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F.X Keller, F. Chata

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F.-X. Keller[a,*] and F. Chata[a]

[*] e-mail address: keller@inrs.fr
[a] Institut National de Recherche et de Sécurité, 54519 Vandœuvre, France

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ABSTRACT

This paper focuses on the prevention of exposure to wood dust when operating electrical hand-held sawing and sanding machines. A laboratory methodology was developed to measure the dust concentration around machines during operating processes. The main objective was to characterize circular saws and sanders, with the aim of classifying the different power tools tested in terms of dust emission (high dust emitter versus low dust emitter). A test set-up was developed and is described and a measurement methodology was determined for each of the two operations studied. The robustness of the experimental results is discussed and shows good tendencies. The impact of air-flow extraction rate was assessed and the pressure loss of the system for each machine established. For the circular saws, 3 machines over the 9 tested could be classified in the low dust emitter group. Their mean concentration values measured are between 0.64 and 0.98 mg/m^3 for the low dust emitter group and from 2.55 and 4.37 mg/m^3 for the high dust emitter group. From concentration measurements, a machine classification is possible – one for sanding machines and one for sawing machines - and a ratio from 1 to 7 is obtained when comparing the results. This

classification will be helpful when a choice of high performance power tools, in terms of dust emission, must be made by professionals.

INTRODUCTION

Wood dust is classified at the French national level on the list of carcinogen materials (INRS ED974) and the decree of December 23rd 2003 fixed a value for the mandatory occupational exposure limit to wood dust of 1 $mg.m^{-3}$ effective from July 1st 2005 in France. In the short and medium terms, occupational exposure to wood dust can cause skin and respiratory diseases: eczema, conjunctivitis, rhinitis, asthma and pulmonary fibrosis. In the long-term, it can be at the origin of primary cancers of the nasal cavities and of the ethmoïd bone. In France, the population exposed to wood dust during their occupational activities is greater than 300,000. Professional diseases associated with this activity are recognized according to table N°47 of the Social Security general regime and to table N°36 of the agricultural regime. On average, more than 120 cases of occupational illness linked to wood dust, including 70-80 cancers, are listed each year for the general regime (DRP, 2016).

Reinforced prevention methods were imposed under the Carcinogen, Mutagen, Reprotoxic decree of February the 1st 2001: risk evaluation, substitution by a less dangerous agent (rarely applicable to wood), working in a closed system and methods of collective protection

(capture at the source), training of staff, regular assessment of exposure (annual control of Occupational Exposure Limit values), following exposure, medical monitoring, etc.

Today, industrial managers in this profession have to choose machines without having any information concerning their characteristics in terms of dust emission. Effectively, the suppliers and manufacturers of hand-held machines are not currently obliged to notify the users of the dust emission levels of their apparatuses. Furthermore, the machine directive is vague concerning the subject of dust emission and the European norms are not necessarily re-applicable to hand-held machines.

Woodworking requires the use of hand-held machines to carry out representative tasks by the worker. For example, amongst the most commonly encountered we can count sanding and sawing. Hand-held machines are amongst those that have the highest emission levels and in most cases dust capture systems are not of effective design (BIA, 2003). Following the "wood dust" campaign from March to June 2008 (Lamy, 2009) initiated by the French Ministry of Labour, 3105 companies (in the building sector, wood and sawmills, furniture building) were visited. The hand-held machines were found to be connected to an aspiration system in only 20% of cases, and in more than 60% of cases the OEL value was exceeded.

A previous study, entitled "Evaluation of the capture performances for 3 types of hand-held woodworking machines – INRS study" that concerned hand-held electric machines from the workshop or construction site (Muller, 2010) concluded that many machine hood collection devices were not effective. The operations studied were sawing, ripping and sanding. The aim was to draw up an overview of the situation in terms of dust capture of existing material but not to develop a standardizable method.

Trials in companies were carried out to evaluate the occupational exposure of the workers using the most efficient materials identified during laboratory tests (Muller, 2010). Individual samples were taken from 22 workers from 13 carpentries (manufacture of beams, doors, staircases, etc.). The results showed that in situations where good occupational practices were respected – frequent cleaning of the workshops using a centralised vacuum system, the exclusive use of vacuum tools – the occupational exposure measured varied from 0.4 to 1.1 times the OEL value for sanding operations and from 0.6 to 1.3 times the OEL value for sawing (OELv = $1mg.m^{-3}$) (Lamy, 2009 and Muller, 2010). All the study results depend on respect of the suction flow rates recommended for each type of machine. These flow rates can only be ensured during the whole period of work if industrial vacuums are used and are regularly cleaned.

