WORKING PLACE CONDITIONS IMPACT ON WORK INJURY OCCURRENCE IN THE TIMBER HARVESTING PROCESS

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Abstract

Influence of chosen meteorological phenomena on the selected factors of work injuries registered in the timber harvesting process in the Slovak forest sector was analyzed. Fall of person as one of the injury kinds happened during the rain, resp. on the slippery surface in 68% of all cases. Legs were the most often injured parts of body and the number of 41 cases registered on the damp surface and the number of 36 cases occurred, when it was raining. Within the cause 12 (a work risk) the most injuries happened on slippery surface and during the rainfall. The methods of analysis, synthesis and following comparison were used while elaborating this work. There was also statistical analysis carried out. Dependency of specific source of injury, an injury causative variation and the kind of injury on soil surface conditions was analyzed and this was validated with the significance level 5%.

The new EU strategy for the years 2007 – 2012 has suggested to reduce the total work injuries occurrence rate by 25% in EU-27 by the year 2012 (Komisia európskych spoločenstiev, 2007). Effective tool for work injuries elimination is prevention. On the end of paper, authors recommend basic measures observance for prevent the work injuries occurrence in timber harvesting process.

Key words: work injury, weather condition, forestry, timber harvesting process.

Classification JEL: M 140 Corporate Culture, Social Responsibility

1. Introduction and problems

Most of the works within the timber harvesting and transportation process is realized in forest. Specific production-technical conditions are characteristic for this working environment. The principal, ergo the harvesting process, is realized mainly in winter months. These months are also the most hazardous season of the year in term of a risk of work injury occurrence (Suchomel at al., 2008, p. 80). An important part in this case is played by factors as for example snow cover, frozen forest floor, resp. soil surface, different sorts of precipitations and the like. Although, the snow amount in forest stands is smaller than the snow amount on forest free area, the snow cover variability is considerably higher in the forest, and under certain conditions, the snow cover can persists here up to three weeks longer, in comparison with the forest free area (Hríbik et al., 2009, pp. 141-143). The movement of persons in forest stands is very exhausting and hazardous, what is, except of the above, caused also by the often tree tops and branches breakage (Hríbik, Škvarenina, 2007, p. 5).

Average annual precipitation total for the whole territory of Slovakia is 747mm (1951 – 1980 areal mean) of which 65% is evaporated and 35% represents runoff (Lapin et al., 1997).

Besides the falling precipitations we know still precipitation deposit (horizontal precipitations) that can be different in dependence on conditions in which the condensation occurs. Hoar frost, frost cover, soft rime and glaze belong to the solid precipitation deposit and dew and moistening belong to the liquid products of condensation on the Earth’s surface (liquid precipitations).

Dew forms in the evening and at the night in the warm season on the horizontal areas of active soil surface, plant leaves and the like. Dew formation is supported by clear sky, clean air, calm, smaller heat conductivity and small specific heat of matters.

Hoarfrost are some ice crystals of different form, few millimetres long, on the grass, soil surface, or snow cover formalizing. It forms, when the temperature of the objects on which the hoarfrost forms is well below 0°C.

Moistening is a thin coating of water drops, which forms on vertical areas, e.g. walls, trees, columns and the like during the cloudy and windy weather.

Frost cover forms if the temperature falls below 0°C. Most often the structure of frost cover is crystalline structure, but it can be formalized also from a thin clear ice layer. That is very dangerous for aeroplanes, remote electric lines and voice grade channels, trees etc.

Soft rime forms by the severe frost and fog. Supercooled fog drops impinge onto a cold exposed object and get frozen and so they give rise to soft ice crystals on branches, needles, line wires, wire fence and other thin items. Ice prisms can easily fall off by the gentle breeze or frost cover.

Glaze forms by the temperatures from 0 till – 15°C. By these temperatures, precipitations, in the form of supercooled liquid drops, fall onto exposed objects and get frozen and cover these with transparent or opaque ice coating. This ice coating can be a few cm and abnormal a few dm thin. In extreme situations, the branches can break, the electric line wires can tear and the roads can change into icerink under the ice weight (Špánik et al., 1999).

