WOOD RESEARCH
61 (6): 2016
983-992

GRANULOMETRY OF SELECTED WOOD DUST SPECIES OF DUST FROM ORBITAL SANDERS

Iveta Marková
Matej Bel University in Banská Bystrica, Faculty of Natural Sciences
Department of Environmental Management
Banská Bystrica, Slovak Republic

Eva Mračková
Technical University in Zvolen, Faculty of Wood Technology Sciences and Technology, Department of Fire Protection
Zvolen, Slovak Republic

Alena Očkajová
Matej Bel University in Banská Bystrica, Faculty of Natural Sciences
Department of Technique and Technology
Banská Bystrica, Slovak Republic

Juraj Ladomerský
Matej Bel University in Banská Bystrica, Faculty of Natural Sciences
Department of Environmental Management
Banská Bystrica, Slovak Republic

(Received March 2016)

ABSTRACT

Formation and presence of dust in the timber premises is part of the technology. Dust is generated as a byproduct based on the method of machining. The paper deals with granulometric analysis of selected samples of wood dust sessile oak (*Quercus petraea* Liebl.) and from deciduous multiple-pore wood there was chosen European beech (*Fagus sylvatica* L.) and alder (*Alnus glutinosa* L.) and the mixture taken directly from timber production of grinders SCM SANDYA 300RCS) for the purpose of selecting the percentages of the various fractions (0.032; 0.063; 00:08; 0.125; 0.250; 0.5; 1; 2 mm) of samples of wood dust. Wood dust samples were made using a hand orbital sander BOSCH PSS 200AC and sizing on the automatic mesh vibratory sieve machine Retsch AS 200 control. The most frequent percentages of dust particles (between 50-79 %) in all samples of wood dust there were fractions of 32 and less than 32 μm (bottom). The most abundant percentage creates conditions of the risk of inhaling and respirable components contained in the fraction over 32 μm and the potential of formation of a dust-air explosive mixture. Comparison of results granulomertic fractions contribution of wood sanding dust typically processed wood in the furniture industry (beech, oak, spruce, fir, and alder) was significantly confirmed of the particle size.

KEYWORDS: Wood dust, orbital sander, granulometric analysis.

INTRODUCTION

During the mechanical processing of wood (sawing, planing, milling and grinding) large amount of dust and chips is created, which in terms of risk assessment represents a potential risk of fire and damage to the health of employees (Kamal et al. 2015, Borošová et al. 2014). Wood dust formed during the treatment of wood, in particular in grinding, is flammable and can form an explosive mixture with air Zigo et al. (2014), Amyotte (2013). Amyotte and Eckhoff 2010). The wood industry is among the sectors where dust is generated as an undesirable waste (Krentowski 2015) (Top et al. 2016). According the particle size of the wood dust is possible to assume in which form the wood dust occurs in operations.

The fractions with a larger size have tendency to settle (Tureková et al. 2007, Tureková 2008). The number of micro fractions (below 100 microns) evokes the emergence of rough powder form. Such particles are typical especially in sanding wood operation, which is essential technological operations of each wood product prior to its final surface treatment.

Different types of wide-belt sanders, narrow-belt sanders, special sanders and hand sanders (belt, disk, vibration) withvarious ways of extraction are parts mainly in furniture establishments (Očkajova et al. 2014). Modern devices have already a built-in vacuum system, which aim is to remove up wood dust maximally from the operation, but not all operations the latest technology, resulting in the occurrence of dust in a work area. It is similar with the use of hand-held electric sanders, which include a built-in extraction system but its performance is not as effective as a central suction.Amount of emerging dust, the size and the shape of individual dust particles depends on the particle size distribution of the grinding device, on the pressure of the grinding device to grinding material, on the grinding speed, griding material, grinding direction and others.

To assess the behavior of dust from different aspects, such as its ability to separation of different types of separators, his health action, the ability of settling abilities explosions and others, is necessary to know its granulometric composition, what means number or weight number of particle in certain range if its size (Mračková et al. 2016).

In manufacturing process produces almost exclusively polydisperse powders containing particles of different sizes ((Očkajová et al. 2006, Rogozinski et al. 2015, Rohr et al. 2015, Očkajová and Banski 2013).

