Comparison of Gravimetric and Photometric Methods in Determining Low Mass Concentrations of Airborne Wood Dust

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The sensitivity of an optical device was evaluated when determining the mass concentration of inhalable wood dust under conditions where workers' exposure was below 0.25 mg/m³. Samples were collected during the processing of oak wood using a belt sander (BS) and thermally modified (TM) ash wood using a four-sided planer (4SP). The Split2 (SKC) optical device, operated in active mode, consists of an optical sensor and an inlet component with an Institute of Occupational Medicine (IOM) filter holder for inhalable dust. Gravimetric determination of respirable and inhalable dust mass concentrations was performed using a Higgins-Dewell respirable dust cyclone and an IOM inhalable dust sampler. Measured exposure levels for the inhalable fraction near the BS and 4SP machines ranged from 0.02 to 0.219 mg/m³ (N = 18). The Split2 optical device significantly overestimated the inhalable dust concentration during the belt sanding operation ($p = 0.02$). This overestimation may be related to the high average proportion of the respirable fraction (70.3%). However, no statistically significant overestimation was found for the four-sided planer operation ($p = 0.13$). Based on the ratio of gravimetric to photometric mass concentrations, two specific photometric correction factors are recommended for the Split2 optical device under these specific working conditions: 0.24 for the belt sander and 0.48 for the four-sided planer.

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INTRODUCTION

Hardwood dust is classified as a carcinogenic substance according to Directive (EU) 2017/2398 on the protection of workers from the risks related to exposure to carcinogens or mutagens. The Directive prescribes an occupational exposure limit value of 2 mg/m^3, which refers to the mass concentration of the inhalable dust fraction measured or calculated over an 8-hour reference period. Despite the fact that the gravimetric method remains the foundational reference technique, and that the measurement setup and sampling conventions must comply with HRN EN 481 (1993), many authors have evaluated the applicability of photometric determination of aerosol mass concentration (Koch *et al*. 2002; Thorp and Walsh 2007; Proto *et al*. 2010; Sousan *et al*. 2016; Halterman *et al*. 2018; Zhang *et al*. 2023; Özdemir and Albayrak 2024; Gül and Korkmaz 2025). When utilizing these methods, special attention must be paid to the influence of particles size on the sensitivity, and consequently the reliability of the optical direct-reading devices. The physical properties of the aerosol (including particle size, density, refractive indexes and light-scattering characteristics, morphology, and moisture content) can vary widely. These variations are determined by the wood species, the type of working machine, parameters of the wood processing kinematics, the suction system efficiency, and seasonal microclimate fluctuation (air temperature, relative humidity, and air flow velocity) within the working environment (Thomas and Gerbhart 1994; Lanki *et al*. 2002; O'Shaughnessy and Slagley 2002; Tatum *et al.* 2002; Dado *et al*. 2017; Moazami *et al*. 2023). Previous studies on workplace dust exposure have shown that the type of wood processing machine has a significantly greater influence on mass concentrations than wood species or exhaust quality (Kos *et al.* 2004). The shape of the airborne wood particles generally can be decribed as fibrous; that is, the ratio of the length to the width of the particle is greater than 3 (Beljo Lučić *et al*. 2005). The precision of an optical device is significantly affected by the prevailing particle size, and at relatively low dust concentrations, they are predominantly fine particles of respirable fraction. Due to the different responses of optical devices to varying physical properties of dust, photometric response increases as aerodynamic particle diameter decreases (Thorp 2007; Moazami *et al*. 2023). For particles with an aerodynamic diameter under 10 µm, the photometric response has been shown to equal that of the reference Institute of Occupational Medicine (IOM) sampler, resulting in a photometric correction factor of approximately 1 (NIOSH 1998; Rando *et al*. 2005a). However, other results have shown that optical devices significantly underestimate the inhalable mass concentration and overestimate the respirable dust concentration (Thorp 2007; Moazami *et al.* 2023). According to EN 481 (1993), the respirable fraction has a median aerodynamic diameter of 4.25 µm with a geometric standard deviation of 1.5. This also means that particles smaller than 4 microns will not be deposited in the inhalable zone even though they are included in that fraction because they will pass into the respirable zone (Jiménez *et al*. 2011). The share of respirable mass concentration in inhalable dust mass concentration (c_r / c_{inh}) or in total dust (c_r / c_{tot}) depends on numerous factors influencing particle formation. As a rule, both the share (c_r / c_{inh}) and (c_r / c_{tot}) fractions increase as overall dustiness decreases (Sass-Kortsak *et al*. 1986; Muranko *et al*. 2001; Kos *et al*. 2004; Noto *et al*. 2016; Čavlović *et al*. 2022).