All above mentioned factors are an integral part of ***forest working environment*** and they influence the performance of forest activities. Very often the source of work injuries is the workplaces or road traffic places as the sources of employees fall (sources group IV), where the severe conditions of weather can cause an increased risk of employees slip or fall occurrences. The hazard is increased also at handling with materials, burdens and objects (these present the most often frequent source of work injury in forestry – source group V). Workers are endangered at the felling and yarding process, when under these conditions, the self-motion of timber is more probable. Therefore, it is very important to take into account the weather as a factor, not only in order to reduce the frequency of work injury occurrence, but also in selecting the appropriate techniques and technologies (Slančík et al. 2009, p. 189), which in interaction with the severe weather conditions can increase the risk of injury occurrence.

Suchomel et al. (2006, p. 42) analyzed the influence of selected meteorological conditions over the injury occurrence in forest work. Cyclonal types proved to be far more influential in terms of work related injuries compared to anticyclonal types. Overall 96-forest work related injuries had been registered in cyclonal and 63 work related injuries in anticyclonal types of weather. Out of cyclonal types of weather, low pressure trough Bp (25%) registered the biggest injury appearance. Out of anticyclonal types of weather, it proved to be the southeast anticyclonal situation SEa (19%). Biotropic effects of weather on workers concentration and injury occurrence had been evaluated. Klun and Medved, (2007, p. 56) compare the fatal injuries occurring at professional and non-professional workers in forestry in chosen European countries. In the case of fatal work injuries it is possible to assume the significant influence of meteorological condition on the occurrence of these injuries.

The aim of the article is to analyze the impact of chosen weather factors on the occurrence of work injuries in the group of forest workers.

2. Material and methods

For the analysis of the influence, that meteorological phenomena have on the occurrence of work injuries, it was necessary to choose branches[1], which would be typical for their location in lowland and highland areas (in the terms of current climatic classification of the Slovak territory). These criteria were met by branches Liptovský Hrádok, Námestovo and Kriváň.

Geographical location of the branch ***Liptovský Hrádok*** is in the fold of Liptovská kotlina. The territory is characterized by a great relief dynamics; it is altitudinal differentiated and

[1] Regional branches of the state-owned enterprise Lesy SR, š. p.

therefore climatically diverse with annual average temperatures range 0.2 to 6.3°C. Average annual rainfall is in the interval 690 – 1810 mm. The snow cover lasts in this area for about 80 to 222 days.

Area and location of the branch ***Námestovo*** belongs to the geographical region of Orava. This area is altitudinal differentiated, therefore also climatically considerably heterogeneous with annual average temperatures range 6.0 – 0.5°C. Average annual rainfall is in the interval 720 – 1200mm. The snow cover lasts in this area for about 150 to 220 days.

The branch ***Kriváň*** is geographically located in the Poľana mountains. This area is (regard to its great orographic diversity) also climatically heterogeneous with the annual average temperatures 7.7 – 2.5°C. Average annual rainfall is in the interval 720 – 1200mm. The snow cover lasts in this area for about 120 to 190 days (Hríbik, Škvarenina, Kyselová, 2008, p. 347).

Primary data for the weather based work injuries frequency evaluation were information about the weather, which characterized a certain day, or hour when the work injury occurred and a concrete location on which the meteorological and precipitation-gage station was selection dependent. We used following concrete data: air temperature, rainfall (mm), snow cover (cm), and soil surface.

For the determination of temperature, the altitude of the location of the work injuries occurrence was important. Basic methods used for the determination of temperature were interpolation or regressive theorem, which enabled us to assign other missing data by using the known temperatures.

Data about rainfall and snow cover were collected from precipitation-gage stations which enabled a considerably precise condition setting, because the density of the precipitation-gage stations network is wider than the density of meteorological stations.

The work injuries frequency can with no doubt be influenced by the soil surface and the occurrence of various weather effects. These are listed in **meteorological stations** in the ***form of code,*** as for example:

A = rain, freezing rain, rain shower,
B = snow, snow shower,
I = dew,
P = coherent snow cover 1 cm and more,
M = fog, ice fog, ground fog.

