EFFECT OF SELECTED FACTORS ON WOOD DUST EMISSION FROM CHAINSAW

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Abstract
Excessive exposure to wood dust can cause serious health problems. The aim of this study was to investigate the influence of the cutter shape and wood species on airborne wood dust concentration during chainsaw cross-cutting operations. Inhalable and respirable wood dust mass concentrations were measured using a real-time aerosol monitor DustTrak DRX. Statistical analysis was based on the Scheirer-Ray-Hare test. The results of this study indicate that both examined factors have a significant influence on respirable fraction of the wood dust mass concentration.

Key words: *wood dust; chainsaw; mass concentration; measurement.*

INTRODUCTION

Chainsaw is power-driven tool designed to cut wood with a saw-chain and consisting of an integrated compact unit of handles, power source, guide bar and saw-chain (*ISO, 2017*). Chainsaw is a source of many significant hazards (e.g. mechanical, thermal, noise, vibration, physical load, exhaust fumes, airborne wood dust). International standards *ISO 11681-1* (*2022*) and *ISO 11681-2* (*2022*) specify the safety requirements and/or measures to eliminate the hazards or reduce risks for chainsaws. A significant body of research exists regarding the exposure of chainsaw operators to noise (e.g. *Neri et al., 2018; Rukat et al., 2020; Huber et al., 2021), vibration (e.g. Kováč et al., 2018; Landekič et al., 2020; Iftime et al., 2022*), and physical load (e.g. *Cheţa et al., 2018; Arman et al., 2021; Grzywiński et al., 2022*). Several studies have been performed to determine carbon monoxide (*Lesczyński, 2014*; *Hooper, Parker & Todoroki, 2017*) and exhaust fumes (*Neri et al., 2016*) concentration within the breathing zone of chainsaw operators and explore simultaneous exposure to exhaust fumes and noise (*Schwarz et al., 2019*).

However, very few published studies have addressed the exposure of chainsaw operators to airborne wood dust. *Horvat et al. (2005)* carried out comparison between measured mass concentration of respirable particles and total dust for sample pairs collected in felling dead standing fir-trees and maximum permissible concentrations for fir-wood. In another study, *Horvat et al. (2007)* reported significant difference between mass concentrations of oak wood respirable particles in winter during the final cut and on thinning in summer, while the difference between mass concentrations of total dust was not so apparent. *Marchi et al. (2017*) found that exposure to wood dust varied widely with different silvicultural treatments, while no significant difference were found for different type of chainsaw fuel. The study (*Marenče, Mihelič & Poje, 2017*) demonstrated that cutting chain selection and proper chain preparation are crucial for achieving high productivity and reducing health risk. *Dimou et al. (2020)* showed that the concentration of inhalable dust is in inverse proportion to the increase in breast height diameter, implying that larger trees generated lower dust amounts.

Factors thought to be influencing the exposure of chainsaw operators to airborne wood dust have been explored only in several studies. Together, these studies outline that exposure of chainsaw operators to airborne wood dust was usually lower than current occupational exposure limits. Nevertheless, several authors highlight that occupational exposure limits are based on epidemiological studies from furniture industry and so it does not reflect the special conditions prevailing in the outdoor workplaces.

To the best of our knowledge, no previous studies have been undertaken to investigate influence of saw chain type and wood density on wood dust emission from chainsaw. The aim of this study is to explore the effect of the cutter shape and wood species on airborne wood dust concentration during chainsaw cross-cutting operations.

MATERIALS AND METHODS

The experiment was designed as two-factor full factorial experiment involving two levels of cutter shape and two levels of wood species. Each treatment was replicated five times so that the total number of runs was 20. The layout of experimental setup is shown in Fig. 1. In order to investigate the influence of aforementioned factors on the dust emission formation, cross-cutting experiments were carried using factory-fresh cordless chainsaw (MSA 220 C, Andreas Stihl AG & Co. KG, Weiblingen, Germany) with lithium-ion battery (Stihl AP 300 S). Battery was charged by hi-speed charger (Stihl AL 500). The chainsaw was equipped with a 35 cm length guide bar (Stihl Rollomatic E) as specified by machine manufacturer. A single individual, experienced in the use of the chainsaw, performed cross-cutting operations.
The saw chains under study were full chisel chain (Stihl Picco Super 3) and semi-chisel chain (Stihl Picco Micro 3). To avoid any effects on dust measurements due to the condition of the saw chain, only a chains originally sharpened by manufacturer were used for each test cycle. The saw chains were lubricated with chain oil (Stihl BioPlus) and tensioned according to manufacturer's recommendations.