Generally, the optical device should always be compared to a reference gravimetric sampler for an accurate measure of airborne dust particle concentration by determining the average photometric correction factor (Thorpe and Walsh 2013). The complexity of using photometry to determine the mass concentration of wood dust across different wood species is reflected in the wide range of correction factors of the Split2 optical device, from 1.0 for wet fir wood to 4.4 for dry oak wood (Čavlović *et al*. 2009). Baltrėnas and Kvasauskas (2005), using the Microdust Pro optical method at an airflow rate of 2.0 L/min, were found to overestimate wood dust mass concentrations by 2.9% compared to the reference gravimetric method within the concentration range of 60 to 66 mg/m³. Furthermore, due to the increased splitting tendency and brittleness of TM wood, as well as its degraded mechanical properties, the woodworking machines do not require as high a feed force as is the case with untreated wood (Hlásková *et al.* 2021). The thermal degradation of hydrophilic groups in hemicellulose enhances dimensional stability, but it weakens the cell wall matrix, resulting in a higher chipping (*i.e.,* an increased tendency of the material to fracture and splinter into small pieces) during machining compared to untreated hardwood.

In previous research, worker exposure to respirable and inhalable wood dust, as well as the photometric response of optical device in relation to the gravimetric method, mainly was determined under conditions where inhalable wood dust mass concentrations exceeded 1 mg/m³. The partial novelty compared to previous research is the evaluation of the Split2 optical device at inhalable dust concentrations below 0.25 mg/m³. Investigating direct-reading instruments under these increasingly clean workplace conditions has significant practical value for modern occupational hygiene monitoring. The aim of this research is to determine the characteristics of these two wood dust monitoring methods, determine the photometric correction factors of direct-reading optical devices, and quantify the proportion of respirable particles within the inhalable mass concentration (c_r / c_{inh}) as a possible influence on the sensitivity of the optical sensor. Specifically, this study aims to determine the extent to which optical device underestimate or overestimate airborne mass concentrations relative to the reference gravimetric method within low-exposure (0.25 mg/m^3) occupational environments.

EXPERIMENTAL

Materials

Wood dust samples were collected in a production plant during the processing of oak wood (*Quercus robur* L.) with a belt sander (BS) (Costa Levigatrici S.p.A, Schio, Italy) and TM ash wood (*Fraxinus angustifolia*) with a four-sided planer (4SP) (Weinig, Tauberbischofsheim, Germany). Both machines were connected to a central suction system. The TM ash wood was obtained by initial drying at 35 to 60 °C until reaching an 8% to 10% moisture content. This was followed by heating the wood at a rate of 4 °C per hour, a heat treatment at 203 to 210 °C for 5 h, resulting in a total heating process duration of 53 h, and subsequent gradual cooling at a rate of 7 °C per hour until reaching 70 to 80 °C over a period of 23 h.

During an 8-hour work shift, 374 solid oak wood panels, measuring 3230 mm x 660 mm with a total area of 608.2 m^2, were sanded at a feed speed of 12 m/min, utilizing 80-grit followed by 120-grit sandpaper. At a feed speed of 19 m/min, profiles were milled on the edges of 1560 TM ash wood elements measuring 2750 mm x 125 mm x 24 mm, with a total volume of 11.8 m^3.

Methods

Gravimetric determination of wood dust mass concentration

The mass concentrations of respirable and inhalable wood dust from production plant ambient air were determined gravimetrically using personal sampling pumps equipped with two types of filter holders: a Higgins-Dewell respirable dust cyclone (Casella, Bedford, UK) and an IOM inhalable dust sampler (SKC Ltd., Dorset, UK). Wood dust sampling was in accordance with the European standards for measuring airborne particles as specified in EN 481 (1993) and CEN/TR 15230 (2005). When a mixture of multi-sized airborne particles is inhaled, larger particles settle in the upper respiratory tract (inhalable fraction), whereas smaller particles penetrate deeper into the respiratory system through the tracheobronchial zone to the alveoli (respirable fraction). Specifically, the inhalable fraction represents the mass fraction of total airborne particles inhaled through the nose and mouth, while the respirable (or alveolar) fraction is the mass fraction of inhaled particles that reach the alveoli.