Soil surface conditions:

0 – dry soil surface,
1 – wet soil surface,
2 – slushy soil surface (water is standing in smaller or bigger pools),
3 – bare soil surface and frozen,
4 – soil surface covered with glaze and ice, though without snow or a thawing snow,
5 – snow or a thawing snow (with ice or without the ice) covers less than a half of the soil surface,
6 – snow or a thawing snow (with ice or without the ice) covers more than a half of the soil surface, though not the whole surface,
7 – snow or a thawing snow (with ice or without the ice) covers the whole soil surface,
8 – dry, loose snow, dust or sand covers more than a half of the soil surface, though not the whole surface,
9 – dry, loose snow, dust or sand covers the whole soil surface.

Work injuries data were taken from the existing state-owned enterprise Lesy SR work injuries database (Suchomel et al., 2008, pp. 33-35). From the database following data on these criterions were used: the kind of injury, the injured body parts, and the cause of injury (criteria were used according to the Ministry of labour, social affairs and family regulation nr. 500/2006 which imposes the model record about registered injury). **Examined injuries** were registered during the following phases and activities of the timber harvesting and transportation process: phase of wood felling and yarding, work process at forest depot, wood transport phase, work process at conversion depot and lower landing, repair and maintenance activity and control activity of technical and economic workers. Data was processed with Microsoft Excel. Afterwards different types of charts were created and evaluated.

3. Contigency Table

Because in the work is necessary to analyze the relationship between quality characters, for this purpose the method of Contingency Table was used.

When we have two plural qualitative factors A, B, of which the first occurs in the variations (degrees) A_1, A_2, A_3, ... A_k and the other occurs in the variations (degrees) B1, B2, B3 ... B_m, their sorting brings *k x m* contingency table type which is shown in Table 1.

Table 1: Example of Contingency Table

Factor B		**Degrees of factor B**						**Σ**
Factor A		$\mathbf{B_1}$	$\mathbf{B_2}$	**...**	$\mathbf{B_j}$	**...**	$\mathbf{B_m}$	
Degrees of factor A	$\mathbf{A_1}$	n_{11}	n_{12}	...	n_{1j}	...	n_{1m}	n_1
	$\mathbf{A_2}$	n_{21}	n_{22}	...	n_{2j}	...	n_{2m}	n_2
	.	.	.					.
	.	.	.					.
	.	.	.					.
	$\mathbf{A_i}$	n_{i1}	n_{i2}	...	n_{ij}	...	n_{im}	n_i
	.	.						.
	.	.						.
	.	.						.
	$\mathbf{A_k}$	n_{k1}	n_{k2}		n_{kj}		n_{km}	n_k
Σ		n_1	n_2	...	n_j	...	n_m	n

Source: general knowledge

The degree of dependence between the plural form qualitative factors A, B, is measured by a comparing of actual frequencies in particular stages of the Contingency Table n_{ij}, with the expected multiplicity n'_{ij} assuming the independence of factors A, B. Expected dependences are calculated according to equation:

$$n'_{ij} = \frac{n_i \cdot n_j}{n} \qquad (1),$$

They are calculated by multiplying of the marginal frequencies (n_i for factor A and n_j for B factor) range divided by a set of *n*.

The basis for the calculation is the quantity χ^2 (chi square), which is specified by the relationship:

$$\chi^2 = \sum_{i=1}^{k} \sum_{j=1}^{m} \frac{n_{ij}^2}{n_{ij}} - n \qquad (2).$$

The calculation of χ^2 is done directly in the contingency table, where the expected frequencies n'_{ij} or also the differences $(nij - n'_{ij})$ are recorded in each grade (box table) except the actual frequencies. Other symbols n, k, m are known from the text.