Degree of crushing of the base material is determined by particle size analysis, which is one of the characteristic ability of powder to produce dispersion system (Mračková et al. 2016). The particles which pass through a sieve of the mesh size and locate on the next smaller sieve of mesh size are added to the fractions with the size range of the given two mesh sizes. Set of particles in each size range is formed by sizing, from where the cumulative grading curve derives with the appropriate procedure (Očkajová et al. 2014). Depending on the size of dust particles it is divided into broad and silk (airborne), its particle size is up 30 μm. Part of airborne dust up the particle size of 5 μm is called respirable dust (Tureková 2008). Their penetration into the airways depends on the size of dust particles. Dust particles with dimensions> 100 μmin the environment quickly settle and do not penetrate into the body (Tureková 2008). Smaller particles with dimensions

<5 μm, so-called respirable fraction tend to remain in the air and in case of inhalation they penetrate into the lungs (Tureková 2008 Aghová 1993, Weinrich and Demers 2005).

The aim of this paper is analysis and comparison of granulometric structure fractions of wood sanding dust from typically processed wood in the furniture industry (beech, oak, spruce, fir, alder) prepared by hand belt grinder (Bosch) and dust mixture (beech, oak, spruce) obtained in furniture establishments, focusing on microfractions (particles with a diameter of ≤ 100 μm) and impact assessment woods and particle size [particle size < 100μm]. Grinding was chosen as the technological process of machining of wood, which assumes increased demand for separation device and fire safety.

MATERIAL AND METHODS

Preparation of wood dust samples

Three folders were prepared for the preparation of wood dust with dimensions (300x50x50 mm) for any wood species that have been dried to a moisture content of about 8 ÷ 10 %. Five wood samples were selected with regard to their most frequent industrial processing and furniture establishments and also well represent coniferous, deciduous and circular-porous deciduous multiple-pore wood. From coniferous wood there were selected spruce (*Picea excelsa*) and fir (*Abies alba*), from deciduous circular-pore wood oak was selected (*Quercus petraea* Liebl.) and deciduous multiple-pore wood European beech was chosen (*Fagus sylvatica* L.) and alder (*Alnus glutinosa* L.). The sixth sample was taken directly from timber production from the premises of grinder (SCM SANDYA 300RCS), powder mixture consists of spruce, beech and oak dust.

Wood dust samples were made using a hand orbital sander BOSCH pss 200ac. Samples were prepared by a specialist in grinding. For the purpose to bring grinding process as close to reality as it is possible, in terms of pressure of the grinding surface of the component, grinding speed and grinding direction (cross). Sandpaper was used with grain size P 80 in experiments (P 80 Norton H231). The dust was collected in a manual extraction equipment pocket of belt sanders, from where it spilled into plastic bags, which were carefully sealed in order not to increase the moisture of obtained dust. About 300 g of dust was obtained from each folder, which was mixed and this prepared sample for all wood species (1 kg) was the basis for the granulometric analysis.

Wood dust samples moisture was determined by gravimetric method (Tab. 1) and then sieve analysis was made on the automatic vibration sieving machine Retsch AS200 control by STN ISO 3310-1: 2007-03 (25 9610). The bag is cleared after each wood dust species by used a vacuum cleaner. Different types of wood dust were divided in nine fractions according to the mesh size sieve on sieving device based on sieve analysis.

Tab.1: Gravimetric determination of wood dust samples moisture.

Kind of dust	Spruce	Oak	Beech	Alder	Fir	Mixture
Moisture (%)	6.4 ± 0.12	6.5 ± 0.14	6.2 ± 0.08	6.4 ± 0.11	6.4 ± 0.14	6.1 ± 0.08

Sieve analysis was carried out on an automated vibratory sieving machine RetschAS200 control; a set of control stainless steel sieves, diameter of sieve 200, height 50 mm, diameter of sieve mesh 0.032; 0.063; 0:08; 0.125; 0.250; 0.5; 1; 2 (mm). Shares of residues on each sieves and bottom were researched using digital laboratory balance Radwag WPS510/C/2 with accuracy of weighing 0.001 grams. Sieving parameters: amplitude 2 mm·g^{-1}, with an interval of 10 s, sieving time 20 minutes.