Sampling was conducted daily on a single machine per shift using 14 Casella Apex personal pumps to simultaneously collect nine inhalable and five respirable wood dust fraction samples (Table 1). The flow rate was set to 2.0 L/min for the IOM inhalable dust samplers and 2.2 L/min for the respirable dust cyclones. Because of the sensitivity of the integrated optical device, the entire measuring assembly, including the personal sampling pump and the filter holder, was arranged in a fixed, stationary position. The use of personal samplers for stationary collection was performed in accordance with CEN/TR 15230 (2005). The sampling equipment was arranged in fixed stationary positions within the workers' breathing zone, placed on a tripod at a height of 1.5 meters and located exactly 1 meter from the processing machinery sources, where the operators stood during their work shifts. This setup allowed for the representative measurement of workplace airborne concentrations directly affecting the workers. Whatman 25-mm quartz filters (QM-A) were conditioned in the desiccator at 20 ± 1 °C and 47.5 ± 2.5% relative humidity for 24 h both before and after the sampling. Before weighing, electrostatic charges were discharged from each filter using a Mettler Toledo U-electrode. Weighing was performed using a Mettler-Toledo MX-5 microbalance (Mettler-Toledo International Inc., Greifensee, Switzerland) with a readability of 1 μg (10^{-6} g). The mass concentration of wood dust was determined gravimetrically in accordance with the ZH 1/120.41 (1989) standard.

Photometric determination of wood dust mass concentration

Continuous measurement of airborne particle mass concentration was performed photometrically using a Split2 real-time aerosol optical device (SKC Ltd., Dorset, UK, 2006). The instrument includes a data processing unit with a digital display, and an entry inlet part containing an IOM inhalable dust sampler with an integrated optical sensor. The optical part of the optical device uses an infrared light source located at an angle of 90° relative to the photodetector. The optical device was connected to a Casella sampling pump (Bedford, UK), and set to an air flow of 2.0 L/min. The sampled air passes through the photometric optical sensor and then through the gravimetric filter holder (Fig. 1).

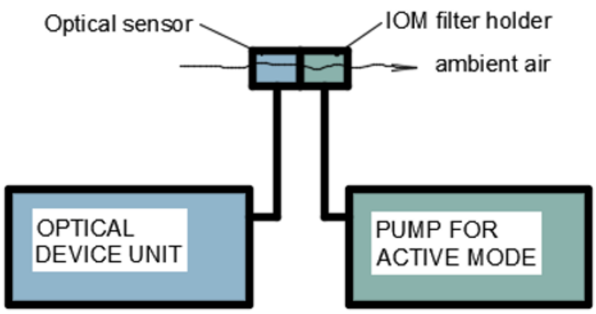

Fig. 1. Optical device connected to the sampling pump and the IOM filter holder

Continuous measurement of the mass concentration was conducted in accordance with the National Institute for Occupational Safety and Health (NIOSH) Method 0600 (1998), described in the *Manual of Analytical Methods* (NMAM).

The optical device uses the principle of near-forward light scattering of infrared radiation to provide immediate, real-time measurement of airborne dust concentration in mg/m^3. As particles pass through the optical path between the lenses, light scattering changes the intensity reaching the photodetector, generating an output signal proportional to the mass concentration of the suspended particles in the occupational environment. The mass concentration displayed by the optical device is calculated as a Time-Weighted Average (TWA) rather than a simple arithmetic mean, thus accounting for the precise duration of each detected airborne concentration at the monitored workplace. The internal software multiplies each measured concentration by its duration, sums these values, and divides by the total measurement time. The Split2 optical device was set to record the mass concentration every second, continuously during the work shift. Consequently, this calculation provides an accurate representation of occupational exposure over the operational period or an entire 8-hour work shift. The intention of this study was to continuously operate the optical device simultaneously during stationary breathing zone sampling of the respirable and inhalable fractions using the gravimetric method. During an 8-hour shift, sampling of the respirable and inhalable fractions with the gravimetric method was combined with three photometric measurements for the BS and two for the 4SP.