Expected frequencies must be also calculated for the table boxes where the actual frequencies are not occurring. The frequencies in the respective boxes enter the calculation of x^2 with the value:

$$\frac{(0-n'_{ij})^2}{n'_{ij}} = n'_{ij} \qquad (3),$$

The formula gives reliable results when the sample size $n > 40$. If any of frequencies in the contingency table is too small (less than 5), there must be made the appropriate correction to make the result reliable. As the most advantageous could be marked the correction that was proposed by Yates (Myslivec, 1957, In Šmelko, Wolf 1977, p. 160) residing that we add the value of 0.5 to the minimum frequency and the other frequencies we adjusted in the way that the marginal frequencies remained unchanged. In the case that $20 < n < 40$ and any of the expected frequencies n'_{ij} is less than 5, the class in which the frequency is included should be merged with the neighboring (closest relative) class of A or B factor. For the range set $n < 20$ this methodology should not be used at all.

Variable χ^2 is the basis for a test of hypotheses about the independence of factors A and B. Its small values argue in favor of the hypothesis, the large values against the hypothesis.

In practice, the compliance with the asymptotic distribution is considered to be sufficient if $e_{ij} > 5\ \forall i,j$. If the $x^2 > x^2_{(k-1)\,(m-1)}(\alpha)$, the hypothesis of independence of factors A, B is rejected. The critical values of $x^2_{(k-1)\,(m-1)}(\alpha)$ are tabulated, while *(k-1) (m-1)* represents the number of degrees of freedom.

Sometimes the x^2 is also called the ratio of assurance. The value of x^2 variable tells whether the dependency between factors A and B could regarded as statistically significant or not. It does not say, however, about the dependence degree of these factors. Degree of dependence can be expressed by a coefficient of correlation of two plural qualitative factors A, B, which is calculated by the formula Čuprov (Urbach, In: Šmelko, Wolf, 1977, p. 160):

$$r_{AB} = \sqrt{\frac{\chi^2}{n \cdot \sqrt{(k-1)\cdot(m-1)}}} \qquad (4).$$

4. Results

The number of 1654 work injuries has been recorded within the state-owned enterprise Lesy SR, š.p. during the years 2000 – 2007. This number includes 1256 work injuries in the timber harvesting and transportation process, what represents 76% of a total. 24% of all work injuries was registered in others forest activities such as silviculture, forest protection, hunting etc. (Suchomel et al., 2008, p. 53).

The total sum of work injuries registered in the branches Liptovský Hrádok, Námestovo and Kriváň in the research period in the timber harvesting and transport process was 209 (Figure 1). From all injuries, 36% occurred by rainfall, ice rain, or rain shower. In 24 work injury cases it was snowing or snow occurred and also in 24 cases snow cover of minimally 1cm was recorded. In 13% of days (27 cases) when the work injuries occurred dew was stated in the locality which in case of forest work equally as all other mentioned meteorological factors is a significant aspect in maintaining work safety in the sense of work injuries origins group IV – work, or road traffic area as a source of employees falls where 29% of injuries were stated in the timber harvesting process in the Slovak forestry sector (Suchomel et al., 2008, p. 68).