Following on from these different observations, the aim of this study was to develop a methodology to measure wood dust emissions around hand-held machines. Measures of the suction flow and pressure loss were also integrated into this approach. In parallel to the progress of this study, normalization tasks in the context of CEN/CENELEC (European Committee for Electrotechnical Standardization) were undertaken to attempt to *impose* at least a labelling of the machines, with the aim of informing the user of an indication of the dust emission level generated, the recommended suction flow rate and the associated pressure loss, and of unifying the diameters of the attachment ducts linked to the vacuum network. This latter information is needed to allow the fitter to size the suction centre so that it is adapted to the machines connected to the network. In the long-term, the benefits of the study should lead to completing the labelling of the machines according to the dust emissions that they generate (classes A, B, C and D for example).

In the frame of this study, two types of hand-held machines were tested. We have selected 4 sanders and 9 circular saws. Sanding is one of the most widespread machining procedures for woodworking – mainly of raw wood. It generates rather fine wood dust. Sawing is also an extremely widespread operation, used to cut both raw wood and chipboard. The dust created

during sawing is of a different particle type from that issued from sanding and circular saws are very emissive machines (Muller and Fontaine 2010). The dust shape also differs. These two characteristics have an influence on the response of the sensors used during tests (Harper 2002). Wood dust morphologies induce a bias during the measurement of concentration with optical counters. The determination of the shape factors and densities of these dusts is not straightforward (Chata, 2015 and Gorner, 2009).

Choice of the test method

Several standard methods exist to determine the emission of a polluting source.

- EN 1093 – 1: Choice of test methods
- EN 1093 – 3: Method on the test bench to measure the emission rate of a pollutant
- EN 1093 – 8: Parameter of pollutant concentration, method on the test bench
- EN 1093 – 11: Decontamination index

In this study we chose the EN 1093-3 norm as the reference to establish the test procedure. We placed the pollutant source in a ventilated cabin (Figures 1 and 2), in which we controlled the rate of air flowing through the test chamber. The dimensions of the main cabin are length (L) = 4.5 m; width (l) = 3 m; height (H) = 3 m. Downstream, a converging portion leads to an extraction conduit of 1 m in diameter and 15 m in length. An extraction ventilator linked to this conduit allows the airflow rate in the cabin to be regulated over a range from 8,500 to 50,000 $m^3.h^{-1}$. During our tests, a fixed flow rate of approximately 13,000 $m^3.h^{-1}$ is maintained, so as to have a 0.4 $m.s^{-1}$ mean horizontal air velocity. This speed guarantees a controlled flow in the cabin and particle transport that predominates over sedimentation. We are focusing on particle with aerodynamic diameter in the order of 10 µm to 100 µm (inhalable dust) and with a density of ~1000 $kg.m^{-3}$. For this type of particle the sedimentation velocity is in the range of 5.10^{-3} $m.s^{-1}$ which is 80 times lower than the air velocity fixed in the cabin. The ventilated cabin was adapted to standardize the airflow, from upstream to downstream, using a diffusing canvas at the entrance, (Chata, 2015 and Welling, 2009). A workbench on which the machining operations were carried out was installed in the cabin. The different sampling points were placed downstream in the ventilated cabin and a detailed experimental and CFD study was performed in order to characterized the sensor

positions and the concentration field at these locations (Chata, 2015). All the tests carried out during this study for sanding and sawing operations were performed with a robot (KR60 KUKA Roboter GmbH, Augsburg Germany). This allowed the reproducibility of machining cycles during testing to be ensured as fully as possible. A standard document EN 50632-1 applied to woodworking machines is developed and aims at measuring the amount of dust in a closed room around the machine and its extraction system. This standard is aiming at measuring the dust generated in a workshop placing different sensors in the room plus one on the operator but it is not directly linked to a pollutant emission rate measurement.

MATERIALS AND METHODS

A ventilated test cabin was developed to measure dust emission from hand-held wood saws and sanding equipment. The characterization of emissions from electrical hand-held machines was carried out by the intermediary of dust measurements generated during machining operations. Trial cycles of the machining processes were developed and are described in this article. From these measurements it is possible to achieve a classification of

the different machines and confirm that some materials are more efficient than others in terms of dust collection hoods.

The orbital sanders used during these tests are all connected to the electrical sector (no battery-driven machines were used) and have the plate diameters and references indicated in Table I below. The papers used during the measurements were ordered from the corresponding machine manufacturers and the grit type is specified:

The circular saws tested are all connected to the electrical sector (no battery-driven machines were used) and show the characteristics defined in Table II below (blade diameter, blade thickness, number of teeth, the electric power of the motor and the max. rotational speed):

During the tests, all the machines used were connected to a Local Exhaust Ventilation (LEV) system (Spanesi 4BD 11kW – Spanesi France s.a.r.l) by means of plug connectors present on the machines (each protection hood (provided by the tool manufacturer), diameter and nozzle shape differs depending on the constructors' choice). The Local Exhaust

Ventilation system is located outside of the ventilated cabin in order to not affect the pollutant emission of the tested machines.