Measurement process (STN ISO 3310-1: 2007-03)

- Location of sieve stacks on the vibration sieving machines Retsch AS 200c.
- The weighed sample of the grinding dust (30 g) on the laboratory scale and the relocation to the upper sieve of sieve shaker.
- Containment of a set of glass lid, sieving 20 minutes.

After the finishing of sieving on the residues in the sieves and we weighed on the bottom and wrote down into the table. For each sample there were carried out five measurements used for evaluation of average values from 5 measurements.

RESULTS AND DISCUSSION

We evaluated results of the sieve analysis using the distributive curves of selected wood dust samples as well as by one-way analysis of variance to determine whether there is statistical significance of the impact species on the particle size distribution of grinding dust and whether here is a statistical significance of the effect of wood on dust particles proportion less than 100 μm.

By weight and the percentages of the various fractions of selected samples of wood dust after the sieve analysis were evaluated using distributive curves. The percentage sum of obtained values is always less weight compared to samples from the loss during sorting. The obtained distributive curve (Fig. 1) defines the dependence of proportional representation of weight of certain grain sizes (fractions) in the analyzed group of natural ground.

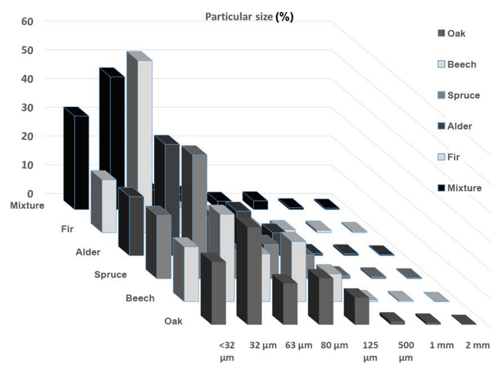

Fig. 1: Distributive granularity curves of selected wood dust samples.

The most abundant fractions in all wood dust sample fractions were 32 μm and less than 32 μm (bottom), which represented in oak samples 55.83 % of the total sample of oak wood dust (Fig. 1). Fractions of 2 and 1 mm (0.99 % of the total weight of the sample) were the least abundant fractions of oak wood dust samples. In a sample of beech wood dust fraction consisted of 32 and 32 μm less than 49.58 % of the whole sample. Least abundant fractions were fractions 2 and 1 mm (0.5 % of the total sample weight of beech wood dust). In the sample of spruce wood dust fraction 32 over 32 μm and formed 65.13 % of the total sample less than spruce and abundant fractions are fractions of 2 and 1 mm (1.01 % of total weight). Fir wood dust sample is represented in 59.27 % fraction formed 32 less than 32 μm from weight of the sample and 0.98 % from weight represent fractions of 2 and 1 mm. Alder wood dust sample has the highest representation in the fraction of 32, less than 32 μm and that o 78.26 % from weight of the entire sample. The least a number of fractions were fractions of 2 and 1 mm, which formed 1.21 % of the total weight compared with the other samples. A wood dust mixture sample copies the frequency of alder wood dust samples, where fractions of 32 less than 32 μm and they formed 78.74 % of the entire sample (Fig. 2a, b).

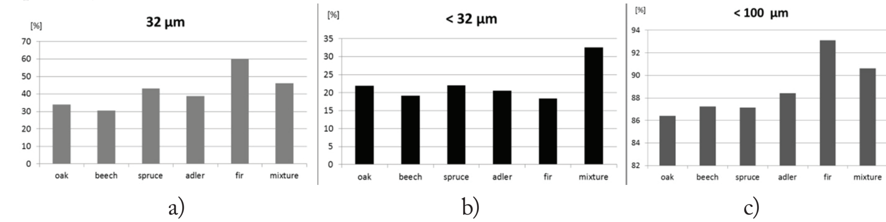

Fig. 2: Mutual comparisons of the frequency of dust particles in selected samples of wood dust samples a) the percentage fraction of 32 μm, and b) the percentage fraction less than 32 μm and c) the percentage of factions less than 100 μm (bottom 32, 0.63, 80 μm).