Calculation of the limit of detection

Because the use of a blank was difficult due to the small masses of the samples, the mass limit of detection (LOD) was obtained from the standard deviation (s_m) of the three lowest masses (m_{min}) from a few samples within the group of samples collected from the same woodworking place. The limit of detection was calculated as three times the value of that standard deviation (HRN CEN/TR 15230).

Statistical analysis

The geometric mean, as a better indicator of wood dust emission than arithmetic mean, was chosen to show the average value of the mass concentration. Statistical differences in mass concentrations between samples collected by different methods, different filter holders, or near different working places were tested using Student's t-test. The Mann-Whithey U-test was used when the condition of homogeneity of variance was not fulfilled. Pearson's correlation analysis was performed using Excel 2021. Descriptive statistics of variables and statistical analyses were conducted using the statistical software STATISTICA 14.0.0.15.

RESULTS AND DISCUSSION

Very low worker exposure to inhalable wood dust, and consequently to the respirable fraction, was measured near the BS processing oak wood and the 4SP processing TM ash wood. The highest measured mass concentration of inhalable dust was 0.219 mg/m^3 during processing of oak wood on the BS in the wood panel production plant. The geometric mean was 0.054 mg/m^3 for all mass concentrations of the respirable fraction (N = 9), and 0.077 mg/m^3 for of all mass concentrations of inhalable dust (N = 18) obtained by the gravimetric method. The share of the mass concentration of the respirable fraction in the mass concentration of inhalable dust averaged 70.3% (Table 1), which may have a significant impact on the sensitivity of an optical device.

Table 1. The Share of Respirable (c_r) in Inhalable Mass Concentration (c_{inh})

Type of Working Machine / Wood Species	Type of Filter Holder	*N*	Mass Concentration			The Share c_r / c_{inh}
			Geometric Mean	Minimum	Maximum	
			(mg/m^3)			(%)
Belt Sander / Oak wood	R	5	0.050	0.031	0.109	58.6
	I	9	0.085	0.032	0.219	
Four-sided Planer / TM Ash Wood	R	4	0.058	0.038	0.088	85.9
	I	9	0.068	0.020	0.164	

The mass limit of detection calculated for respirable samples was 0.009 mg, and for inhalable samples, it was 0.018 mg. All sample masses were higher than the LOD values, except for one sample of the respirable fraction, which was removed from the calculation. Exposure levels for the inhalable fraction next to the BS and 4SP ranged from 0.02 to 0.219 mg/m^3. All mass concentrations of inhalable dust were far below the limit value of 2 mg/m^3, which is the prescribed limit of exposure to increased risk.

Statistical testing using the Student's t-test showed that the two groups of mass concentrations of the respirable fraction next to the BS and 4SP did not statistically differ ($p = 0.72$), as well as the mass concentration of the inhalable fraction ($p = 0.49$). The mass concentrations of the two different particle fractions collected next to the BS or next to the 4SP also do not differ statistically significantly ($p = 0.15$ and $p = 0.44$, respectively) (Table 2). With this in mind, the combined respirable and inhalable mass concentrations were tested for both machines, and neither of these two groups of data were significantly different ($p = 0.09$) (Table 3).

Table 2. Comparison of Respirable (c_r) and Inhalable Mass Concentration (c_{inh}) Between Two Types of Woodworking Machines

Samples Group		Standard Deviation (mg/m^3)	Homogeneity of Variances Test		Student's t-test
			F	p	p
R	BS	0.031	1.522	p > 0.05	0.72
	4SP	0.025			
I	BS	0.061	1.627		0.49
	4SP	0.048			
BS	R	-	3.785		0.15
	I				
4SP	R	-	3.540		0.44
	I				

Table 3. Comparison of Respirable (c_r) and Inhalable Mass Concentration (c_{inh}) for both Woodworking machines

BS and 4SP	N	Mass Concentration*	Standard Deviation	Homogeneity of Variances Test		t-test
		(mg/m^3)		F	p	p
I	18	0.092	0.054	3.896	p > 0.05	0.09
R	9	0.058	0.027			