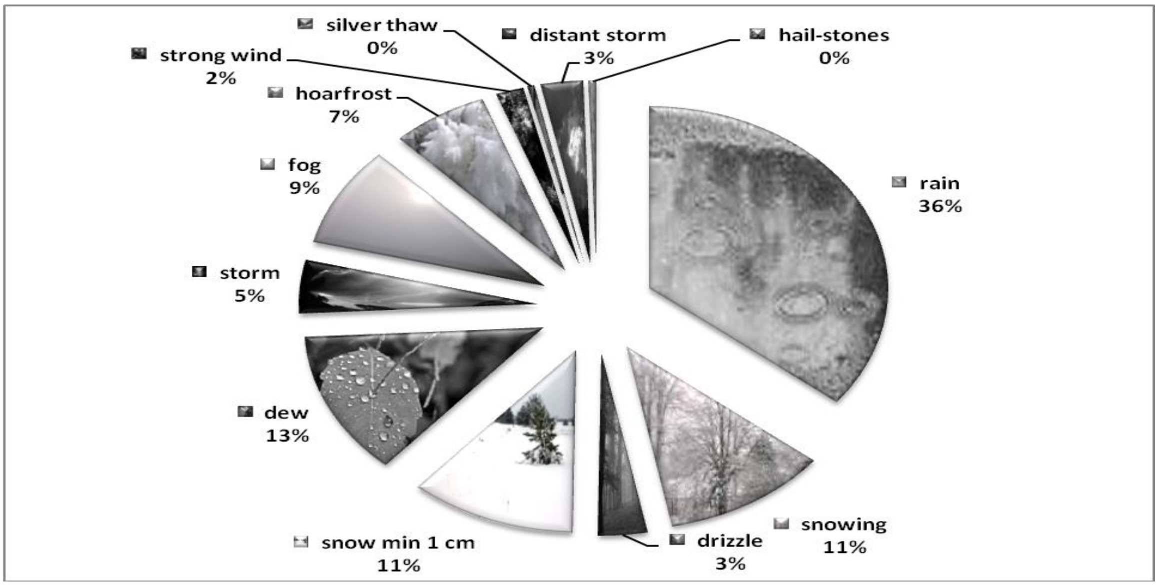

Figure 1: The most occurring meteorological factor by work injuries
Source: own study

The second picture (Figure 2) shows the share of manners of injury occuring by specific meteorological phenomenon influencing the working conditions. Almost in all occurring cases of injury categories the rain is dominating factor. 91% of all injuries happened during unfavourable weather. Fall of person as one of the injury kinds happened during the rain, resp. on the slippery surface in 68% of all cases.

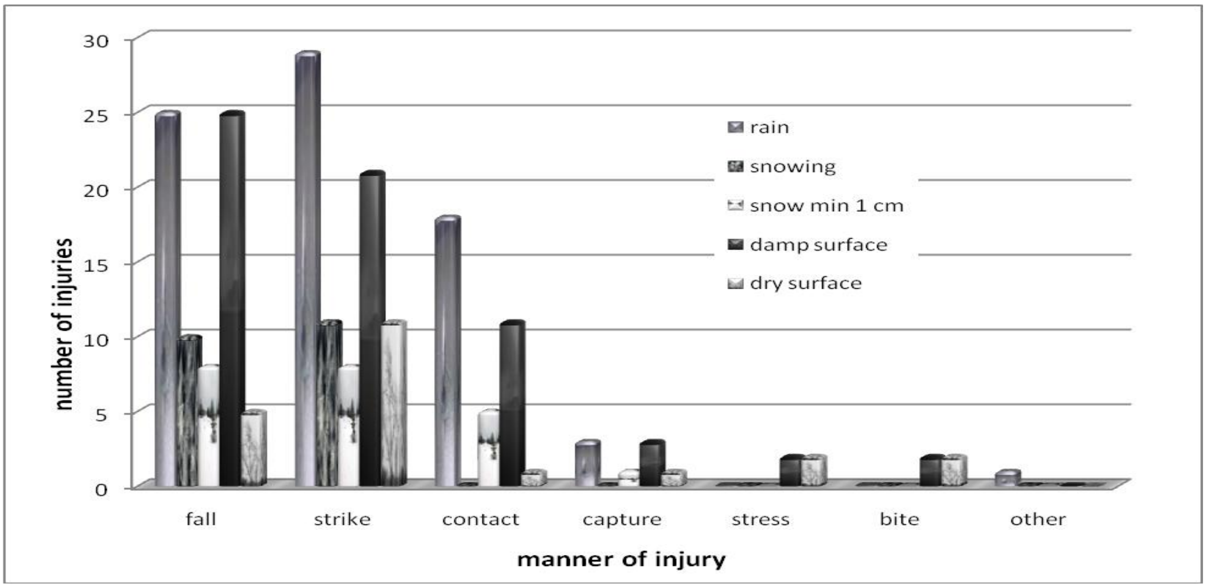

Figure 2: The manner of injury by occurring meteorological phenomenon
Source: own study

However, it is interesting that unfavourable weather could have influenced the work injury occurrence also in the cases of injury kinds „stroke” and „contact” (87% of all injuries by stroke and all manners of injuries „contact with a sharp, point or ragged surface” happened during unfavourable weather). These mentioned injuries occurrence in the unfavourable weather could be caused by a distractibility, tiredness or simply by workers' „meteosensitivity”.

