Ensuring the labor safety of workers at sanitary checkpoints of agricultural enterprises

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Abstract. The article proposes the improvement of working conditions and environmental efficiency of the process of washing equipment (tractors and cars) in an agricultural organization. For this purpose, a washing point was designed with the selection of mass-produced required equipment, a technology that provides an environmental effect by reducing water consumption for washing by reusing it. At the same time, engineering and design calculations were carried out to justify the units and parts of the proposed technical device. Organizational measures are proposed to exclude injuries and morbidity of the washer. The economic efficiency of the designed technical device is determined.

1 Introduction

Agriculture as a branch of the world economy plays a significant role in human life. Its main goal is to meet the needs of the population in food, and industry in raw materials.

Agricultural enterprises are part of the agro-industrial complex, which, in addition to the production of crop and livestock products, includes other activities related to the processing of products, their storage, transportation, marketing, as well as related activities related to the agro-industrial complex (for example, energy, engineering and others) [1-2].

All production activities are carried out only in specialized premises equipped for this type of work. For example, in order for all livestock industries to fully function, various veterinary facilities are needed. The veterinary and sanitary checkpoint in this sense plays an important role not only in observing simple hygiene standards, but also in the system of preventive and anti-epidemic measures, and functions in accordance with environmental requirements [3].

In order to comply with all necessary sanitary and technological standards during the functioning of agricultural production, a development is proposed that allows to reduce water consumption for disinfection and washing in order to comply with environmental requirements during the technological process.

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2 Materials and methods

To conduct the study, the requirements for the organization of sanitary checkpoints on the territories of agricultural enterprises, as well as an analysis of the state of the sanitary checkpoint of an agricultural enterprise, were studied. As a result, the development of engineering and technical measures for the disinfection and washing of agricultural machinery was proposed, which meets the requirements of environmental safety and labor protection [4]. To perform various technological operations, the agricultural enterprise is equipped with tractors (MTZ-82; T-16; DT-75), a set of tillage implements, sprayers and other equipment that requires maintenance and washing.

The presence of mobile technical means is associated with the need for (scheduled and unscheduled) repairs and maintenance procedures, which requires pre-cleaning and external washing. Also on the territory of the agricultural enterprise there is a sanitary checkpoint, which was not originally equipped according to all the requirements and standards, but is currently used to store feed.

The sanitary checkpoint and the disinfection complex as a whole are in a non-working condition (Figure 1).

Fig. 1. Sanitary pass of an agricultural enterprise.

Before installing the disinfectant complex, it is necessary to carry out a number of measures to improve the internal state of the sanitary checkpoint - clean the room from clutter (food, rubble, garbage), carry out repairs, insulate the wires [5-7].

Next, the working conditions of workers were analyzed, according to the results of which one can see the incidence of workers in the whole enterprise and separately when performing work on washing agricultural machinery for 2020-2021 (Table 1) [8].

According to Table 1, in general, it can be considered that workers engaged in washing agricultural machinery fell ill with common colds relatively more often than in the whole enterprise, this can be seen from the incidence rate (Ci), if presented by calculating it per 100 employees, similarly to the generally accepted occupational injury frequency rate (Cf).

As mentioned above, the incidence of morbidity among workers who wash equipment on average over the past 2 years turned out to be somewhat higher than in the whole enterprise. Thus, the average value of Ci according to the data of 2020-2021 during washing is 24.8 versus 21.8.

Table 1. Statistical data on employee morbidity associated with washing.

Index	Years	
	2020	2021
In general for the enterprise		
Amount of workers	16	16
Number of sick	4	3
Incidence rate, Ci	25	18.7
When washing		
Amount of workers	6	6
Number of sick	1	2
Incidence rate, Ci	16.6	33

This can be explained by the circumstances that the technology of washing agricultural machinery adopted on the farm leads to the fact that the worker is often exposed to significant wetting (wetting) of clothing and footwear; especially when washing components and assemblies of the lower part of the vehicle.

Along with this, having considered the washing technology adopted at the enterprise, it should be noted that it has a certain negative factor from an environmental point of view. Namely:

- The volume of water used for washing is completely irretrievably lost.
- The runoff water contains compounds harmful to the environment in the form of mineral oil inclusions.

