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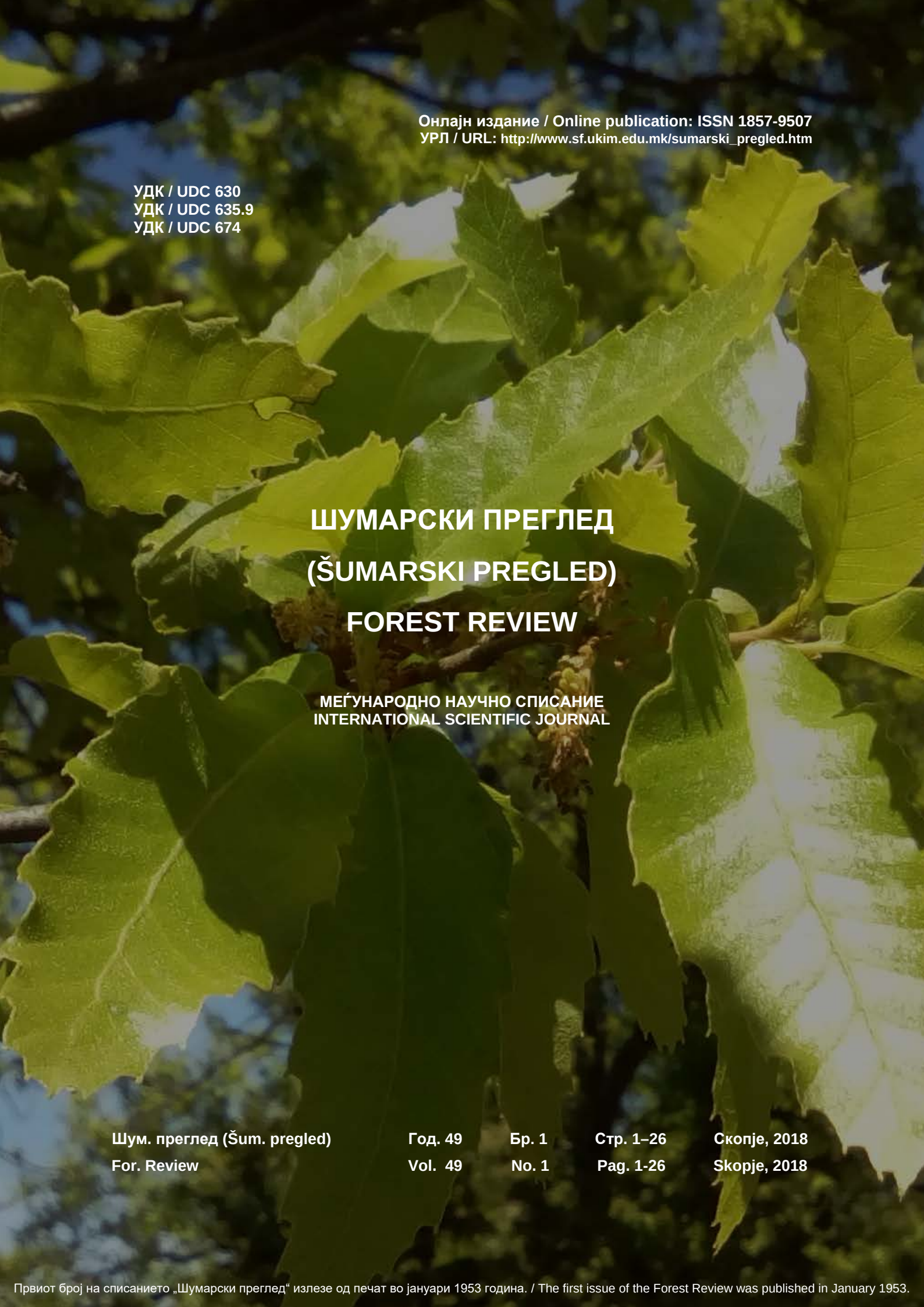

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CONTENTS

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Forest Review, 2018, Vol. 49, No. 1: 1-5.
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Original scientific article

Comparative analysis for the exposure of workers to vibrations in forestry and agriculture