It is very interesting that in the wood dust samples there were some percentage differences in all the fractions, however, in a percentage comparison of all the fractions of less than 100 μm (bottom, 32, 0,63, 80 μm) there were obtained very similar results for all monitored wood dust in the range from 86.4 to 93.1 %; 86.4 for oak, 87.23 %, for beech 87.13 for spruce, 88.4 % for fir 93.1 for alder and 90.61 % for the mixture (Fig. 2c).

These results correspond with the results (Očkajová and Banski 2013), which studied the quantity of particles under 100 μm in wood dust samples of beech, pine and spruce obtained from narrow-belt grinder in premises. Our research also answered this question that the quantity of particles less than 100 μm are following: 91.95 % for beech (granulity 80), 85.07 % for pine (granulity 80), 95.01 % for spruce (granulity 120) (Očkajová and Banski 2013). Higher values can be caused by wood species, where diffusion of properties depends on growing conditions, from the point of strain, from individual down force of the grinding heel by the operator himself, it is also used other granulity of the grinding agent in spruce, where we have supposal for the formation of finer particles using the grinding equipment with a higher grit number.

Obtained results are also correlated with the authors Očkajová et al. (2014), where they studied beech dust obtained using hand grinders (laboratory experiment), which worked in an embedded system with a constant contact pressure, constant cutting speed and carefully selected timber sample (no bumbs and other wood defects). Percentages part of particles <100 μm 94.28 % was obtained for a hand abrasive-band grinding machine (in grinding a peak on the fibers) and the percentages part of those particles 96.29 % was for the hand-operated circular grinder. These values are higher compared to the values obtained in the real process, which can be justified by the fact that just in laboratory experiments pressure of the grinding equipment may not be optimal elected to the sample surface, speed grinding, grinding model, the cross-grinding was not used (combination of sanding along the fibers and vertically on the fibers) and the results could affect the specific physical and mechanical properties of edged wood. Obtained results were subjected to statistical analysis to evaluate the impact of tree species on the particle size distribution of grinding dust and the impact of tree species on the proportion of dust particles less than 100 μm, using a statistical analysis model (Tab. 2) according to the formula: $x_{ip}=x+a_i+e_{ip}$ where x is the percentage value of abundance in even distribution, ai effect of the its fraction, e_{ip} random variation.

Basic tabular analysis of variance shows that differences between the fractions in the trees are not statistically significant. Division into fractions is not uniform. Percentages proportion of the various wood dust samples is significantly different from size fractions (Fig. 3). In statistics, the number of degrees of freedom is the number of values in the final calculation of a statistic that are free to vary.

Tab. 2: Basic table of diffusion analysis of wood dust samples and their fractions.

	SS Sum of Squares	Degr. of Freedom	MS MeanSquare	F -ratio	p propability
Intercept	6616.1	1	6616.1	265.8	0.000
Fraction granularity	9103.4	8	1137.9	45.7	0.000
Wood species	0.0	5	0.0	0.0	1.000
Error	995.6	40	24.9		

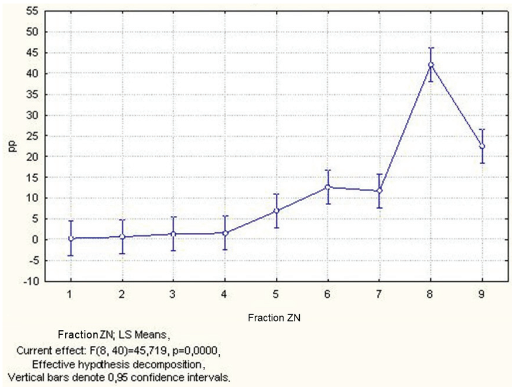

Fig. 3: Statistical dependence of the percentages proportion of individual wood dust samples from size fractions. Legend: name of axix y is pp percentages proportion, name of axis x is "Fraction ZN" and designation of fraction in the picture is followed: 1=2 mm, 2=1 mm, 3= 500 µm, 4=250 µm, 5=125 µm, 6=80 µm, 7=63 µm, 8= 32 µm, 9=› 32 µm.

The Fig. 3 confirms difference statistically insignificant in the first four fractions. Statistically, most of the particles are in fraction 32 µm (8), and in the fraction> 32 µm (9). Statistically significant differences are not in the fractions of 125 µm (5), 80 µm (6), 63 µm (7) and in the first four fractions (2 mm, 1 mm, 500 µm, 250 µm).