Description of the sanding set-up (Figure 1):

We developed a test procedure for sanding that consists of a linear, reproducible and controlled machining cycle. The cycle duration was fixed at 10 minutes, corresponding to 10 "there and backs" on the working table. The forward speed was kept constant to 1 $cm.s^{-1}$ and the machining rotational speed was set to the maximum for each sanders. Before and after each operating cycle, the wooden plank was weighed to determine the amount of wood removed during the test (Sartorius balance LA8200S – accuracy: hundredth of gram). The dimensions of the planks are: length 800 x width 790 x thickness 16 mm. For sanding operations we have selected beech rectified raw wood as it is a common type of wood widely used in the industry. All the machines were connected to the LEV system via a high vacuum central unit. Two vacuum flow rates were tested for each machine - 80 $m^3.h^{-1}$, which is recommended by the French prevention institution to obtain satisfactory collection performances (INRS ED6052, 2009), and 40 $m^3.h^{-1}$ which is representing a degraded airflow

in order to evaluate in the laboratory the loss of collection efficiency for a diminished flow rate. This second flow rate allows the impact of a reduction in suction on the emission from machines to be estimated. A 0 $m^3.h^{-1}$ flow rate was tested once in order to confirm the impact of the suction flow rate on the concentration values (Table III). Each of these tests was repeated at least three times to assess the dispersion and variability of the measurement of dust concentration. The sanding paper was replaced at the beginning of the test for each machine. The working methodology is composed of the following phases: 1) start of the measurement devices and the machine, 2) waiting time (2 min), 3) machining operation (10 min), 4) end of the machining operation (machine stopped), 5) waiting time (2min), 6) stop of the measurement devices.

Description of the sawing set-up:

A method was setup to mimic a sawing cycle. A first step in the methodology was done with 25 linear cuts during a 7 minutes cycle time. Then a second step was carried out with 4 linear cuts during a 3 minutes cycle. Planks of chipboard were used for the test. The planks had dimensions of length 800mm x width 790 mm x thickness 16 mm. The volume and

weight of the cut wood are known for each circular saw tested. For each machine, new blades were used for these trials to eliminate any possible impact of blade blunting. All the machines were connected to a high vacuum suction system and the maximum suction flow rate was measured for each machine. These measurements were carried out with a 28 mm diameter connection tube. Each test was repeated at least three times. A schematic view of the test cabin used for sawing trials is shown in Figure 2. The working methodology is composed of the following phases: 1) start of the measurement devices and the machine, 2) waiting time (2 min), 3) machining operation (7 min/3 min), 4) end of the machining operation (machine stopped), 5) waiting time (2min), 6) stop of the measurement devices.

Experimental method developed

The measurements of dust concentration were carried out using three types of sensor. An APS 3321 particle counter (Aerosol Particle Sizer - TSI Incorporated, Shoreview, MN 55126 USA) allows the real-time particles size distribution and emitted wood dust concentration to be obtained by the measurement of the time of flight of the particles [from 0.5 µm to 20 µm – logging time 1s]. A microbalance (TEOM Series 1400 – Tapered Element Oscillating

Microbalance – Thermo Electron Corporation, Greenbush, NY 12061, USA) measures the real-time (logging time 10s) total mass of dust deposited on a filter. The measurement flow rate is set to 2.5 $l.min^{-1}$ and the concentration measured is the max. concentration analysable without a size-selective sampler. Three real-time particle counters (Lighthouse HH3016 – Worldwide solutions, Fremont CA 94538 USA) class the particles [from 0.3 µm to 25 µm – logging time 1s] into 6 channels and give a concentration value for each of these channels, as well as the overall concentration of the particles. The 5 sensors were placed in the ventilated cabin downstream of the dust source for measurements carried out on the sanders. For measurements pertaining to circular saws, the APS is positioned in the ventilation cabin extraction duct. Indeed, the emissions from sanders are much reduced compared to those from circular saws. The concentration figures measured by APS in the conduit for sanding tests would entail major uncertainties in measurements and would not necessarily allow different machines to be discriminated from each other. For sanders the quantity of dust that has to fly to the APS in the conduit coupled with the equipment size-selective property (max. 20 µm) will led to smaller values compared to what will be measured in the ventilated cabin downstream of the dust source. For the machining operations a moving average was used in order to establish the concentration values measured by the different real-time sensors. The

average was done for a 600 sec. measuring time for sanding and a 180 sec. measuring time for sawing.

Measurement of the pressure losses and the suction flow rate

Pressure loss was measured for each machine tested in order to evaluate the pressure restriction level from the machines and show that some machines require more energy to move the extraction air at 80 m^3/h. The measurement of the flow rate was made by the intermediary of a calibrated Venturi tube, a manometer (MP200, Kimo SA) and a flow meter (Preso, Badger Meter Inc.) placed in the vacuum duct. This measurement was carried out for each of the machines before the start of measurements of dust concentration. It was done on sanders that were turned off, for which the rotating plate was not in contact with the workstation. For each circular saw test, the nominal vacuum suction was fixed as the maximum suction that could be attained with the high vacuum installation. The pressure loss measurement was established for each machine tested. This test was carried out for each circular saw before beginning measurements of dust concentration. It was performed on machines that were turned off.