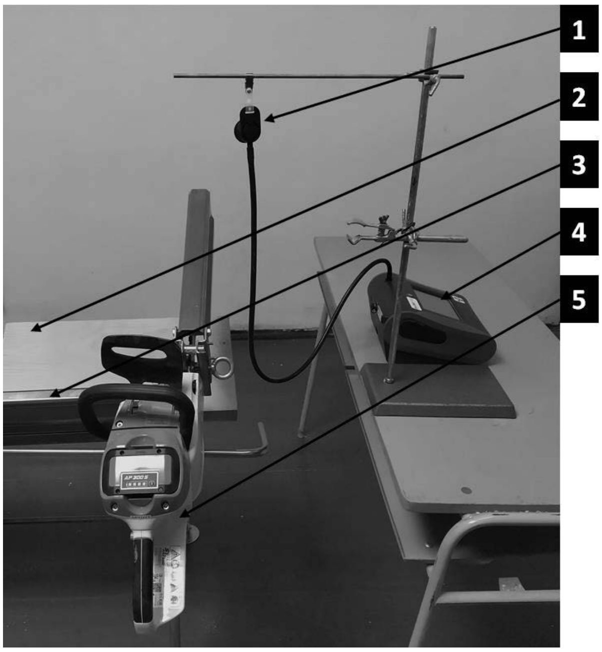

Fig. 1 Layout of experimental setup: 1- sampler, 2 - specimen, 3 - sawhorse, 4 - monitor, 5 - chainsaw

The tree species under the study were beech *(Fagus sylvatica L.)* and spruce *(Picea Abies (L.) H. Karst)*. Test specimens in the form of planks of 500 mm × 250 mm × 50 mm in dimension were conditioned to a final moisture content of 12% before experimentation. The sawhorse with chainsaw holder (Magg 120009, PHT a.s., Praque, Czech Republic) was used for clamping the test specimens.
Inhalable and respirable wood dust mass concentrations were measured using a desktop aerosol monitor (DustTrak 8533 DRX, TSI Inc., Shoreview, MN, USA). Real-time monitor measured and recorded wood dust mass concentration every second. Before each sampling event, the zero offset calibration was performed with HEPA filter, as recommended by the manufacturer. Plastic IOM sampler (IOM Multi-dust sampler, SKC Inc., Eighty-four, PA, USA) was connected to monitor inlet using conductive tubing. Fixed-point sampling was employing, the sampler was positioned at breathing zone of operator. Each sampling event lasted 5 minutes.
The temperature and relative ambient humidity was monitored using microclimatic conditions monitor (Testo 480, Testo SE & Co., Titisee-Neustadt, Germany). All tests were conducted at ambient temperature of 20 °C ± 1°C and at relative ambient humidity of 36 % ± 1 %.
In this study, data normality was tested by Shapiro-Wilk test. The Scheirer-Ray-Hare test was used to assess effects of cutter shape and wood species on airborne wood dust mass concentration. All statistical analyses were performed using a Microsoft Excel freeware add-on Real Statistics.

RESULTS AND DISCUSSION

Fig. 2 shows an example of the temporal variations in aerosol monitor response with time for generated beech dust during cross-cutting.

