

## ASSESSMENT OF OCCUPATIONAL RISKS OF MECHANIZED PROCESSES FOR CHEMICAL PROTECTION OF PLANTS

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**Abstract.** Since chemical plant protection products (pesticides) are widely used in agricultural production in Ukraine today, the risks of poisoning and occupational diseases of workers are high, which requires research into the suitability of expert risk assessment methods in the case of mechanized processes of applying pesticides of high toxicity and dispersion. The aim of the work is to assess the occupational risks of workers during spraying of agricultural crops and to justify measures to reduce high levels of risks. In the work during mechanized spraying of agricultural crops on the educational and research farm of the Lviv National University of Veterinary Medicine and Biotechnology named after S.Z. Gzhytsky (Ukraine), occupational risks were calculated in the presence of various threats, using the method of expert assessments. Within the framework of the 5-point risk gradation used, it was established that the degree of basic risk of a dangerous situation that could lead to poisoning of workers with pesticides is 36 points; the risk of injury to workers by the working bodies of a tractor, sprayer and machines for preparing working mixtures is 27 points; the risk of injury to workers due to the action of other dangerous factors is 18 points. The calculated estimates, which correspond to the average degree of occupational risk according to the 5-point gradation of individual risk factors, indicate the need to implement additional protective measures (ensuring current monitoring of the technical condition of the tractor cab and elements of the ventilation system, providing workers at workplaces with backup sets of personal protective equipment, etc.) and causes the need to recommend them for inclusion in regulatory documents on occupational safety in agricultural production.

**Keywords:** pesticides, professional risks, method of expert evaluations, occupational safety, sprayers.

### Introduction

The risks of poisoning and occupational diseases associated with the use of pesticides and agrochemicals in agricultural production remain quite high [1]. The issues of assessing occupational risk due to the action of chemicals in the “man – machine – working conditions” system during mechanized spraying of agricultural crops and the development of preventive measures on this basis to prevent poisoning and occupational diseases are relevant.

The results of research on the development, improvement and use of methods for analyzing the processes of formation, occurrence of accidents and industrial injuries are presented in many publications [2; 3]. The developed methods are based on a logical analysis of dangerous situations, identification of industrial hazards, circumstances and conditions of their formation and development, which allows taking preventive measures to avoid the effects of dangerous factors. Methods for constructing failure schemes of mobile agricultural machinery [4] and operator errors of various complex systems [5] also involve mathematical processing of models in order to obtain quantitative values of the probabilities of undesirable events. The determined parameters of the level of danger can be used when planning organizational measures, developing and improving the designs of technical means and safety devices, reducing the level of danger or avoiding it in workplaces.

Literature sources indicate that the level of harmful effects of pesticides on human health, and therefore occupational risks, depend on the combined effect of many factors [6; 7]. First of all, these are the hazard class, chemical composition and physicochemical properties of the pesticide, its oral, inhalation and dermal-resorptive toxicity, cumulation and mutagenicity coefficients, methods, technologies and means of application in the field, environmental parameters (temperature, humidity, wind speed and direction), the volume of the treated area and its location relative to the points of preparation and refueling of sprayers [8; 9]. Additional factors that increase the occupational risk of workers during mechanized spraying of crops are errors in the selection of drugs and in application doses calculating, violation by workers of occupational safety requirements at all stages of work with toxic substances, use of protective equipment that is inappropriate for the type of pesticide or ignoring them [10; 11].

An important role in the level of occupational risk during pesticide application is played by the technical characteristics and condition of sprayers, which affect the level of mechanization of work, and therefore the degree of possible contact of workers with pesticides, as well as the accuracy of pesticide dosing [12; 13].

The purpose of this work is to substantiate the list of possible occupational risks of workers during chemical protection of agricultural crops by spraying, determine the levels of danger and justify measures to prevent them.