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ABSTRACT: Healthy and safe working conditions are prerequisites for sustainable management of forest and agriculture workers. In practice sustainability can only be ensured by properly instructed and trained workers doing a good job. Long term exposure to either hand-arm or whole-body vibration has been associated with the development of certain musculoskeletal disorders. Many sawmill employees are exposed to vibration on a daily basis. This paper aims to analyze data for safety and protection of workers in forestry and agriculture professions who are exposed on negative effects caused by mechanical vibrations. For reaching this aim, a questionnaire with 8 questions and 34 offered answers was prepared. The survey was conducted randomly and we had 386 respondents from 500 calls. The contacted people who refused to respond were not taken as a parameter in any analysis. Several cities from north, central, south, east and west region of Macedonia were points of interest. The people were contacted telephonically by National phone network of home phone numbers. The results from workers in forestry and agriculture professions were separate in four segments: determination of exposure on vibration by professions, determination the amount of vibrations by systems of transsmiting on workers, daily exposure to vibration *A(8)* and implemented vibration control measures. In forestry professions we have the biggest percent of workers who are working with powered hand tool followed from the workers who operate special forestry vehicle and the least are workers that working with non-powered tools. When we are talking about how the vibrations are transmitted, professional workers with hand held operating tool are most exposed on vibration system called hand-arm vibration (HAV), the opposite of the workers who are managing forestry vehicles that are mostly exposed to the whole body vibrations. In daily exposure on vibrations *A(8)* hand tool operators are exposed in a smaller amount of time to vibrations in contrast of workers who operate forestry vehicles. This trend was also followed in the agriculture professions. In implemented control vibration measures in agriculture all segments had very high percentage of positive responses, while in the forestry companies executives need to work on providing trainings for prevention and purchasing new products that produces less vibrations.
Keywords: hand-arm vibrations, control vibration measures, daily exposure *A(8)*, forestry and agriculture

1 INTRODUCTION

The safety and health of workers are a priority on the list of tasks and challenges of employers or managers in all areas of the economy everywhere in the world. Closely related to the safety and health of employees are the risks of injuries and diseases that are partly or entirely caused by physical hazards at the workplace. The most common physical hazards in the working environment are: noise, vibration, ionizing radiation, non-ionizing radiation, microclimate conditions, brightness and increased and decreased atmospheric pressure. In addition to the basic physical characteristics of vibrations in terms of their frequency, vibratory acceleration is particularly important for the potentially harmful effects of vibration on the health of workers exposed to them. Acceleration represents a change of speed in unit of time and is expressed in m/sec^2, that is the amount used to determine the allowed exposure time according to the international standard. Mechanical vibrations to which workers are exposed and receiving them through the fingers or hands when using hand-held vibrating tools are called local vibration, and that is representing, hand-arm vibration exposure (HAV). Negative effects on workers' health caused by local hand-arm vibrations are most often due to the interruption of the supply of blood and oxygen to the fingers resulting from long-term vibration exposure and causes damage to the blood vessels and nerve systems that are initially reversible, but with prolonged exposures eventually become irreversible. It takes a lot of time and effort to measure vibration in all economic areas and branches where workers are exposed to the harmful effects of workplace vibrations during the working day [1]. According to [2], generally the exposure to whole body vibrations is commonly associated with transport or in certain industrial processes operating machinery or sprecialized vehicles, while exposure to local hand-armvibrations is usually associated with a vibrating machine motor, electric or hand tools [3]. The expected harmful effects on health caused from exposure to vibration at the workplace depend not only on the physical characteristics of the vibration, but also on the specifications of the machines and tools used during the performance of the work, the weather conditions at work, the characteristics of the material what is being done, the individual sensitivity and the position of the body in relation to the spread of vibration [4]. The earliest diagnoses of diseases and injuries caused by mechanical vibrations date back to 1862 [5] and are made by French physicist Dr Maurice Raynaud. A more objective system for determining the stage of injury, that is, giving the possibility of providing special classifications of the stages of injury through the vascular and sensoneural phases, by determining the peripheral, vascular and neurological disorders, was proposed and accepted at a thematic workshop held in Stockholm in 1986 [6]. Most common stage of whole body vibration is so called discomfort which can be defined as unpleasent feeling at the workplace and is the most responsible state for reducing the concentration of the worker. It is caused by vibrational acceleration, and depends on the frequency, direction, location of vibration reception and the duration of vibration exposure [8]. There is no way to measure and limit the vibratory discomfort that is individually determined. The initial conditions caused by occupational exposure to the harmful effects of local vibrations are

dominated by symptoms - tingling, pain, stiffness, and seizures of white fingers. Next, further exposure to mechanical vibration causes muscle and bone disorders, and the possibility of changes in the central nervous system is not excluded. Initial symptoms commonly occur suddenly and in most cases are caused by a combination of exposure to vibration in cold and / or under low temperature conditions. Clinical indication that prejudices peripheral circulation damage is a condition called Rayneud syndrome. When this condition occurs as a consequence of occupational exposure to local vibrations, first pallor is observed only in confined zones, in most cases on the fingertips, which is further followed by a feeling of cold in the hands. Furthermore, with the prolonged exposure to the harmful effects caused by vibration, the pallor expands and penetrates the inside of the affected fingers and the final stage of disease is reached "white fingers". The finger blinking latency period in the white finger disease may range from two to 16 years, the stiffness phase of the disease is varying from 2 to 12 years [9]. The exposure assessment of vibration plays an important role in the safety and proper functioning of the worker at his workplace [10]. With our research we will collect valuable data that will help for increasing safety and reduce injury and health damage to workers caused by exposure to mechanical vibration in the workplace.

