been assessed at all workplaces by December 31, 2018. But control measures carried out by inspections of trade unions in a number of regions of the country showed that there is a distortion of the real level of harmful factors. Therefore, the economic departments of enterprises, regardless of the outcome of the special assessment of workplaces, it is advisable to compare the actual loss of working time in the enterprise (the number of days per 100 employees) with estimated losses under favorable conditions of labor, which is determined by the following empirical formula (Mustafina)

$$D \text{ V. u.t.} = (2.42 + 0,167 \ln)100,$$

where B is the average age of employees at the enterprise, years.

If the actual loss of working time at the enterprise is higher than the calculated value, then this indicator focuses on the need to deepen attention to the state of working conditions, audit the results of a special assessment of workplaces and identify those adverse factors that clearly reduce the working capacity and productivity of labor, increase the loss of working time due to diseases [2,3].

4 Conclusion

These data show the level of connection between working capacity and, as a result, labor productivity, with sanitary and hygienic conditions in the workplace. If we assume that the trend of labor productivity growth will remain at the level of 3%, and with the normalization of working conditions in 39 % of jobs, productivity will increase by at least 10%, then this will eventually raise the growth rate in the whole country by almost 7%. In this regard, it is necessary to take measures to normalize working conditions at enterprises that have workplaces with non-conforming sanitary and hygienic standards.

In our opinion, there are several solutions to the problem of accelerating labor productivity growth in the Russian Federation. The first is to bring the working conditions in the workplace to the regulatory requirements by known methods, first of all by normalizing such "efficiency killers" as light, noise, and microclimate parameters. To revise the feasibility of saving electricity at the expense of imperfect (with a dominant dose of blue light in the radiation spectrum or creating the effect of pulsation of the luminous flux) energy-saving light sources to the detriment of efficiency and labor productivity. This, in most cases, does not require significant financial costs, but will allow you to achieve noticeable indicators of labor productivity growth.

The second, longer and more capital-intensive: the exclusion of a person from the zone of harmful factors by removing it through remote control systems with instrument control and video surveillance, in the field-through unmanned flying vehicles, technological processes, full automation of production processes using artificial intelligence and neural networks, or robotization of production. In all these cases, we will eliminate the human factor and, accordingly, the phases of working out and fatigue, ensuring the highest possible level of productivity, but not of labor, but of the production process.

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