To determine the dependency of factors: soil surface conditions and the manner of injury of persons employed in forestry method of contingent tables was used (Table 2).

Formulation of the null hypothesis: no relation between the manner of injury and soil surface condition exist.

Table 2: Manner of injury

Work injuries			
The kind of injury	**Slippery surface**	**Dry surface**	**Σ**
Fall. Contact	102	6	108
	96,57692308	11,4230769	
Others	84	18	100
	89,4230769	10,5769231	
Σ	186	22	208

Source: own study

$x^2 = 5.988557$
Degree of freedom (DF): 1

With the level of significance 5% and the degree of freedom 1 represents the table value chí square 3.8 ($x^2 < x^2_{1(0.05)}$), so we can state that with 95% probability we deny the formulated hypothesis. The term fall includes employees' falls and under the „contact” notion we can understand workers injury with a sharp, pointed, hard or abrasive object.

$r_{AB} = 0.16968$

Existing relation between injury manner and soil surface condition can be on the basis of calculated coefficient $r_{AB} = 0.16968$ defined as very weak.

The share of the injured body parts in dependence of soil surface conditions is represented at the third picture (Figure 3). The legs were the most often injured parts of body, with the 49% share of all analysed injuries. There was the number of 41 cases registered on the damp surface and the number of 36 cases occurred, when it was raining. The second most injured part of body was the hand (22% of all analysed injuries). It was injured in 19 cases during the rainfall and the number of 15 injuries occurred on the damp surface. Injuries of the head were registered in 16% of all evaluated records. Most of these injuries, as well as the leg and hand injuries, occurred during the rainfall (14 cases) and in the conditions of damp surface (11 cases). The body category includes the cases, when the more parts of body (e.g. the head and leg together) were injured.

From the work injuries analyses in timber harvesting process, which have been made up to now, we can state that the most frequently work injury cause is „insufficiency of personal condition of solid job performance“ (the cause 12), which often can be defined as „a work risk“. In harvesting phase, the work risk as a cause was in 67.45% and in the phase of yarding in 59.04% of all occurred injuries registered (Suchomel, 1999, pp. 335, 340). Without prejudice, it has to be admitted, that causation 12 was most frequently used, or is used (and also abused) as „feasible compromise” providing that it does not concern deadly or serious (grave) work accidents which needs to be thoroughly analysed, investigated and where the impact of the paramount source or work accident cause needs to be defined (Suchomel et al., 2008, p. 68). Considering the bad working conditions (unfavourable weather) it is needs to deduce their evident influence on the risk of work injuries occurrence, regardless of work injury cause. Within the cause 12 the most injuries happened on slippery surface and during the rainfall (Figure 4). These conditions can be considered a „component" of forest ecosystem and therefore we can name the cause 12 as a risk. Within the cause 8 – work without authorisation, against the order, breaking the rules and staying in hazardous area, the most injuries happened during the rainfall, resp. on slippery surface, though their share isn't as striking as the previous case.