2 MATERIALS AND METHODS

It was intended to make the poll randomly, and it would be subject to analysis by 386 respondents in several cities in the Republic of Macedonia. In order to achieve this goal, we have taken the task of creating a questionnaire in which, through certain questions, we will get answers, which will be statistically analyzed and graphically visualized in appropriate mathematical software (ANOVA, SPSS, and Excel).

Questionnaire with 8 questions and 34 offered answers was prepared. The survey was conducted randomly and we had 386 respondents from 500 calls. The contacted people who refused to respond were not taken as a parameter in any analysis. Several cities from north, central, south, east and west region of Macedonia were points of interest. The people were contacted telephonically by National phone network of home phone numbers. The survey was conducted for seven months.

3 RESULTS

3.1 Determination of exposure to vibrations in forestry professions

Forestry as a commercial branch has a wide range of activities and from here comes the important function that plays in the environment. Forestry professions have a large spectrum, so in our research, based on the responses of the respondents, we analyzed four forestry professions. Answers from the conducted scientific survey are presented on Figure 1.

From presented results on Figure 1 in form of pie, we can conclude that the largest percentage of forestry workers surveyed work on the profession related to the management of a certain hand-held power tool, followed by the workers who manage a professional forestry vehicle and the lowest percent representation is among workers who work with a no powered hand-held tool. These results indicate that the number of workers who in the description of their working profession have the task of operating with certain hand tools versus those who manage certain off-road forestry vehicles is significantly larger. From this indicator we can further consider improving the working conditions of these workers, increasing safety and reducing the risk during working hours.

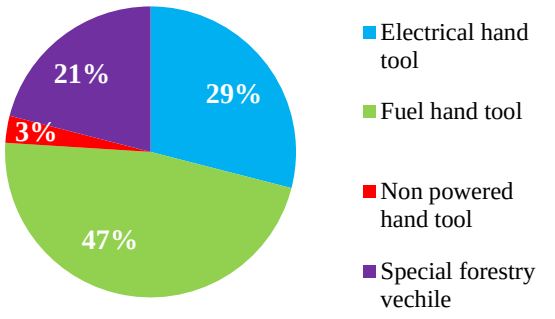

Figure 1: Total percentage of people exposed to vibration in forestry professions

In addition to the previous analysis of exposure to vibrations of workers in forestry professions, we investigate the percentage of exposure on the basis of which systemthe vibrations act. The answers from this part of the questionare are represented in Table I.

Table I: Quantity of exposure to vibrations in a view of acting system in forestry professions

Type of vibration	Forestry jobs			
	Fuel hand tool	Electrical hand tool	Non powered hand tool	Special forestry vehicle
	Percent %			
Hand – arm	93	88	95	2
Whole body	0	3	5	91
Hand – arm and whole body	7	9	0	7

*Responses in the survey were obtained by sample of 386 respondents

The vibration system is very important indicators since the vibrations of a local character do not have any common features with the vibrations that are received with the whole body (general vibrations). Different properties generate various problems and risks, so a different basis for their reduction and prevention is required. From the results presented above we can determine the expected opinion of this indicator in the professions of the forestry sector, i.e. the strongest action of the vibrations from the hand-arm system we have at forestry professions that in their description have tasks related with a hand tool, while diametrically opposite to them are the workers who manage professional forestry vehicles, here we have 98% acting vibrations that are received through the whole body system versus 0% of workers from this forestry profession who are exposed to vibrations of a local (hand-arm vibration) character.

3.1.3 Daily exposure to vibration *A(8)* in forestry professions

Using the answers from the conducted survey, data on the daily exposure *A(8)* in forestry professions were obtained. The mathematical analysis determines the percentage exposure of vibrations in the forest professions presented in the Table II below. The daily exposure was analyzed in quarterly zones, i.e. the respondents were asked to assess whether their exposure to vibrations in eight hour workday is less than two hours, greater than two and less than four, greater than four and less than six and a maximum daily exposure six and eight hours.