Measurement of dust concentration

The wood dust emission measured during a sanding or sawing cycle is characterized by signals recorded with the different sensors. These signals have similar appearances irrespective of the sensor used. However, their heights are different due to instrument sensitivity, measurement type and measurement frequency. When the concentration signals recorded for some 10 minutes of sanding were analysed (Figure 5), a measurement plateau was observed. This plateau represents the establishment of the emission of wood dust in the air, generated by the sander. From the experimental values measured with the different sensors during the time cycle we calculated a moving average of concentration which is then used and plotted.

RESULTS AND DISCUSSION

In the next two graphs (Figures 3 and 4) we show an example of the measurement of the particle distribution size of wood dust generated by either sanding or sawing. Particle size distributions upon sanding and sawing are centred at around ~3µm: the dust issued from the operations is relatively fine and it could be confirmed that the particles do not perturb the airflow in the cabin. However, a difference can be noted between sanding and sawing dusts at the level of 5 - 15 µm. The particle volume distribution shows a clearer difference between the measurements carried out with sanding dust and with sawing dust. The sawing curve gives an optimum centred at 10 µm that is approximately two-fold higher than that of sanding. This difference is a factor that explains the higher concentration generated by sawing operations.

Machines pressure losses

The pressure losses are generated by changes in the section of the air passage in the vacuum duct, as well as by the different machine hoods. Some restrictions of passage section invoked pressure losses that can be extensive. These pressure losses are directly linked to the

energy consumption of the high vacuum extraction system. As an example for sanders, at a flow rate of 80 $m^3.h^{-1}$, the pressure loss varied between 10 kPa and 17 kPa. As an example, for circular saws, at a 130 $m^3.h^{-1}$ flow rate (order of magnitude of flow rate measured during our tests), the pressure loss values vary between 20 kPa and 35 kPa.

Sanders

Preliminary trials showed an increase in the concentration measured in the ventilated cabin when the suction flow was decreased from 80 $m^3.h^{-1}$ to 0 $m^3.h^{-1}$ (Table III). These measurements were made using a single sander. Later, only two suction flow rates were taken into account (80 and 40 $m^3.h^{-1}$).

After a first series of tests carried out to setup the measurement methodology, we performed systematic assays following the sanding cycle that uses two detection apparatuses (TEOM and APS). The total of the results are grouped in the following two graphs (Figures 6 and 7). It can be seen that machine n° 1 (with an 80 $m^3.h^{-1}$ extraction flow rate) releases more dust than the three others (by a factor of 7 approximately). In Figure 7, it can be seen once again that reducing the vacuum strength (from 80 to 40 $m^3.h^{-1}$) diminishes the collection efficiency. Only machine n° 3 retained relatively high collection efficiency.

From these measurements, we calculated the average and standard deviation for each machine tested, for the two flow rates. The results obtained using the two measurement apparatuses (TEOM and APS) were found to be homothetic.

- the relative positions of the different machines were identical, irrespective of the instrument used.
- the use of one measurement system or the other led to the same classification of the machines (low dust emitter versus high dust emitter).

By carrying out a variance analysis on the experimental values, the inter-machine variability could be calculated for 80 and 40 m^3/h and this was found to be significant with respect to test reproducibility (Abramowitz and Stegun, 1972). For that we used the Fisher test (F), which allowed two variances to be compared according to their ratio, provided that this ratio does not exceed a theoretical value ($F_{CRITICAL}$ in the Fisher table). For example, starting from measured values (80 $m^3.h^{-1}$ flow rate) with TEOM we calculated $F_{TEOM} \simeq 342$, APS gave $F_{APS} \simeq 287$, compared to an $F_{CRITICAL}$ of $\simeq 3.4$. For reference, the values with a 40 $m^3.h^{-1}$ flow rate are $F_{TEOM} \simeq 44$ and $F_{APS} \simeq 223$, compared to $F_{CRITICAL} \simeq 3.6$. This confirmed the inter-machine variability and allowed an inter-comparison of the different machines.