Statistical evaluation of the results of sieve analysis shows that statistically the most particles are in fractions of 32 µm, and then in the fraction over 32 µm. Due to excessive dust formation just above fractions, which also include a respirable dust component, the risk of serious danger to the health of employees is increasing. Dustiness in the workplace, due to the formation of wood dust is harmful to the human body (Tureková 2008) and represents one of the fundamental issues of safety and workplace hygiene. Tureková et al. (2007) presents the results of studies dealing with the issue of harmful effects of dust on human health and notes that a small portion of dust is inhaled into the lungs in dust inhalation so called respirable fraction, which consists of particles with dimensions smaller than 5.0 µm. The greater part of the dust is collected in the conducting airways (nose, larynx, tracheobronchial tree). Hygienic aspects presented by the conventions of dust in the dust in terms of STN EN 481 (2011) and US-EPA (Fig. 4) present the character of dust according to its size. The intervention fraction 20-30 µm comes to our attention, where the possibility of inhalation of wood dust is manifested.

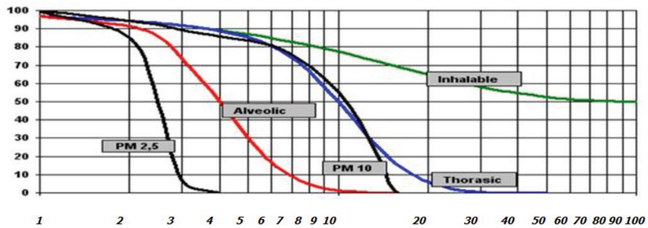

Fig. 4: Comparison of the conventions in the area o fdustiness in terms of STN EN 481 (2011) and US-EPA (Spellman 2016). Legend: values M_{10} and $PM_{2,5}$ represent the dust in μg.m^{-3}, where at least 50 % of the particles are smaller than 10 μm (M_{10}) or than 2.5 μm (M 2.5).

The United States Agency for Environmental Protection (US - EPA) has introduced additional criteria for evaluation of dust, concrete values M_{10}, $PM_{2,5}$ and PM_1 put in μg·m^{-3} M_{10} represents the dustin μg·m^{-3}, where at least 50 % of the particles are smaller than 10 μm (particles with an aerodynamic diameter of 10 mm). Significant percentages proportions of samples fractions of wood dust were obtained (Fig. 2b), which are significantly different, but it cannot be said with certainty that M_{10}, $PM_{2,5}$ and PM_1 are in above fractions.

Obtained results by our experiment that copied the classic premises (pressure of the grinding agent was not expressly intended to the surface of the workpiece, a grinding speed was not designated, grinding direction was not intended and expertise operating the grinder was used in grinding) they did not show statistical significance of influence of timber on the proportion of particles less than 100 μm even generated under the same conditions of grinding (Dzurenda et al. 2010). These claims can be supported by results (Očkajová et al. 2014), where the use of other types of grinders (wide) and similar results were obtained in grinding of various sintered materials. Proportion of particles less than 100 μm 96.16 % was obtained in sanding MDF on the wide belt sander, proportion of particles <100 μm 89.21 % was obtained in grinding DTD on wide belt sander.

Emerging percentages proportions of dust fractions represent an increased risk of explosive dust- air mixtures formation in an enclosed workplace. According to STN 26 007 (STN ISO 3569: 1995-09), based on the size of the particles dust is classified into a very fine powder designed as A D2 (0.07 to 0.40 millimeters), fine dust D1 (0.50 to 3.50 mm), fine-grained dust C (3.60 to 13.0 mm), medium grained B (14.0 to 75.0 mm) and coarse-grained (more than 75.0 mm) and irregularly shaped - fibrous dust particles (Očkajová et al. 2010, Dzurenda and Orlowski 2011). It can be stated for all tested samples that a very fine and fine dust are the dominant components. In terms of the risk of explosion there is given fraction with an optimal fuel and concurrently, the risk of explosion increases with an increase of the very fine dust proportion. The finer dust means the higher maximum explosion pressure and the maximum rate of explosion pressure rise (brisance), and thus the smaller ignition energy is required to initiate dust-air mixture.