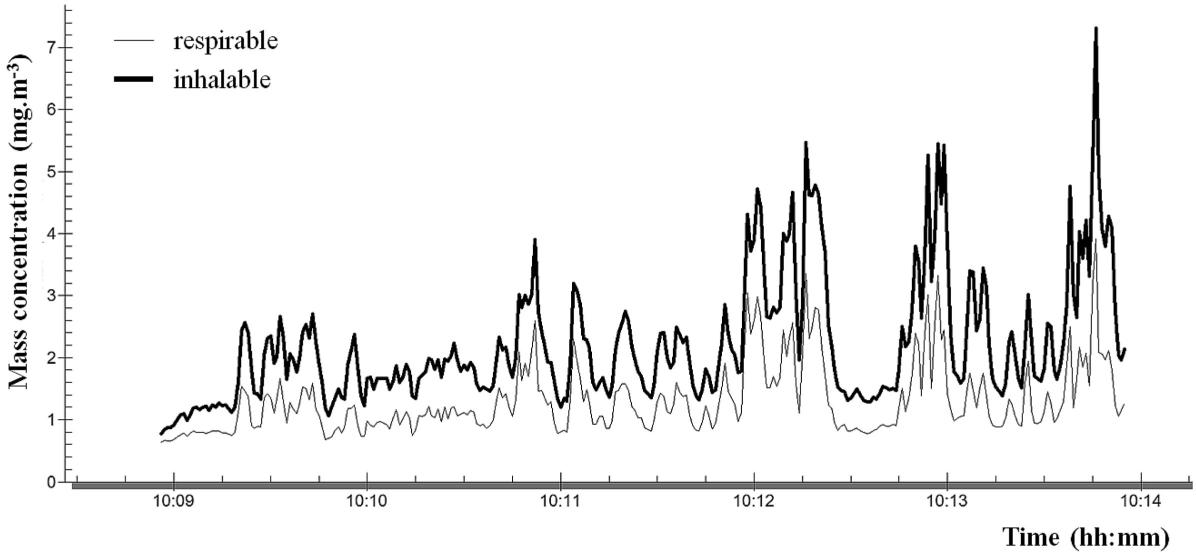

Fig. 2 Temporal variations in aerosol monitor response during cross-cutting of beech wood with semi-chisel cutter

Influence of the cutter shape and type of wood on the mass concentration of airborne dust particles emitted by chainsaw is shown in Fig. 3 and Tab.1

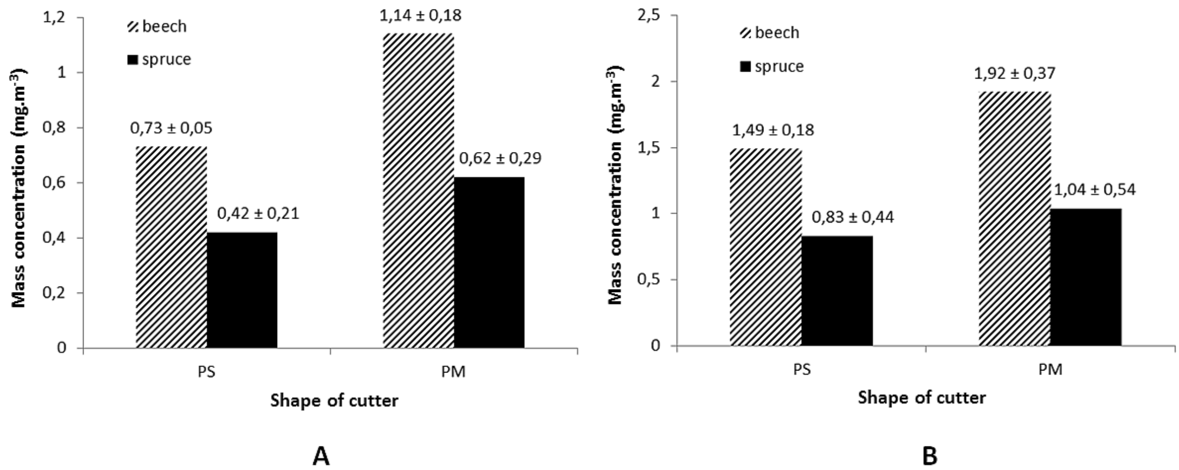

Fig. 3 Effect of cutter shape (PS - full chisel, PM - semi-chisel) and wood species on the mass concentration (arithmetic mean ± standard deviation, n=5): A – respirable fraction, B – inhalable fraction

In a case of respirable fraction, the highest average mass concentration of 1.14 mg.m^{-3} was realized using treatment beech wood and semi-chisel profile of cutter. On the other side, the minimum average mass concentration of 0.42 mg.m^{-3} was measured using treatment full chisel profile of cutter and spruce wood.