Circular saws

The sum of the results for a first set of five machines is regrouped in Figure 8 (first step). Both the TEOM concentration values (black cross) and the APS concentration values (blue circle) are plotted for machines 1 to 5. As for the sanders, we carried out an uncertainty calculation to determine whether or not it was statistically possible to differentiate the machines from each other on the basis of dust emission measurement. Starting from this variance analysis, we calculated the inter-machine variability. For the values measured with the TEOM equipment the results were: $F_{TEOM} \simeq 90$ and for APS: $F_{APS} \simeq 50$, with an $F_{CRITICAL}$ value of $\simeq 3.0$. This allowed us to conclude that inter-machine variability is significant with respect to test reproducibility. For sawing tests, we observed a standard deviation of the plateau stability of about 10 to 50 % and regarding the test repetitions, we obtained a standard deviation ranging from 5 to 40 % (Figure 8). Despite these high standard deviations, the machines can be clearly discriminated from each other

- The tests were of a long enough duration (reduction of the impact of plate stability)
- The test protocol allowed a "satisfactory" reproducibility for the establishment of a classification (of the 5 machines, two "families" could be distinguished)
- Starting from the TEOM measurements, machines 1,3 and 5 generated much less dust than machines 2 and 4 did (a ratio of 8:1)
- For four of the 5 machines, the conclusion concerning the classification is identical irrespective of the experimental device used (TEOM or APS)

Following the first series of tests with five circular saws, which allowed us to setup the measurement methodology, and to verify its robustness, we widened our trials by adding four additional machines to the five circular saws previously used (second step). The tests for the 9 circular saws were carried out and the results are shown in the following figures. To simplify the procedure, only the concentration values measured with TEOM are shown (for similarities in tendencies between TEOM and APS). The main results are shown in Figure 9 and Table V. We have plotted the TEOM concentration values (blue circle) for several measurements done for machines 1 to 9. The extraction flow rates applied to the machines during the tests are also plotted (black triangle). This figure demonstrates that machines 1, 5 and 7 give lower

concentration values than the other machines. The ratio between the lowest average and the highest is approximately 7. Two groups of machines can be distinguished: one (low dust emitter) where the machines show an average below 1.5 $mg.m^{-3}$ (between 0.6 and 1 $mg.m^{-3}$) and the other (high dust emitter) where the machines have an average above 2 $mg.m^{-3}$ (ranging from 2.4 to 4.4 $mg.m^{-3}$). These values could be used for relative comparisons of tools. We carried out a variance analysis test for these 9 machines. From this, we calculated the inter-machine variability. The TEOM value is $F_{TEOM} \simeq 51$ with an $F_{CRITICAL}$ value of $\simeq 3.2$. This allowed us to conclude, as above, that the inter-machine variability is significant compared to the reproducibility of the tests.

The average concentration values are regrouped for each machine, with the corresponding vacuum flow rates (Figure 9). The flow values were between 109 and 134 $m^3.h^{-1}$, whereas the emission of the machines varied by a factor of 7. In Table IV the values of dust concentration and the wood mass removed by the machines during the test cycle are summarized. The mass removed is in a range from 68 g to 106 g. There is no clear correlation between the dust concentration measured and the wood mass removed. As an example for machine n°1, concentration = 1 $mg.m^{-3}$ and wood mass = 76 g, for machine n°4, concentration = 3.7 $mg.m^{-3}$

and wood mas = 76 g. This is due to the fact that some machine hoods are designed in order to capture more efficiently wood dust from the cutting process.

In order to perform more experimental testing, two circular saws were selected from the previous results: machine n°5, which is part of the lowest emissive group and machine n°2, which is part of the highest emissive group. We performed series of tests at different date and plotted the results of dust concentration measured with TEOM and APS equipment (Figure 10 and Table VI). The last points show the influence of the blade exchange from machine n°2 to machine n°5. No significant impact can be noted. The difference in terms of dust concentration measured with the two real-time instruments is clearly stated between the two machines.

CONCLUSION

During this study, a methodology for the measurement of dust emission by hand-held electric wood-working machines was set-up. The results obtained show that it is possible to develop a classification of the machines for a given type of machining (sawing or sanding). An analysis of the robustness of the methodology was carried out and this allowed the discrimination between different machines to be confirmed (circular saws and sanders). The measurement of dust concentration is according to the EN 1093 – 3 standard and is simple and accessible for the manufacturers of hand-held machines, at the level of its implementation. We established a correlation between concentration measurements in conduits with a particle counter (APS) and gravimetric measurements in the cabin (TEOM). The studies using circular saws initially concerned tests on 5 machines, to confirm the stability of the measurement method. Afterwards, 9 circular saws were tested, allowing a classification of these machines to be developed. The studies concerning 4 orbital sanders validated the methodology for a second type of machining and a classification is presented. Starting from measurements of dust concentration and classification of the machines, it is possible to propose recommendations to the profession. The importance of the vacuum flow imposed on the dust extraction nozzles present on the different machines was confirmed.

Several flow rates were tested on the sanders and the corresponding concentration levels were measured. Possible optimization of machine protection hoods was observed and measurements of pressure loss established the progress points. This methodology allowed the development of systematic measurements of dust levels around hand-held machines. The information provided about the equipment concerning dust emission from hand-held machines will be useful for prevention and will make the choice of a machine showing good dust collection performances possible.