CONCLUSIONS

Wood dust is also part of the biomass, which is currently used as an alternative fuel such as renewable energy sources. Experts assess the potential concerns associated with the use of biomass fuels when combusted in terms of health and safety as well as the risk of explosion. Special attention is paid to wood dust and particulate composition. The size of dust particles influences on the behavior of generated dust mixtures in the environment. From the results can be drawn the following conclusions:

- at least abundant fractions of samples of wood dust fractions were 2 and 1 mm, from 0.5 to 1 % of the total weight of the sample,
- percentages proportions of particles 32 over 32 µm represent the values from 49.58 % of the total sample weight of beech wood dust up to 78 % of total weight of alder wood dust sample from the sanding process with orbital sander BOSHpss200AaC,
- percentages proportions of particles less than 100 µm from the automatic vibration sieving machine RetschAS200 control represents the values from 86 to 94 %,
- the most abundant percentages proportion creates premises of the risk of inhaling respirable components contained in the fraction less than 32 µm and potential of dust-air explosive mixture creation.

ACKNOWLEDGMENT

This work was supported by the Scientific Grant Agency of the Ministry of Education, science, research and sport of the Slovak Republic and the Slovak Academy of Sciences project No. VEGA 1-0547-15 „Experimental measurement and modelling of fugitive emissions“ (60 %) and by the Slovak Research and Development Agency under the contract No. APVV-0057-12 (40 %).

REFERENCES

1. Amyotte, P., 2013: An introduction to dust explosions: Understanding the myths and realities of dust explosions for a safer workplace. Elsevier Inc. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-84899749632&partnerID=tZOtx3y1, 280 pp.
2. Amyotte, P.R., Eckhoff, R.K., 2010: Dust explosion causation, prevention and mitigation: An overview. Journal of Chemical Health and Safety 17(1): 15-28.
3. Ághová, Ľ., 1993: Hygiene. Banská Bystrica: Osveta. 1993, 268 pp. ISBN 80-217-0515-9 (in Slovak).
4. Borošová, D., Klöslová, Z., Drimal, M., 2014: Estimating uncertainty and quality of lead determination in human blood. Carpathian Journal of Earth and Environmental Sciences 3(1): 23-30.
5. Dzurenda, L., Orlowski, K.A., 2011: The effect of thermal modification of ash wood on granularity and homogeneity of sawdust in the sawing process on a sash gang saw prw 15-M in view of its technological usefulness. Drewno : Prace Naukowe, Doniesienia, Komunikaty 54: 27-37. Retrieved from http://yadda.icm.edu.pl/yadda/element/-bwmeta1.element.baztech-article-BATA-0015-0031.
6. Dzurenda, L., Orlowski, K., Grzeskiewicz, M., 2010: Effect of thermal modification of oak wood on sawdust granularity. Drvna Industrija 61(2): 89-94.
7. Kamal, A. , Malik, R.N., Martellini, T., Cincinelli, A. 2015: Source, profile, and carcinogenic risk assessment for cohorts occupationally exposed to dust-bound PAHs in Lahore and Rawalpindi cities (Punjab province, Pakistan). Environmental science and pollution research international 22(14): 10580-10591.