## Materials and methods

Occupational risk analysis involves studying the adverse effects of hazards on objects of influence and substantiating management decisions to reduce the level of risk. This paper proposes to investigate occupational risks and develop safety measures for mechanized pesticide application processes in crop production using the expert assessment method [14; 15], which allows determining the probabilities of hazardous events taking into account expert evaluation. Occupational risks  $R$  in points were determined by the formula:

$$R = P \times D \times V, \quad (1)$$

where  $P$  – probability of an adverse event (injury, poisoning or occupational disease);  
 $D$  – consequences of an adverse event;  
 $V$  – expert assessment of the level of influence of the probability of adverse events and their consequences on occupational risk.

It is proposed to use a 5-point gradation of the coefficients of formula (1). The probability of an undesirable event occurring was characterized in points in the following range: 1 point – unlikely; 2 points – random; 3 points – likely; 4 – very likely; 5 points – the threat is present all the time.

The consequences of an adverse event were characterized in points in the following range: 1 point – minor (minor injury, temporary deterioration of health); 2 points – insignificant (minor injuries and illnesses without hospitalization, signs of occupational disease); 3 points – significant (serious injury requiring hospitalization of the victim); 4 – significant (severe injuries with permanent deterioration of health, occupational diseases); 5 points – catastrophic (injury of a group of workers, fatal consequences).

Experts assessed the impact of the combination of the probability of adverse events and their consequences on occupational risk on a 5-point scale: 1 point – insignificant impact; 2 points – small impact; 3 points – significant impact; 4 points – more significant impact; 5 points – very large impact.

The following ranges of points were chosen as gradations of the level of occupational risk: 1-4 points (insignificant level); 5-10 points (low level); 11-50 points (medium level); 51-100 points (high level); 101-125 points (very high level). An insignificant level of occupational risk is considered an acceptable level of safety without reservations; a low level requires increased attention to work safety; a medium level cannot be considered acceptable without the implementation of protective measures; the other two levels of occupational risk are recognized as unacceptable.

## Results and discussion

In this work, the occupational risks of machine operators during the preparation of pesticide solutions and mechanized spraying of agricultural crops were assessed in the fields of the Northern Campus of the Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnology Lviv (Ukraine). Expert research was carried out during May-June 2022 on a field area of about 130 hectares, where the Apache AC1010 self-propelled sprayer was operating.

To analyze occupational risks, the main types of threats that lead to dangerous situations during mechanized spraying of agricultural crops were considered: 1) poisoning of workers with pesticides; 2) injury to workers by the working parts of the tractor, sprayer, and machines for preparing working mixtures [16; 17].

The results of expert assessment of the probabilities of hazardous events, their consequences and calculated values of occupational risk levels, as well as the proposed safety measures are presented in Tables 1 and 2. These tables show the averaged  $P$ ;  $D$ ;  $V$ ;  $R$  scores based on the assessment results, which were presented by 5 experts (university lecturers who are competent specialists in mechanized plant

spraying) for each of the threats. Since in this work the experts were asked to answer simple questions, the number of 5 experts can be considered sufficient.