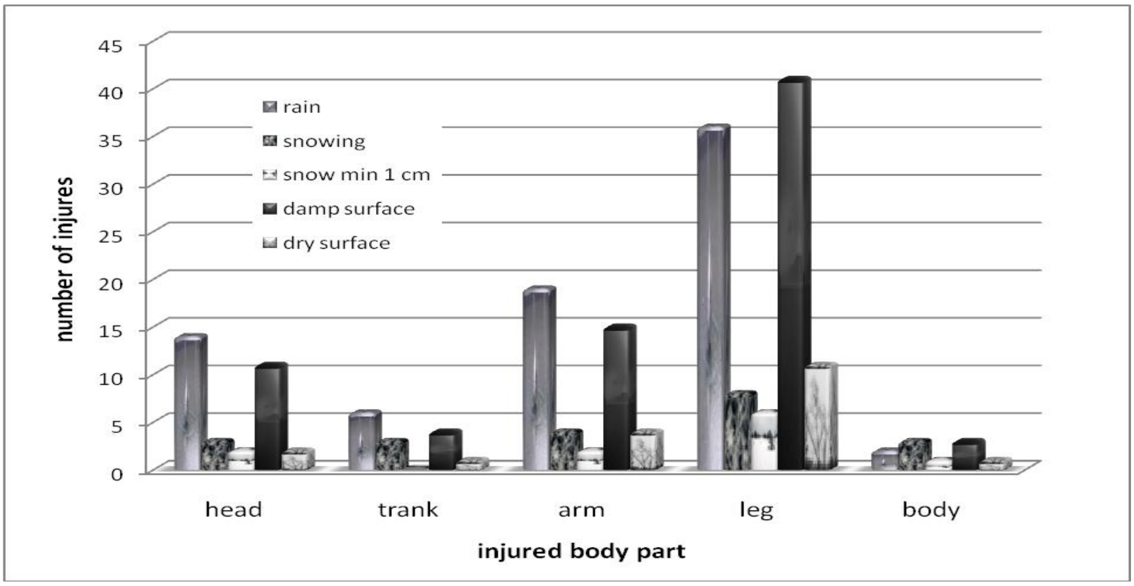

Figure 3: The injured body parts by occurring meteorological phenomenon
Source: own study

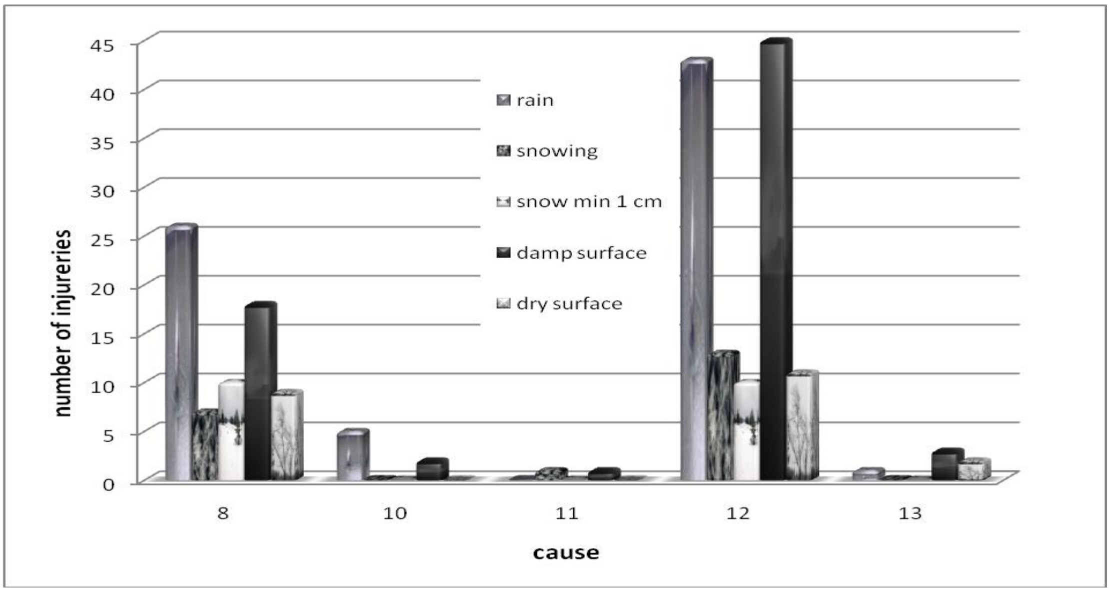

Figure 4: The cause of injury by occurring meteorological phenomenon
Source: own study

To determine the variation dependence (according to the ESAW classification – the variation describes unusual events as for example partial all whole loss of vehicle control or a fall on something or from something) which has caused the work accident and the soil surface condition in the accident occurrence period, the method of contingent tables was used (Table 3).

Table 3: Variation type

Work injuries			
Varian type	**Slippery surface**	**Dry surface**	**Σ**
Material fall, shock	36	12	**48**
	42	6	
Skid, fall, control loss, no coordinated moves	146	14	**160**
	140	20	
Σ	**182**	**26**	**208**

Source: own study

Formulation of the null hypothesis: no relation between the variation type and soil surface condition exist.