Based on the above analyzes, it is proposed to set the following goals and objectives for their solutions:

- Propose a technology for washing vehicles that reduces the harmful burden on the environment.
- Develop a device (equipment) that helps reduce injury and morbidity for operators when washing equipment while increasing the environmental component.
- Conduct engineering and structural calculations of the proposed device.

Further, a critical analysis of existing solutions for organizing the washing of agricultural machinery was carried out.

To begin with, the norms of water consumption for washing cars, tractors, combines were considered and the approximate (actual) water consumption when using manual and mechanical (non-contact) washing was presented. The results are presented in Figure 2.

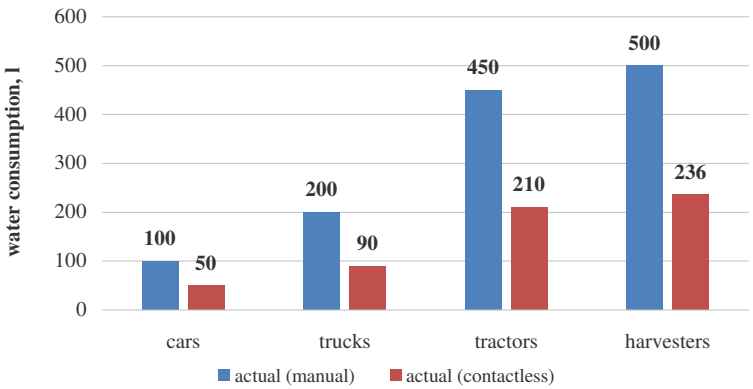

Fig. 2. Consumption of water consumed when washing vehicles.

Stationary cleaning systems Tire Wash SERIES – high power and high capacity wheel washers for cleaning chassis and tires. The modular design allows the addition of chassis wash sections as required.

The need to install sewage pits requires the inclusion of this equipment already at the design stage of the washing post. A closed water supply system with a water purification module is included in the standard scope of supply. The sink is shown in Figure 3.

Fig. 3. Tire Wash SERIES – 1.

Technical characteristics of the Tire Wash SERIES washing system - the productivity of the complex is up to 80 vehicles per hour, and the productivity of the water supply pumps is 4668 l / min. The presented installation has the following number of disadvantages, such as high water consumption and use only for washing the chassis and tires.

Some organizations use stationary vehicle washes, where a tubular collector 2 with a set of nozzles 3 is installed on a stationary frame 1 (Figure 4) [9].

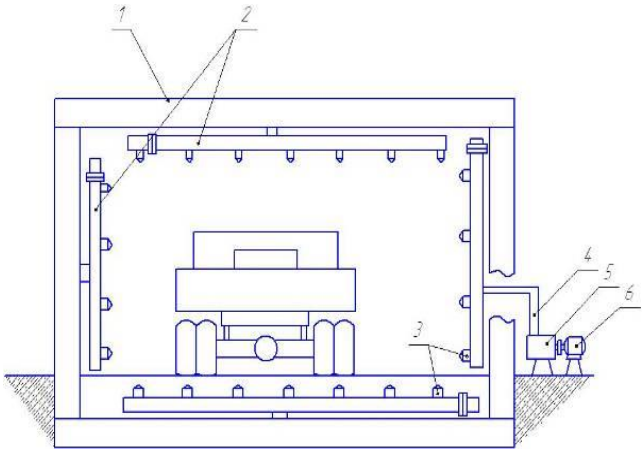

Fig. 4. Scheme of a stationary car wash: 1 – frame; 2 – tubular collector; 3 – nozzle; 4 – pipeline; 5 – pump; 6 – electric motor.

Washing is carried out as follows (Figure 4): water is supplied to a stationary tubular collector 2 by a pump 5, driven by an electric motor 6. Nozzles 3 installed on the collector provide water in the form of jets to the washed surface: from above, from the sides and

from below. To ensure washing along the length of the washed machine, it moves due to the movement of the supporting lower surface or the movement of the machine directly along the stationary surface.

The bottom of the machine is not washable. To eliminate this circumstance, washing is carried out manually with a hose.

In some cases, a lower sink is used with a tubular collector (Figure 5), mounted on frame 1 and having the ability to rotate on a rack 2, hub 6 and disk 7 is manually rotated by lever 5.