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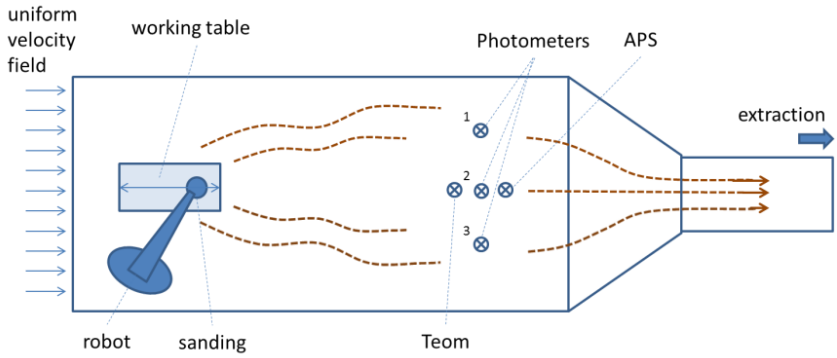

FIGURE 1: Ventilated cabin – View from above – Sanding.

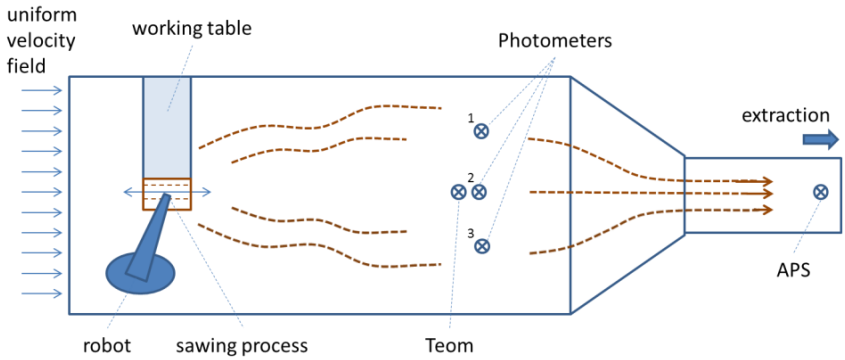

FIGURE 2: Ventilated cabin - View from above - Sawing.

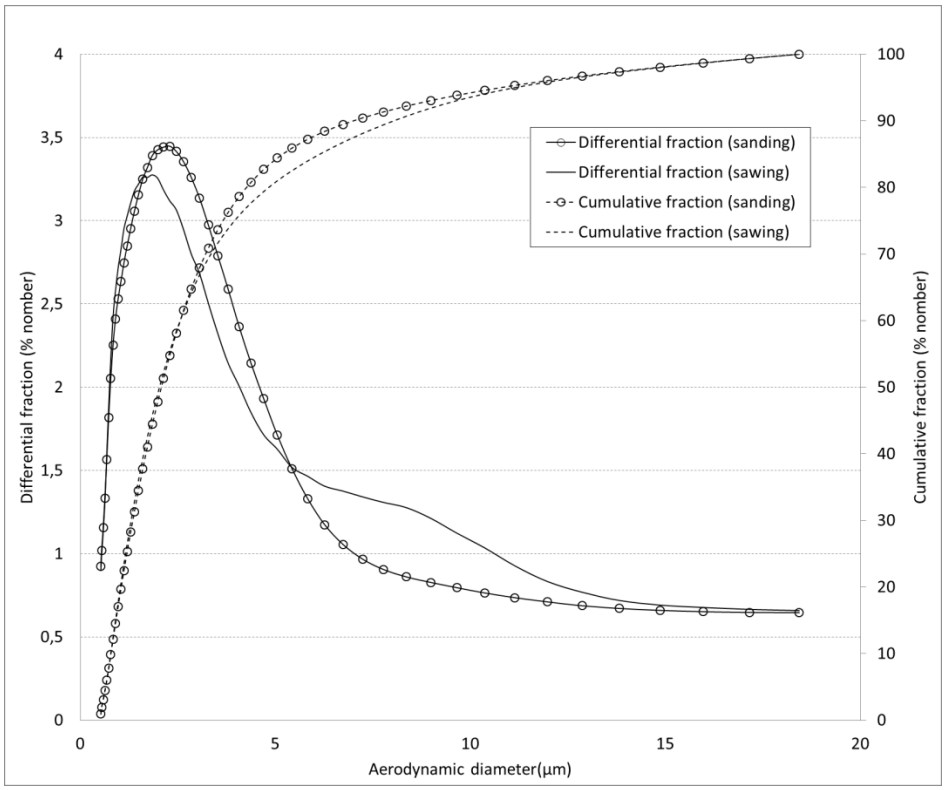

FIGURE 3: Granulometric distribution in terms of number of wood dust entities. Measurements were carried out with APS.