* Arithmetic means

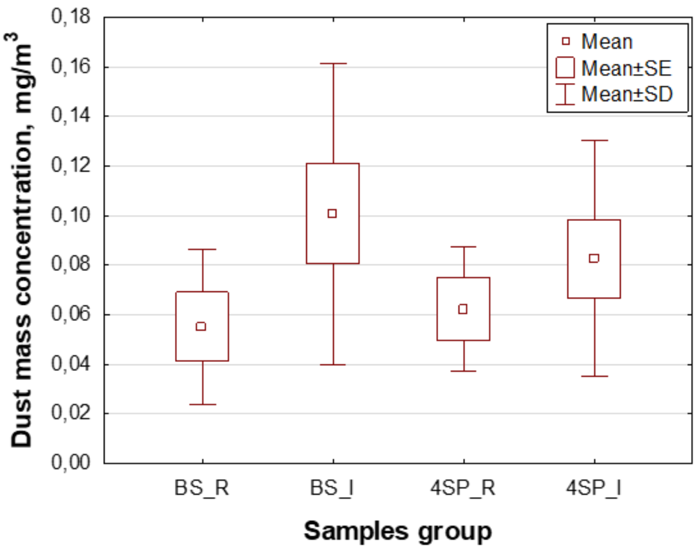

Fig. 2. Distribution diagram of geometric mean values and data variability of inhalable and respirable mass concentrations obtained gravimetrically (SD: standard deviation, SE: standard error of the mean)

The distribution diagram in Fig. 2 shows considerable data variability in the mass concentration data of respirable and inhalable particles obtained near the BS and 4SP, which explains why the concentrations do not differ significantly.

Correlation analysis between respirable and inhalable mass concentrations was performed on the combined dataset from both machines. The mass concentration of the respirable fraction increased with an increase in the mass concentration of inhalable dust (Fig. 3). Pearson's correlation test of all measured mass concentration values for respirable and inhalable dust obtained by the gravimetric method showed a moderate, significant positive correlation ($r = 0.62$; $p = 0.011$). For such low dustiness in the working environment, the share of the respirable fraction in the inhalable dust mass concentration decreased as the inhalable mass concentration increased, indicating a moderate, significant negative correlation ($r = -0.62$; $p = 0.011$).

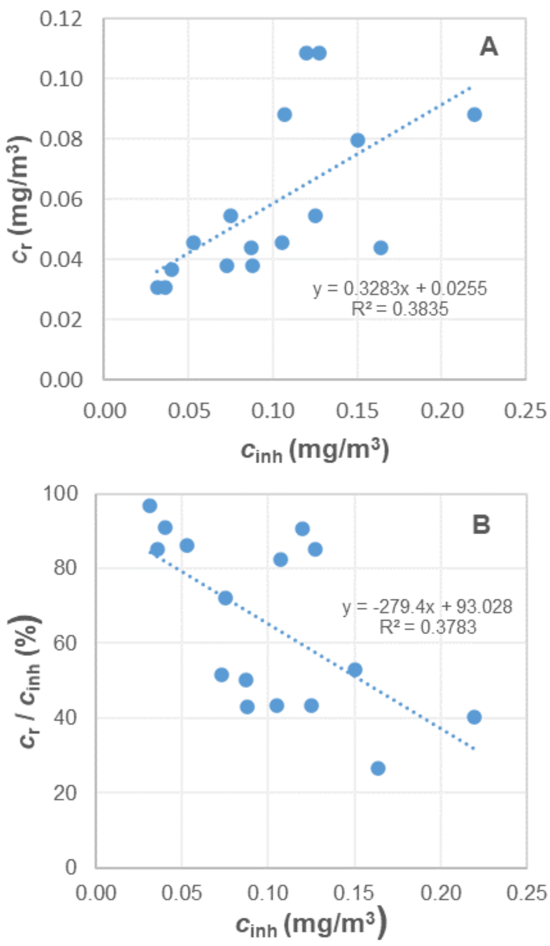

Fig. 3. Correlation between respirable and inhalable mass concentrations (A), and between the share of the respirable fraction in inhalable wood dust mass concentration and the total inhalable mass concentration (B)

Kos *et al*. (2004) also found that when the total wood dust concentration was very low (below 1 or 2 mg/m³), the share (c_r / c_{tot}) exceeded 50%, especially when cutting parameters results in the creation of very fine particles. When determining occupational exposure to oak wood dust in a furniture factory, the share (c_r / c_{inh}) next to a new Computer Numerical Control (CNC) machine was 31%, with a geometric mean inhalable dust mass concentration of 0.22 mg/m³. In contrast, next to a CNC machine without local exhaust ventilation, this proportion was 12% with a mean inhalable dust mass concentration of 1.817 mg/m³ (Čavlović *et al*. 2022).