Table 1

**Poisoning of a worker with a pesticide during operation of spraying agricultural crops**

Threat description	Value			
	<i>P</i>	<i>D</i>	<i>V</i>	<i>R</i>
Personal protective equipment does not meet the requirements of regulatory documents for a specific pesticide	2	3	3	18
Malfunction of personal protective equipment during pesticide application	3	3	4	36
Employees who have medical contraindications to a specific pesticide that were not identified during a medical examination (or were not performed) are allowed to work	2	4	3	24
Inattention of an employee filling a sprayer tank, which led to the spillage of the pesticide working solution	3	3	3	27
Failure of the device for monitoring the level of liquid filling the sprayer tank	2	3	2	12
Sudden change in weather conditions to unfavorable (exceeding permissible air temperature, change in direction and increase in wind speed beyond permissible limits)	3	3	4	36
Pesticide vapors entering the work area of auxiliary workers due to failure (damage) of the working parts of the unit, changes in wind speed and (or) direction	3	3	4	36
Contact of pesticides with the worker's skin due to damage to personal protective equipment and working parts of the unit	3	3	3	27
Leakage of pesticide or working fluid onto the ground due to failure of the unit's working parts	2	2	3	12
Pesticide drift caused by wind, which led to pesticide fumes entering workers' recreation areas	2	3	3	18
Wind drift of pesticides to residential or livestock buildings, to neighboring fields	2	2	3	12
Sprayers are refueled manually without special tools due to malfunctioning machine parts	3	3	4	36
Sprayer boom is manually moved from the transport position to the working position and vice versa without covering the sprayer nozzles	2	4	4	32
Depressurization of the tractor cab during operation, leading to pesticide vapors entering the cab	3	3	4	36
Failure of the tractor cabin ventilation system	2	3	4	24
Sprayer failed during operation, the working fluid is leaking	3	3	4	36
Averaged values of the coefficients of formula (1) and the calculated risk	2.50	3.00	3.44	26.38
Dispersion of expert ratings for individual coefficients of formula (1)	0.267	0.267	0.396	-
Risk of human poisoning by pesticides, determined by maximum values	3	4	4	36
<b>Occupational safety measures</b>				
1. Provide workers at workplaces with backup sets of personal protective equipment to replace them in the event of mechanical damage or failure of filter elements				
2. Ensure mandatory medical examinations of workers before allowing them to perform spraying work				
3. Equip the sprayer preparation and refueling point with a compact weather station				
4. Provide ongoing monitoring of the technical condition of the tractor cab and ventilation system elements				
5. Provide ongoing monitoring of the technical condition of the pressure generation and pesticide distribution system				

The method used in the article allows to convert hazard assessments, as qualitative indicators, into quantitative indicators (points) for comparing risks and identifying the most dangerous ones. Using methods of mathematical statistics for the assessments established by the experts and agreeing on them, based on the results, general conclusions are obtained regarding the degree of danger of the technological process. To obtain a consistent assessment of all experts involved, concordance tools were used. The consistency of the experts' opinions is confirmed by the value of the concordance coefficient within 0.7-0.9 for individual threats.

Table 2

**Injury to the worker by the working bodies of the tractor, sprayer and machines  
for preparing working mixtures of pesticides**

Threat description	Value			
	<i>P</i>	<i>D</i>	<i>V</i>	<i>R</i>
Damage to protective guards of cardan, belt or chain drives of units	2	3	4	24
Exceeding the permissible speed of the sprayer in the field due to the worker's inattention	3	2	3	18
Tractor brake system failure	3	3	3	27
Failure or damage during operation of footrests, railings and protective fences of the tractor, sprayer or machine for preparing the working mixture	3	3	3	27
Failure of the sprayer boom lifting and locking mechanisms	2	2	3	12
Failure of the sprayer hitch, safety chain, etc.	2	3	4	24
Failure of the sound or light signaling of the tractor and sprayer unit	2	2	3	12
Averaged values of the coefficients of formula (1) and the calculated risk	2.43	2.57	3.29	20.57
Dispersion of expert ratings for individual coefficients of formula (1)	0.29	0.29	0.24	-
Overall risk of injury to workers, determined by the maximum values of expert assessments	3	3	4	27
Occupational safety measures				
1. Ensure constant monitoring of the technical condition of protective guards of cardan shaft, belt or chain drives of units				
2. Equip the tractor with a navigator with a high-precision GPS parallel control system				
3. Ensure constant monitoring of the technical condition of components and assemblies of the tractor, sprayer, and machines for preparing pesticide working mixtures				

It should be noted that the 5-point scale used in this work shows the closeness of the assessments of individual experts, as evidenced by the small values of the dispersion of the assessments for the various analyzed threats. The value of the dispersion in Table 1 is a little more only in the case of experts assessing the level of influence of the probability of undesirable events and their consequences on occupational risk *V*, which is associated with a certain disagreement among experts regarding the understanding of this coefficient in formula (1). As a debatable issue, it is worth considering the feasibility of using a higher-level gradation, but with a clear definition of the additionally introduced score levels.