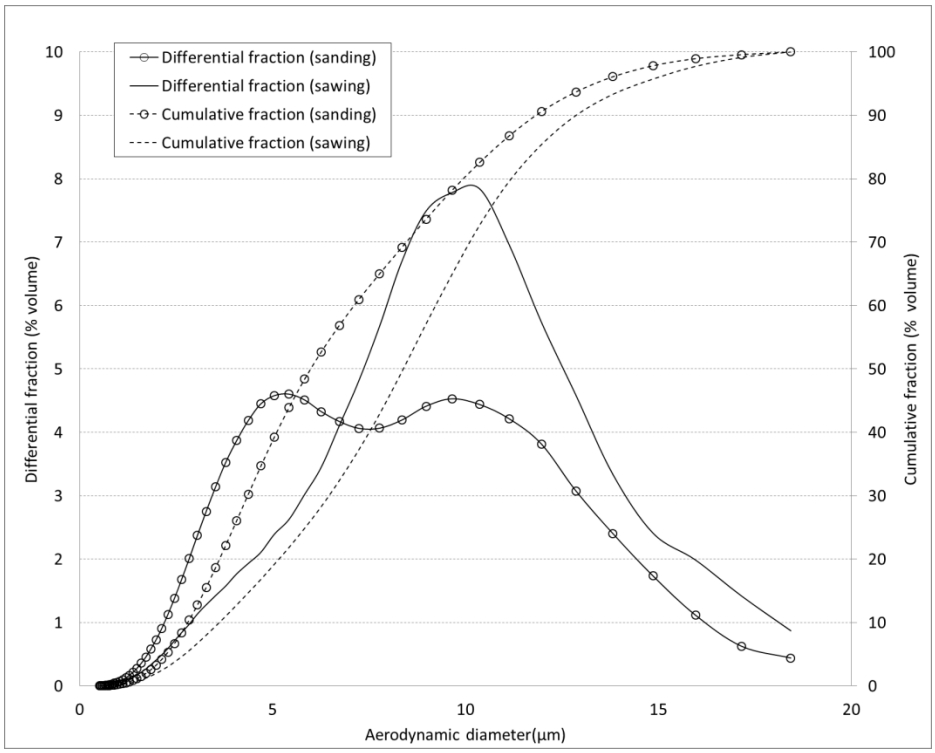

FIGURE 4: Granulometric distribution in terms of wood dust volume. Measurements were carried out with APS.