8. Krentowski, J., 2015: Disaster of an industrial hall caused by an explosion of wood dust and fire. Engineering Failure Analysis 56: 403-411.
9. Mračková, E., Krišťák, Ľ., Kučerka, M., Gaff, M., Gajtanská, M., 2016: Creation of wood dust during wood processing: Size analysis, dust separation, and occupational health. BioResources 11(1): 209-222, Retrieved November 19, 2015, from https://www.ncsu.edu/bioresources/BioRes_11/BioRes_11_1_209_Mrackova_KKGG_Creation_WoodDust_Size_Health_7987.pdf.
10. Očkajová, A., Banski, A., 2013: Particle size wood sanding dust from the narrow-band grinding machines. Acta Facultatis Xylologiae 55(1): 85-90. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.084878087308&partnerID-=tZOtx3y1 (in Slovak).
11. Očkajová, A., Beljo Lučić, R., Čavlović, A., Tereňová, J., 2006: Reduction of dustiness in sawing wood by universal circular saw. Drvna Industrija 57(3): 119-126. Retrieved from http://www.scopus.com/inward/record.url?eid=2s2.033846633132&partnerID-=tZOtx3y1.
12. Očkajová, A., Stebila, J., Rybakowski, M., Rogozinski, T., Krišták, L., Luptáková, J., 2014: The granularity of dust particles when sanding wood and wood-based materials. Advanced Materials Research 1001: 432-437, http://doi.org/10.4028/-www.scientific.net/AMR.1001.432.
13. Očkajová, A., Beljaková, A., Siklienka, M., 2010: Morphology of dust particles from the sanding process ofthe chosen tree species. Wood Research 55(2): 89-98.
14. Rohr, A.C., Campleman, S.L., Long, C.M., Peterson, M.K., Weatherstone, S., Quick, W., Lewis, A., 2015: Potential occupational exposures and health risks associated with biomass-based power generation. International Journal of Environmental Research and Public Health 12(7): 8542-8605, http://doi.org/10.3390/ijerph120708542.
15. Rogozinski, T., Wilkowski, J., Górski, J., Czarniak, P., Podziewski, P., Szymanowski, K., 2015: Dust creation in CNC drilling of wood composites. BioResources 10(2): 3657-3665.
16. STN 26 0070, 1984: Clasification and symbolization of bulk material transported on conveyor equipment.
17. STN EN 481, 2011: Workplace atmospheres. Size fraction definitions for measurement of airborne particles (in Slovak).
18. STN ISO 3310-1: 2007-03 (25 9610) Test sieves. Technical requirements and testing. Part 1: Test sieves of metal wire cloth (in Slovak).
19. Top, Y., Adanur, H., Öz, M., 2016: Comparison of practices related to occupational health and safety in microscale wood-product enterprises. Safety Science 82: 374-381, http://doi.org/10.1016/j.ssci.2015.10.014.
20. Tureková, I., 2008: Fire resistance properties of the importance of food dust in practice. In: Environmental Management 2008. Žilina: Strix et VeV, 2008, s. 161-166. ISBN 978-80-89281-34-3 (in Slovak).
21. Tureková, I., Slabá, I., Duchoň, M., 2007: Risk assessment of dust in the working environment. In: Occupational safety and health 2007: Proceedings/International conference. VII. year. Ostrava, 12.-13.6.2007. - Ostrava: Association of Fire and Safety Engineering, 2007. - ISBN 978-80-7385-004-3. Pp 321-327(in Slovak). (Hodnotenie rizík prachu v pracovnom prostredí. In: Bezpečnost a ochrana zdraví při práci 2007 : Sborník přednášek / nadát. Mezinárodní konference. VII. ročník. Ostrava, 12.-13.6.2007. - Ostrava: Sdružení požárního a bezpečnostního inženýrství, 2007. - ISBN 978-80-7385-004-3). Pp 321-327 (in Slovak).

22. Weinrich, A. J., Demers, P., 2005: Wood dusts. Encyclopedia of toxicology, second edition. Wexler P, Anderson BD, De Peyster A, Gad SC, eds. San Diego, CA: Academic Press, 2005 Mar. Pp 464-467. Retrieved fromhttp://dx.doi.org/10.1016/B0-12-369400-0/00738-9
23. Zigo, J., Rantuch, P., Balog, K., 2014: Experimental analysis of minimum ignition temperature of dust cloud obtained from thermally modified spruce wood. Advanced Materials Research 919-921: 2057-2060, http://doi.org/10.4028/www.scientific.net-/AMR.919-921.2057.

*Iveta Marková
Matej Bel University in Banská Bystrica
Faculty of Natural Sciences
Department of Environmental Management
Tajovského 40
97401 Banská Bystrica
Slovak Republic
Corresponding author: iveta.markova@umb.sk

Eva Mračková
Technical University in Zvolen
Faculty of Wood Technology Sciences and Technology
Department of Fire Protection
T. G. Masaryka 24
96053 Zvolen
Slovak Republic

Alena Očkajová
Matej Bel University in Banská Bystrica
Faculty of Natural Sciences
Department of Technique and Technology
97401 Banská Bystrica
Slovak Republic

Juraj Ladomerský
Matej Bel University in Banská Bystrica
Faculty of Natural Sciences
Department of Environmental Management
Banská Bystrica
Slovak Republic