In a case of inhalable fraction, the highest average mass concentration of 1.92 mg.m^{-3} was realized using treatment beech wood and semi-chisel profile of cutter. On the other side, the minimum average mass concentration of 0.83 mg.m^{-3} was measured using treatment full chisel profile of cutter and spruce wood.

Tab. 1 Summary of the Scheirer-Ray-Hare test results. The test was performed to detect the effect of factors Wood species and Cutter shape on wood dust mass concentrations. Meaning of statistical variables: *H* refers to the value of the Scheirer-Ray-Hare test; $P < 0.05$ represents significant differences, while $P > 0.05$ represents no significant differences.

Variable	Factor	***H* statistics**	***P-value***	**Sign.**
Respirable fraction	Wood species	7.405	0.006	Yes
	Cutter shape	4.805	0.028	Yes
	Wood species x Cutter shape	0.205	0.650	No
Inhalable fraction	Wood species	8.691	0.003	Yes
	Cutter shape	1.462	0.226	No
	Wood species x Cutter shape	0.205	0.650	No

Currently there is no specific standardized procedure for measurement the dust concentration produced by chainsaw. Real-time inhalable and respirable dust measurements in breathing zone of chainsaw's operator were used to investigate the influence of the cutter shape and wood species on airborne wood dust concentration during chainsaw cross-cutting operations.

Comparing results of airborne wood dust concentration evaluation from different experimental setups and field measurements reported in literature is very difficult. However, results of this study are consistent with results reported by several authors (*Horvat et al., 2005*; *Horvat et al., 2007*; *Marchi et al., 2017*; *Dimou et al., 2020*) in that hardwoods (angiosperms) generated higher dust concentrations than softwoods (coniferous).

Several limitations to this study need to be considered. We did not determine size and photometric calibration factors for the aerosol monitor. The DustTrak DRX monitor is factory calibrated to the respirable fraction of standard ISO 1210-1, A1 test dust. We assumed that the optical properties of beech and spruce wood aerosols are not diametrically different. Intention of this study was to investigate if there is any difference between different settings rather than to determine real occupational exposure to airborne wood dust. For this reason, it was sufficient to know relative mass concentration values. Thus we performed only zero calibration procedure for compensation of zero drift. Reported values of inhalable wood dust are underestimated due to limitation in the size range of DustTrak DRX. Feed force exerted during cross-cutting may have an effect on mass concentration and size distribution of emitted airborne wood dust. Design of the study did not allow to control the feed force. However, all the cross-cutting trials were performed by the same person using the least possible feed force to make experiments in a repeatable way. A minor limitation of this study can be considered in connection with use of safety enclosure. Safety enclosure as a part of sawhorse reduced amount of airborne dust wood which has been emitted to breathing zone of operator.

CONCLUSIONS

This paper investigated the formation of airborne wood dust emissions depending on cutter shape a wood species. Based on experimental results, the following findings are concluded for the specific case:

- In a case of respirable fraction, both the cutter shape and wood species significantly influence airborne wood dust mass concentration. For semi-chisel shaped cutter it was observed higher values of airborne wood dust mass concentrations than for cutting using full chisel chain. For cross-cutting of beech wood it was observed higher values of airborne wood dust mass concentrations than for spruce wood.
- In a case of inhalable fraction, only a type of wood significantly influences airborne wood dust mass concentration. Similarly, for cross-cutting of beech wood it was observed higher values of airborne wood dust mass concentrations than for spruce wood.

In order to extend this approach in future research, different wood species and cutter shapes should be considered. Based on further experiments with these different settings, the impact of the settings on the generation of airborne wood dust emissions can be verified and described more generally.

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