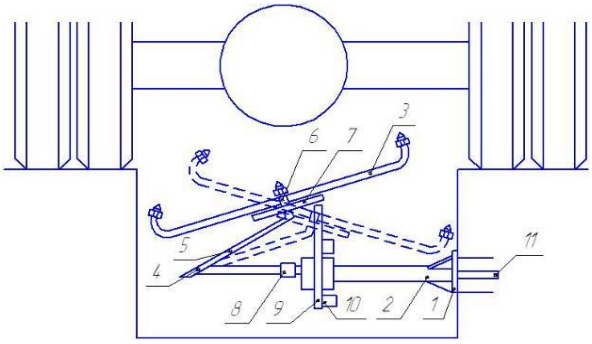

Fig. 5. Lower tubular manifold: 1 – frame; 2 – racks; 3 – rotary collectors; 4 – nozzles; 5 – lever; 6 – hub, 7 – disk; 8 – bearing support; 9 – copiers; 10 – counterweight.

The advantage of this washing is the low consumption of the washing liquid, but the disadvantage is the limited amplitude of the collector oscillations due to the stable operation of the installation with small oscillations of the copier, the consequence is the low efficiency of the mechanical action of the washing liquid jets on the contaminated surfaces.

Examples of serial and used technical means are places equipped for washing in the form of boxes with waterproofing devices, in the form of polyethylene curtains. Water is supplied by a centrifugal pump through the barrel with a nozzle that sprays the water jet. The movement of the jet along the length and height of the washing car or tractor is carried out manually by the operator. The disadvantage of this technology is that the operator is in close proximity to the supplied water jet. Such technology and technical means are used, as a rule, in most agricultural enterprises.

Thus, all available methods and devices for washing should be abandoned, in addition, they are not environmentally friendly. In this regard, it is necessary to propose (develop) other devices and techniques that ensure the environmental friendliness and safety of the process.

3 Results and Discussion

The result of the development will be a simplification of the design while cleaning the bottom and body of the vehicle, the wash is equipped with a circulating water supply system, separate supply of water and disinfectant is possible, as well as ensuring non-contact operation to improve the conditions and safety of the operator (Figure 6).

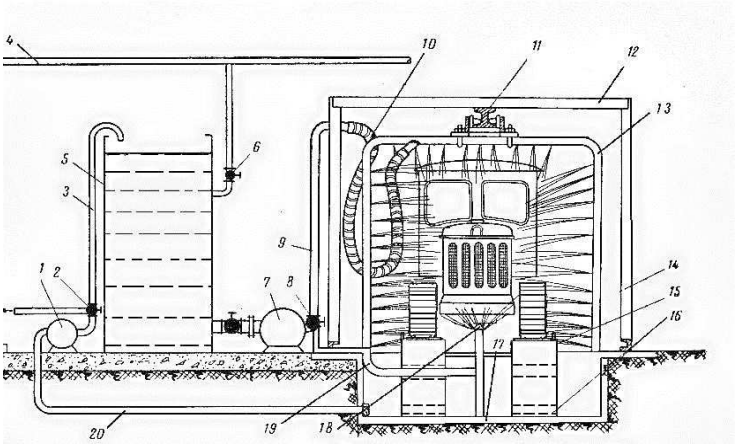

Fig. 6. Scheme of the proposed washing of tractors [10].

The proposed developed installation consists of a washing chamber (pos. 14), the frame of which is welded from channel No. 18 and angle No. 5, then lined with polycarbonate with a thickness of at least 6 mm. Inside the chamber itself, a concrete overpass (pos. 15) with through holes (pos. 16) is installed to equalize the water level in the tank (pos. 17) for drained dirty water when washing the vehicle.

Inside the washing chamber, from above, to the transverse beams (pos.12), a beam No. 12 of an I-section (pos.11) is fixed, along which a cart with a frame attached to it (pos.13), made of a steel pipe with a diameter of 50 mm, moves along the chamber on rollers (pos.13) [11]. with holes 4 mm in diameter in a checkerboard pattern, the distance between the holes in a row is 50 mm.

In the lower part of the washing chamber along the entire length, a metal pipe with holes oriented to the vertical and a certain angle from the vertical with holes of 4 mm is horizontally installed. The distance between the holes are arranged similarly to the frame.

For the entry and exit of the vehicle in the chamber, double-leaf gates are made in width and height that are convenient for the corresponding maneuver.