Analysis of the data in Tables 1-2 shows that the risk of worker poisoning by pesticides is 36 points, and the risk of worker injury by the working parts of the tractor, sprayer, and machines for preparing working mixtures is 27 points. These values correspond to an average level, and therefore the risk cannot be considered acceptable without the implementation of protective measures. The calculated risk level indicates that even if the requirements of the regulatory documents in force in Ukraine regarding occupational safety during spraying are met, as a result of the action of probabilistic factors, dangerous situations of poisoning (injury) of workers may arise, which requires the use of additional occupational safety measures [18].

The highest risk values (36 points) were obtained for the following threats: sudden change in weather conditions to unfavorable; pesticide vapors entering the work area of auxiliary workers; depressurization of the tractor cab. This allows us to justify additional measures that are not provided for in the current regulatory documents on the safety of spraying in Ukraine, but can be recommended for implementation, and it is necessary to indicate: a) provide workers at workplaces with backup sets of personal protective equipment to replace them in case of mechanical damage or failure of filter elements; b) ensure current monitoring of the technical condition of the tractor cab and elements of the ventilation system; c) equip the sprayer preparation and refueling point with a compact weather station to monitor wind speed and direction, air temperature, etc.

Comparison with scientific studies by other authors [5; 8; 19] showed that the applied approach corresponds to the basic principles of expert assessment, simplification of the methodology is justified for applied work, and the obtained results are within the limits typical for studies with sufficient expert consensus.

The results of the calculations in this work confirm that in Ukraine it is necessary to review regulatory documents regarding safety requirements for transportation, storage and use of pesticides and harmonize them with European standards, in particular with the requirements of the Commission Regulation (EU) 2015/830 of 28.05.2015. In particular, this concerns the introduction of stricter requirements regarding the degree of purification of polluted air in the workers' area, as well as equipping tractors with modern navigation equipment and ensuring proper monitoring of the technical condition of units.

### Conclusions

1. The paper analyzes the risks of poisoning and injury to workers during mechanized spraying of agricultural crops and finds that the occupational risks assessed by experts correspond to an average level.
2. According to the expert assessment method, the risk of a dangerous situation of poisoning a worker with pesticides is 36 points, and the risk of injury to a worker by the working parts of a tractor, sprayer, and machines for preparing working mixtures is 27 points. Accordingly, the risk cannot be considered acceptable without the use of additional protective measures.
3. The performed analysis of unfavorable production factors allows us to substantiate additional organizational and technical safety solutions, to avoid threats to the health of workers during chemical plant protection by spraying, which will contribute to the creation of a safer production environment, prevent the formation of traumatic situations and poisoning. As additional measures that are not provided for in the current regulatory documents on the safety of spraying in Ukraine, but can be recommended for implementation, it is necessary to indicate: a) provide workers at workplaces with backup sets of personal protective equipment to replace them in case of mechanical damage or failure of filter elements; b) ensure current monitoring of the technical condition of the tractor cab and elements of the ventilation system; c) equip the sprayer preparation and refueling point with a compact weather station to monitor wind speed and direction, air temperature, etc.

### Author contributions

Conceptualization, V.T. and O.Vo.; methodology, V.T. and O.Vi.; validation, I.H. and O.Vo.; formal analysis, O.Vo. and V.T.; investigation, O.Vo., V.T., I.H. and O.Vi.; data curation, O.Vo., V.T., I.H. and O.Vi.; writing – original draft preparation, V.T.; writing – review and editing, O.Vo. and V.T.; visualization, I.H. and V.T.; project administration, I.H.; funding acquisition, O.Vi. All authors have read and agreed to the published version of the manuscript.

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