$x^2 = 8.91$

Degree of freedom (DF): 1

With the level of significance 5% and the degree of freedom 1 represents the table value chí square 3.8 ($x^2 > x^2_{1(0.05)}$), so we can state that with 95% probability we deny the formulated hypothesis. This argument can be reasoned so, that the variation material factor fall and worker's shock aren't as much dependant on the soil surface condition as slips, workers falls, loss of control, or uncoordinated moves which occur more probably when the soil on which the worker moves along is slippery.

$r_{AB} = 0.207$

Existing relation between variation according to the ESAW classification and the soil surface condition can be on the basis of calculated coefficient $r_{AB} = 0{,}207$ defined as weak.

When using the contingent tables' method it is also possible to evaluate the relation of particular accident source and soil surface condition (Table 4).

Table 4: Specific injury source

Work injuries			
Specific injury source	**Slippery surface**	**Dry surface**	**Σ**
Slip, fall, trunk, branch, saw	149	12	**161**
	141,649	19,35096	
Others	34	13	**47**
	41,35096154	5,64903846	
Σ	**183**	**25**	**208**

Source: own study

Formulation of the null hypothesis: no relation between the specific source of injury and the soil surface condition exist.

x^2 = 14.046
Degree of freedom (DF): = 1

Critical value chí for the degree of freedom 1 and level of relevance α = 5% is $x^2_{1(0.05)}$ = 3.8. Seeing that the calculated value x^2 (14.046) is greater than the table critical value we can state that with 95% reliability we deny the formulated hypothesis. Slip, fall or injury caused by saw, hatchet, stem, branch, vehicle occur with grater probability on slippery terrain than injuries caused by trees, machinery, animals, small chips or sawdust which aren't in so far conditioned on the soil surface condition.

The association coefficient value r_{AB} = 0.26 characterizes the dependency of specific injury source and the soil surface condition as weak.

5. Conclusion

Based on the attained results may be concluded that from the monitored file of 209 work injuries in 190 cases the occurrence of some metrological phenomenon was stated. The most frequent phenomenon was rainfall (36%), in 13 percent of days (27 cases) where a injury occurred dew was stated in that locality, in 24 cases it was snowing and similar in 24 cases of work injuries occurrence snow cover minimally of 1cm was registered.

Fall of person as one of the injury kinds happened during the rain, resp. on the slippery surface in 68% of all cases. Approximately 91% of all injuries happened during unfavourable weather. Legs were the most often injured parts of body and the number of 41 cases registered on the damp surface and the number of 36 cases occurred, when it was raining. Within the cause 12 (a work risk) the most injuries happened on slippery surface and during the rainfall.

There was also statistical analysis carried out. Dependency of specific source of injury, an injury causative variation and the kind of injury on soil surface conditions was analyzed. Dependency of mentioned factors was validated with the significance level 5%.

Suchomel, Slančík (2005, p. 358) evaluate the hazard of timber harvesting, processing and transportation technologies on the base of a frequency analysis of work injuries occurrence. The most occurred flaw of injury records analysis are just the missing parameters about the weather conditions at the time of the work injury.

The new EU strategy for the years 2007 – 2012 has suggested to reduce the total work injuries occurrence rate by 25% in EU-27 by the year 2012 (Komisia európskych spoločenstiev, 2007). Effective tool for work injuries elimination is prevention.

Prevent the work injuries occurrence in timber harvesting process we can mainly the **following measures observance:**

1. *Work and leisure behaviour observance* – the employer is obliged to set the work and leisure behaviour in accordance with the producers' recommendation. Except the allowable physical burden, harmful factors affecting the activity of a worker (exposure time for specific type of mechanization) must be respected the adverse working conditions, mainly unfavorable weather.
2. *Usage of personal protective working equipment (PPWE)* – employer's duty is to ensure PPWE and the duty of employees is to use them and care for them.
3. *Suitable choice of technique and technology* – except the type of technique also its age and technical condition (noise and vibration level) is significant. The selection of appropriate technology is conditioned by many factors and it is important that staff respect to the defined working processes.

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