A large study in US wood processing plants showed that respirable dust accounted for an average of 16.7% of the total inhalable dust. Across all facilities, the geometric mean exposure levels were 1.44 mg/m³ for the inhalable fraction and 0.18 mg/m³ for the respirable fraction (Kalliny *et al*. 2008). In the Polish furniture industry, machine sanding generates fine dust with a respirable fraction of 25% to 31% in inhalable dust, with inhalable concentrations ranging from 1.5 mg/m³ to 3.7 mg/m³ and respirable concentrations between 0.24 mg/m³ and 1.34 mg/m³. Conversely, operations like cutting and milling result in a lower respirable proportion (below 15%) but higher inhalable concentrations, ranging from 5.0 mg/m³ to over 22.0 mg/m³, with the respirable fraction ranging from approximately 0.4 mg/m³ to 4.0 mg/m³ (Szewczyńska and Pośniak 2017).

Granulometric analysis showed greater fragmentation of TM wood (ash, oak, and pine) compared to untreated wood. This is primarily due to increased brittleness, lower density, and the thermal degradation of hemicellulose during modification. Consequently, the TM material crumbles easily instead of being cleanly cut. However, these fine particles also show a stronger tendency to stick together (agglomerate), which affects how they remain suspended and settle in the air (Barcik *et al*. 2019; Krauss *et al*. 2020; Pędzik *et al*. 2021). Similarly, Hlásková *et al.* (2015) found that sawdust from TM wood contains a higher number of particles with characteristic sizes below 4 µm and 10 µm. In a study quantifying the finest particle fractions generated during the sanding of untreated and TM beech wood, Majka *et al*. (2022) found that both dust types exhibited similar particle size distributions. Specifically, when using narrow belt or handheld sanders on beech wood, this fine fraction (≤ 0.08 mm) can exceed 90% of the generated dust mass (Očkajová *et al*. 2018). Focusing on TM wood, their study confirms the influence of modification temperature on the granularity of TM oak, with changes in the grinding properties starting at 160 ºC. At the temperatures of modification of 200 and 220 ºC, the proportion of the finest dust (≤ 0.08 mm) reaches 2.99% at a feed rate after longitudinal milling of 10 m/min¹ (Očkajová *et al*. 2020).

A study by Pędzik *et al*. (2021) determined the finest particle content in the dust created by machine sanding of six types of hardwood. Laser diffraction analysis specified that the average share of particles smaller than 2.5 µm makes up less than 1.9% of the total mass of dust. Furthermore, there was no statistical difference in the average particle size between ash wood and oak wood dust.

There was no statistically significant difference ($p = 0.39$) found between the photometric mass concentrations (TWA) obtained during oak wood sanding and those obtained during TM ash wood profiling (Tables 4 and 5). Inhalable mass concentrations obtained by gravimetric and photometric methods were also statistically compared (Table 6). The mass concentrations obtained by these different methods differed significantly near the BS ($p = 0.02$), while the measured concentrations near the 4SP did not differ significantly ($p = 0.13$). For the data pairs near the belt sander (BS), the assumption of homogeneity of variances was not met ($p < 0.05$). Therefore, a Mann-Whitney U-test was used to ensure an accurate statistical comparison.

Table 4. Inhalable Mass Concentration (c_{inh}) Determined Photometrically

Type of Working Machine / Wood Species	N	Mass Concentration			
		TWA	Minimum	Maximum	STEL
		(mg/m³)			
Belt Sander / Oak Wood	3	0.450	0.03	0.78	0.465
Four-sided Planer / TM Ash Wood	2	0.145	0.01	0.27	0.175

STEL: 15-min limit exposure

Table 5. Comparison of Inhalable Mass Concentrations (c_{inh}) obtained Photometrically near two Woodworking Machines

Samples Group_ Photometrically	N	Mass Concentration (mg/m^3)	Homogeneity of Variances Test		Student's t-test
			F	p	p
Belt Sander	3	0.450	67.71	p > 0.05	0.39
Four-sided Planer	2	0.145			

Table 6. Comparison of Inhalable Mass Concentrations (c_{inh}) obtained Gravimetrically and Photometrically near the BS and 4FS