Water from the water supply network is supplied through the pipe (pos.4) to the tank (pos.5) of the storage type water heater when the tap (pos.6) is opened. With a centrifugal pump (pos. 7) through a pipe (pos. 19), water is supplied to the pipe (pos. 9), and through a flexible corrugated hose (pos. 10) attached to the pipe, into a movable frame or lower pipe through a three-way valve (pos.8) settled water from the tank (pos.17) through the pipe (pos.20) is pumped by the pump (pos.1) through the three-way valve (pos.2) by the pipe (pos.3) into the tank (pos.5), for reuse or into a sump from which the sludge is pumped out. Washing is carried out by throwing water jets through the hole in the pipes, the movable frame and the lower pipe under the tractor [12].

The movable unit is a structure consisting of a movable trolley on which frame 9 (Fig. 7), the same 13 (Figure 6) is fixed. The trolley moves along the beam on bearings. Its movement is carried out due to the tooth-chain transmission, which is made in the form of two mutually perpendicular gears.

The movement of the movable frame is carried out by turning the handle (pos. 8), which ensures the rotation of the sprocket (pos. 7) through the chain (pos. 6) to transmit rotation, the sprocket (pos. 5) is rigidly fixed on the shaft (pos. 4), for due to this, rotation is transferred to the sprocket (pos. 3), which ensures the movement of the frame from the chain in one direction or another (depending on the direction of rotation of the handle: clockwise or counterclockwise). The ends of the chain (pos.1) are attached to the ends of the trolley together with the frame (pos.9). The sprocket shafts are rigidly fixed to the

brackets by welding to the camera frame. The pitch of each chain is equal to the tooth pitch of each sprocket 15.875.

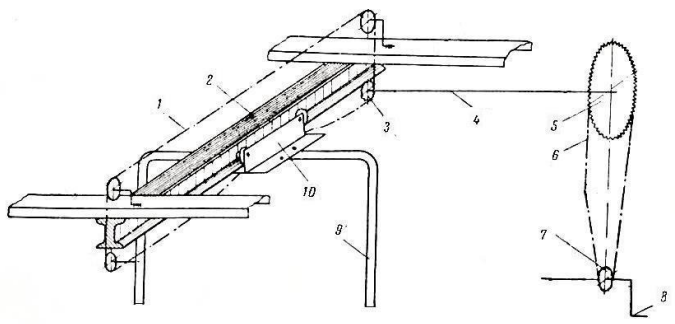

Fig. 7. Upper movable assembly.

The improved design of the washing plant will eliminate these shortcomings and will allow washing vehicles most efficiently, with the least labor and money, and will also provide environmentally friendly water consumption for washing, since the initial water consumption is used repeatedly (repeatedly) in general can be counted at 90 %.

The design parameters of the proposed technical devices were also calculated. Calculation of the overall dimensions of the chamber and the frame for washing, so the dimensions of the washing chamber are taken based on the condition that in length, width, and height it should be 0.35 m (50 cm) more than the dimensions of the washing movable frame (Figure 6) [13].

In turn, the movable frame is made on the basis of the condition that its dimensions should be 0.5 m more than the corresponding dimensions of the equipment (tractor) to be washed, the dimensions of the largest technical tool tractor DT-75 were taken as a basis, where the following overall dimensions are: length - 4560 mm, width - 3660 mm, height - 3350 mm.

Thus, the length of the washing chamber is 6 m, width 4 m, height 3.6 m, dimensions of the movable frame - height 3.6 m, width - 4 m, length (return stroke) - 6 m. Thus, the length of the lower pipe under tractor 6m.

An I-beam of the same length is taken (Figure 7) for the upper movable unit.

To calculate tooth-and-chain gears, we accept the conditions that the speed of movement of the frame (trolley) should be 0.1 m / s. We accept the drive sprocket 7 (Figure 7) with 16 teeth, then the driven sprocket 5 should be with 71 teeth. Thus, the gear ratio is 4.5, all other sprockets are also with 16 teeth.

We determine the rotational speed of the driven sprocket (Figure 7) according to the dependence:

$$n = \frac{v \cdot k}{z \cdot t} = \frac{0.2 \cdot 1000}{71 \cdot 15.875} = 0.2 \text{ rpm} \quad (1)$$

Where n is the rotational speed (rpm); v is the chain oscillation speed, i.e. frame movement speed 9; k – constant coefficient (1000); z is the number of sprocket teeth (71); t – chain pitch (15.875).