Table II: Daily exposure to vibration *A(8)* in forestry professions

Daily exposure *A(8)*	Fuel hand tool	Electrical hand tool	Non powered hand tool	Special forestry vehicle
	Percent %			
exposure< 2h	27	23	15	11
2h<exposure ≤4h	41	48	38	19
4h<exposure ≤6h	22	17	31	44
6h<exposure ≤8h	10	12	16	26

*Responses in the survey were obtained by sample of 386 respondents

From the mathematical analysis of the daily exposure in forestry professions, the following conclusions can be reached. The highest daily exposure to vibrations over four and over six hours is most common with 44 and 26% in the working profession managing professional forestry vehicles. Contrary to them, the lowest daily exposure is 17% in the quarter showing exposure between 4 and 6 hours at operators with fuel hand tools, and the lowest daily exposure for the quarter from 6 to 8 hours of exposure with 10% we have in the forestry profession which involves working with electrical hand tools. These results are most likely a consequence of the description of the work tasks of certain forest professions, more detailed working tasks had handheld operators and they are intervening, in contrast to the workers who manage forestry vehicles whose profession covers daily continuous tasks.

3.1.4 Implemented control measures in the forestry professions

Forestry as an economic branch covers many working professions, which in their description have activities that are carried out on the field, and thus the risk of injury to workers is increased. It is these indicators that give a sign of the enhanced implementation of preventive measures in order to enable workers to work more efficiently and safer.

In the Table III below, the results of our examination are presented.

Table III: Measures for protection and control of vibrations in forestry professions

Implemented vibration control measures (multiple answers are allowed)	**Number of workers who reported control implemented**	**% of workers who are exposed to vibrations**
Provide gloves	59	98
Use vibration dampeners	8	13
Provide vibration absorbing seats	13	22
Purchase products with less vibration	24	40
Provide training on how to prevent health problems caused by vibration	34	57
No control measures provided	6	10

*Responses in the survey were obtained by sample of 386 respondents

The general picture given by the analyzed data on implemented preventive measures in the forest professions is promising. This fact can be taken from high percentage (57%) of workers who replied that their company organizes trainings for preventing health problems caused by vibration. Also the parameter where workers report that their executives didn't take any control measures for preventing them from the negative effects caused by vibration is very small, only 10%. However, in this segment there is still work that need to be done. The companies must consider the fact that high 40% of workers answer that their companies do not purchase new products that produces less vibration.

3.2 Determination of exposure to vibrations in agriculture professions

Following the trends in our research work, a large number of respondents stated that their work tasks belong to the economy branch - agriculture. Based on the answers we defined four professions that will be analyzed in several segments. The percentage of people exposed to vibration in agricultural professions is shown on Figure 2 below.

From the analysis of the presented results in Figure 2 we can summarize that the most represented agricultural profession with 61% of the answers is the management of a particular agricultural professional machine and unlike only 7% of the workers have agreed that their working profession is the management of hand-held electric tools.

The obtained results can be explained by the fact that in agriculture as a branch of industry, profiles of workers of all kinds are needed, but as we can see in our survey, all professions are operational, i.e. they are carried out on the field.

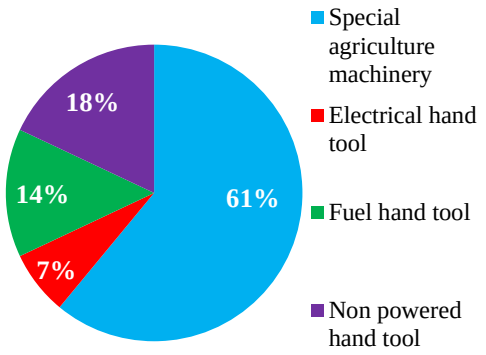

Figure 2: Total percentage of people exposed to vibration in forestry professions

3.2.1 Determination the amount of vibrations by systemson workers in agriculture professions

As we mentioned above because of the different professions in agriculture we have workers who are exposed to different types of vibration in their work positions. Exposure to vibrations from individual systems in agricultural workers is presented in Table IV.