Samples Group		N	Mass Concentration * (mg/m^3)	Homogeneity of Variances Test		U-test / Student's t-test	Correction Factor
				F	p	p	
BS	G	9	0.085	44.97	p < 0.05	0.02**	0.24
	P	3	0.348				
4SP	G	9	0.068	1.081	p > 0.05	0.13	0.48
	P	2	0.141				

* Geometric mean; G – gravimetric method; P – photometric method; ** U-test was added

Correction factors were calculated for the optical device next to each machine. Based on the ratio of gravimetric to photometric mass concentrations, the correction factor for the optical device next to the BS during oak wood processing was 0.24. For the device next to the 4SP during TM ash wood processing, the factor was 0.48. Under these low-concentration conditions, the Split2 photometric instrument significantly overestimated the inhalable dust concentration during the belt sanding operation ($p = 0.02$). However, no statistically significant overestimation was found for the four-sided planer operation ($p = 0.13$). Specifically, the device measured almost two and four times higher inhalable dust concentrations for ash and oak wood, respectively, which is why the correction factor is significantly below 1. When comparing these production environments, it should be considered that they differ by machine type, wood species, and thermal modification. Therefore, differences in wood dust generation and instrument response cannot be attributed solely to a single factor.

Using parallel photometric real-time and gravimetric sampling, Moazami *et al.* (2023), found that real-time optical devices, such as the DustTrak DRX and Split2, underestimate the overall concentration of inhalable dust and overestimates the concentration of respirable particles. Thorp (2007) tested the precision of the Split2 and four other direct-reading dust optical devices among several industrial dust types, sieved pine, and three sizes of aluminum oxide test dust to determine their suitability for measuring the inhalable concentration of airborne dust in workplaces. Each tested optical device significantly underestimated the inhalable mass concentration for all dust variants, and overestimated the respirable dust concentration by up to a factor of two. In similar optical device testing, involving the Split2 and sanded beech wood samples, lower mean calibration factors (the inverse slope) were obtained in passive sampling mode (1.16) than in active mode equipped with a cyclone (2.6) (Thorpe and Walsh 2007).

Several studies have evaluated correction factors for optical devices during wood processing under varying dust concentrations. For instance, a correction factor of 4.4 for determining the inhalable mass concentration of dry oak wood was obtained on a parquet production line with an average concentration of 1.93 mg/m³ (Čavlović *et al.*

2009). In comparison, a similar study on processing dry oak wood using a four-side planer under a lower average inhalable mass concentration (0.754 mg/m^3) gave a correction factor of 3.1 (Čavlović *et al*. 2021). Furthermore, a much lower correction factor of 1.16 was recorded at a low inhalable mass concentration of TM ash wood dust (0.545 mg/m^3), indicating a different photometric response of the optical method. This response may be partly associated with the low proportion of the respirable fraction (12.76%) within the inhalable dust (Čavlović *et al*. 2023). In addition, when measuring lower mass concentrations, the errors of the gravimetric method due to the manipulation of the filters should be taken into account (Rando *et al*. 2005b).

CONCLUSIONS

1. The effectiveness of the optical method with regard to the share of respirable fractions in inhalable dust may be related to the results of measurement by the gravimetric method. The photometric method is recommended to be applied using a previously obtained correction factor for specific occupational exposure. The correction factor for the Split2 optical device showed that the photometric method overestimates the mass concentration compared to the gravimetric reference. During the belt sanding operation, this high photometric response was observed under low dust conditions between 0.02 and 0.164 mg/m^3 ($p = 0.02$). In accordance with previous research, this overestimation by the photometric method may be related to the high proportion of the respirable fraction within the inhalable dust (58.6% for oak and 85.9% for TM ash wood). This is an important distinction because the photometric response may also depend on particle morphology, density, refractive properties, and other aerosol characteristics.
2. Based on the results of this study and statistical testing, two separate photometric correction factors can be recommended for the Split2 device: 0.24 near the belt sander processing oak wood, and 0.48 near the four-sided planer processing thermally modified ash wood.
3. The importance of careful filter handling at every stage of the procedure must be emphasized, as minimizing errors directly reduces sample mass variability, especially at very low concentrations.
4. In practice, a clean working environment with minimal airborne wood dust is increasingly prioritized to enhance machining quality, machine precision, automated production, and occupational hygiene standards. Given the increased awareness of the harmful effects of wood dust, there are increasingly more working environments where worker exposure to wood dust concentrations is well below the increased risk limit of 2 mg/m^3.

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