The cost of manufacturing the proposed device for disinfection and washing of agricultural machinery can be roughly determined as the sum of the cost of manufacturing and the cost of consumables. The cost of consumables includes the cost of purchasing materials for the manufacture of a washing chamber, a movable frame, drive sprockets in

chains, pumps, three-way valves, a drain tank with an overpass, and the cost of consumables for the manufacture of a washing chamber consists of the cost of a corner, polycarbonate, channel for the camera and so on. Thus, the cost of the device (manufacturing of the sink) is approximately 44,917 rubles. The cost of the washing process should also include the cost of the VET-840 heater 20,200 rubles, as well as the cost of electricity for heating water for disinfection and washing [14]. The heater consumes 8.4 kW/h for heating a full tank at a cost of 10 rubles/hour, i.e. 84 rubles.

In addition to the direct (net) economic effect of using the project, it also has a certain social effect in the economic component. It is expressed in the fact that much less water is used for washing than it was used before, which means that the anthropogenic impact on the hydrosphere is reduced. Wastewater does not go to treatment facilities each time, which reduces the overall burden on the environment.

4 Conclusion

The study of existing equipment and the method of washing agricultural machinery and vehicles in agricultural enterprises showed that when performing disinfection and washing, workers are relatively more likely than during other work in an agricultural enterprise to be injured and ill. In addition, the technology used in the agricultural enterprise has a negative impact on the environment. In this regard, it was necessary to improve and develop alternative organizational and technical measures, and the proposed project for the disinfection and washing of agricultural machinery will ensure safety and environmental friendliness in compliance with all environmental and labor protection requirements. This development can be recommended for use in any agricultural enterprises.

References

1. N. Leveson, Saf Sci., **42**, **4**, 237-270 (2004)
2. Thiago Moreno L. Souza, Biosafety and Health, **3**, **1**, 1-3 (2021)
3. RD-APK 3.10.07.05-17. Veterinary and sanitary requirements for the design, construction, reconstruction and operation of livestock premises, https://sudact.ru/law/rd-apk-3100705-17-veterinarno-sanitarnye-trebovaniia-pri-proektirovanii-stroitelstve/rd-apk-3.10.07.05-17/
4. B. Kalymbek, A. Altynbekkyzy, G.K. Shulanbekova, Examination, Procedia - Social and Behavioral Sciences, **143**, 976-980 (2014)
5. H.Z. Naghashyan, A.R. Hakobyan, A.A. Martirosyan, Annals of Agrarian Science, **16**, **4**, 410-412 (2018)
6. E.C. Muniz, R. Verdi, D.J. Jackwood, D. Kuchpel, J.C.Q. Mattos, K. Cookson, Journal of Applied Poultry Research, **27, 2**, 253-261 (2018)
7. J. R. Ryan, Biosecurity and Bioterrorism, **8**, 185-216 (2016)
8. Order of the Ministry of Labor and Social Development, 25 February 2016 No. 76n "Rules for labor protection in agriculture", https://docs.cntd.ru/document/420344857
9. Yu.O. Solomatina, V.M. Khudyakova, N.V. Matyusheva, *Substantiation of the need to install a car wash for vehicles used in the preparation of silage mass in the educational and experimental farm "PUSHKINSKOE",* in Intellectual potential of young scientists as a driver for the development of the agro-industrial complex. Materials of the international scientific-practical conference of young scientists and students, Saint Petersburg, 80-83 (2021)

10. P.N. Tatalev, N.V. Matyusheva, Pat. 2693500 RF Installation for washing cars and tractors / – No. 2018118902 / patent holder FGBOU VO SPbGAU; dec. 05/22/2018; publ. 07/03/2019. Bull. No. 19 (2018)
11. D.A. Kovalev, L.A. Rusinov, IOP Conf. Ser.: Earth Environ. Sci., **990**, 012068 (2022)
12. T.P. Satsuk, V.A. Sharyakov, O.L. Sharyakova, Electr. Engin., **92**, 349 (2021)
13. Yu.R. Dobretsov, S.B. Dobretsova, V.A. Sokolova, T.G. Garbuzova, S.V. Alekseeva, IOP Conference Series: Earth and Environmental Science, **981**, **4**, 042089 (2022)
14. V.N. Malikov, A.V. Ishkov, S.A. Voinash, V.A. Sokolova, E.Y. Remshev, Metallurgistthis, **65**, **11-12**, 1289–1298 (2022)