Table IV: Quantity of exposure to vibrations in a view of acting system in agriculture professions

Type of vibration	Agriculture occupations			
	Fuel hand tool	Electrical hand tool	Non powered hand tool	Special agriculture machinery
	Percent %			
Hand – arm	84	89	93	0
Whole body	7	3	0	94
Hand – arm and whole body	9	8	7	6

*Responses in the survey were obtained by sample of 386 respondents

From the above data we can notice that the system of vibration activity of whole body, i.e. exposure to vibration of a general type, highest percentage over (90%), we have in the working profession that includes management of a professional agricultural machine. This act of vibration that is transmitted to whole body at workers that working with hand held tool no matter if it's powered or not the percent varieties from 0 to around 10%. The act of hand-arm vibration system is highest at the professions, which in their tasks managing hand held tools around 90%. Opposite to them operators of special agriculture, machinery and vehicles have the smallest exposure to hand arm vibrations.

3.2.2 Daily exposure to vibration *A(8)* in agriculture professions

The daily exposure to vibrations *A(8)* as an indicator tells us about the repeated activity of vibration in a certain profession in one working day. The percentage of daily exposure in agricultural professions is presented in a Table V below.

Table V: Daily exposure to vibration *A(8)* in agriculture professions

Daily exposure *A(8)*	Fuel hand tool	Electrical hand tool	Non powered hand tool	Special agriculture machinery
	Percent %			
exposure < 2h	24	21	17	12
2h<exposure≤4h	47	44	32	27
4h<exposure≤6h	29	23	37	38
6h<exposure≤8h	10	12	14	23

* Responses in the survey were obtained by sample of 386 respondents

The analyzed results of indicator *A(8)* showing that the highest percentage (24%) of exposure less than 2 hours per day is in the profession of working with fuel hand tools, which is approximately the same as with other agricultural professions dealing with hand tools in general, in contrast to a statistically smaller value of 12% in the profession involving the management of an agricultural machine. This trend continues in other quarterly indicators of daily exposure, so the increase in quarterly daily exposure, the percentage of representation in agricultural professions that involve the use of hand tools decreases, in contrast to the professions that include the management of a professional agricultural machine where the percentage of daily exposure increases in proportion to the higher exposure in time.

3.2.3 Implemented control measures in the agriculture professions

Agriculture is a widespread economy branch and occupies a large percentage of industry in almost all countries of the world. This fact has been proven in our survey and from here we continue with an analysis in the area of implemented preventive measures in agriculture. In Table VI the results of the analysis are presented.

From the results presented in the Table VI, we can clearly see the high percentage of implemented measures in all segments of agriculture. The most popular measures are the use of protective gloves and vibration absorbing seats. A very significant high percentage of positive answers we have in the indicator - providing new products that are safer for workers, make the work more efficient and easier, and at the same time, they produce fewer

vibrations, reducing the risks of occurrence of diseases caused by exposure to vibration. Also very important indicator is the organization of trainings and training camps that speak about the protection from vibrations for preventing health problems arising from vibrations. In this indicator we have 66% positive responses, so we can say that this is an indicator that shows us a stable developed branch in our country. It is very important in the future to maintain this high trend of positive indicators, so there should be close cooperation with both state institutions and private domestic and foreign investors.

Table VI: Measures for protection and control of vibrations in agriculture professions

Implemented vibration control measures (multiple answers are allowed)	Number of workers who reported control implemented	% of workers who are exposed to vibrations
Provide gloves	282	88
Use vibration dampeners	45	14
Provide vibration absorbing seats	234	73
Purchase products with less vibration	196	61
Provide training on how to prevent health problems caused by vibration	212	66
No control measures provided	86	27

*Responses in the survey were obtained by sample of 386 respondents

4 CONCLUSIONS

Our questionnaire, which was modified for the needs of this scientific research, fulfilled the set goals and tasks. With statistical processing of the received answers we collect data that shows the real image in forestry and agriculture in a view of safety of workers. From obtained results we can reach following conclusions.

In forestry professions we have the biggest percent of workers who working with powered hand tool followed from the workers who operate special forestry vehicle and the least are workers that working with non-powered tools. In the speaking of way how the vibrations are transmitted, professional workers with hand held operating tool are most exposed on vibration system called hand-arm vibration (HAV) opposite of the workers who managing forestry vehicles that are mostly exposed to whole body vibrations. In daily exposure on vibrations *A(8)* hand tool operators are exposed smaller amount of time to vibrations in contrast of workers who operate forestry vehicles.

In the implemented control measures for protection from vibrations forestry workers stated that in their company's interest for providing training on how to prevent health problems caused by vibration is very small, as for purchasing new products that produces smaller amount of vibrations.

In agriculture professions at the point of view on system of acting of the vibrations and daily exposure on vibrations *A(8)* the results following the trend that is noticed at the forestry professions.

Speaking of implemented control measures for vibration in agriculture we have high percentage of positive responses in all segments, which can be indicator of one really stable and developed branch in our country.

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