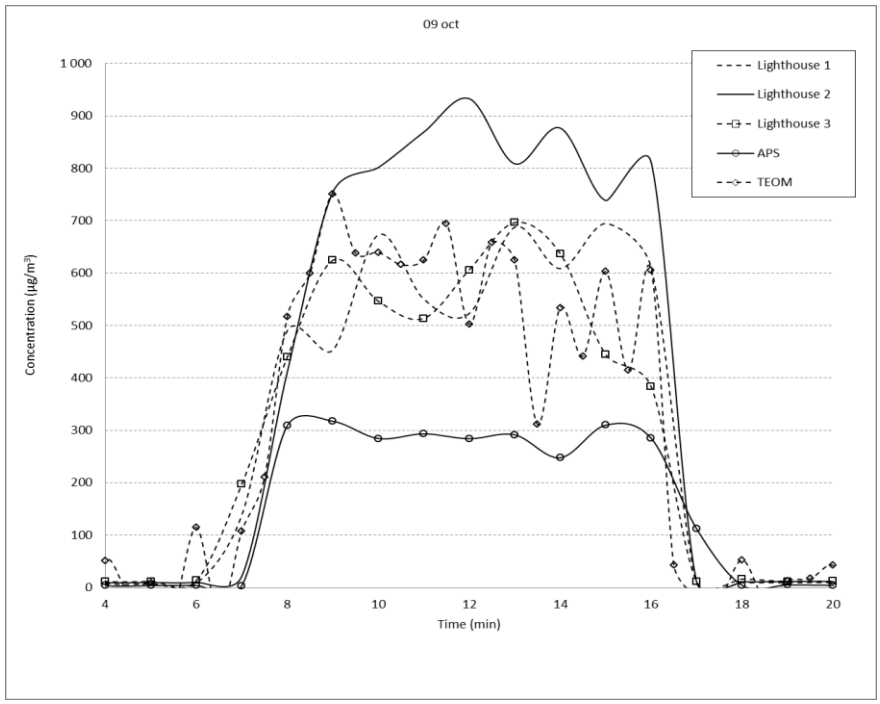

FIGURE 5: Concentration signals – Machine n°4 – 40 $m^3.h^{-1}$

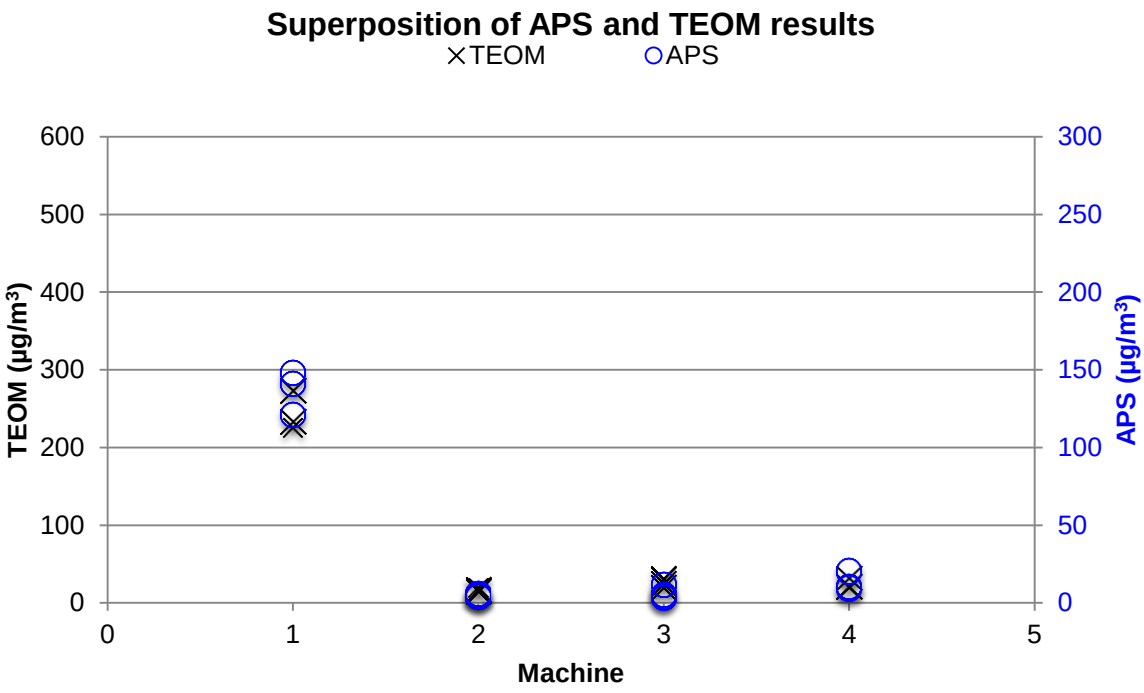

FIGURE 6: Results for sanders (80 m^3/h, paper 120).

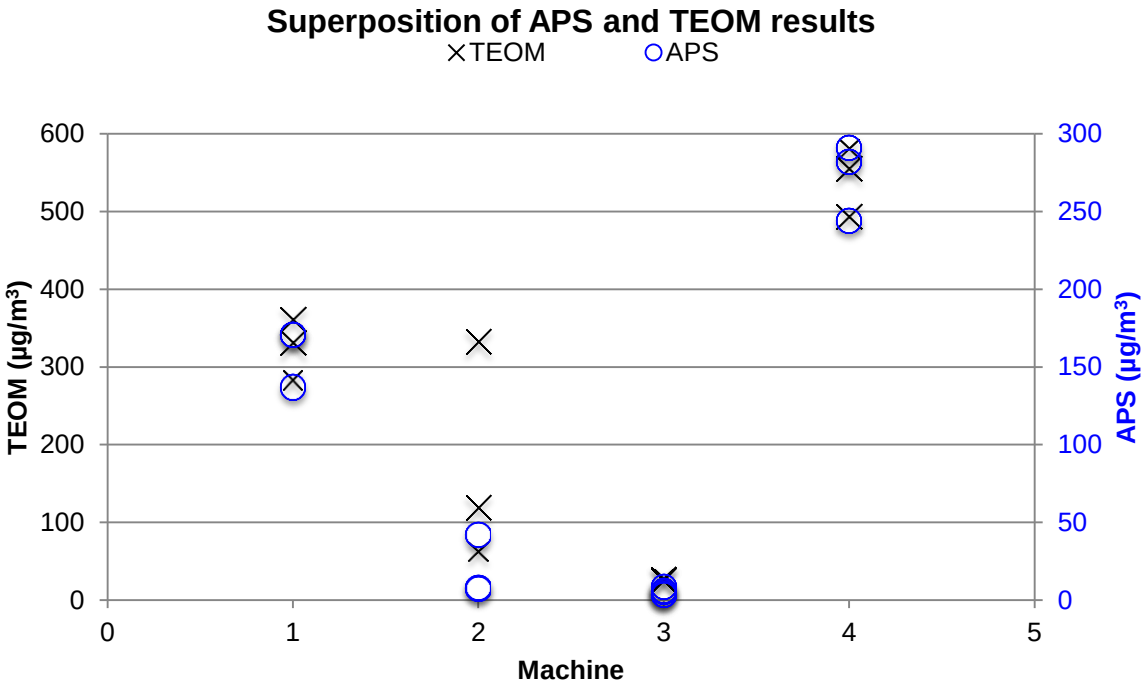

FIGURE 7: Results for sanders (40 m^3/h, paper 120).

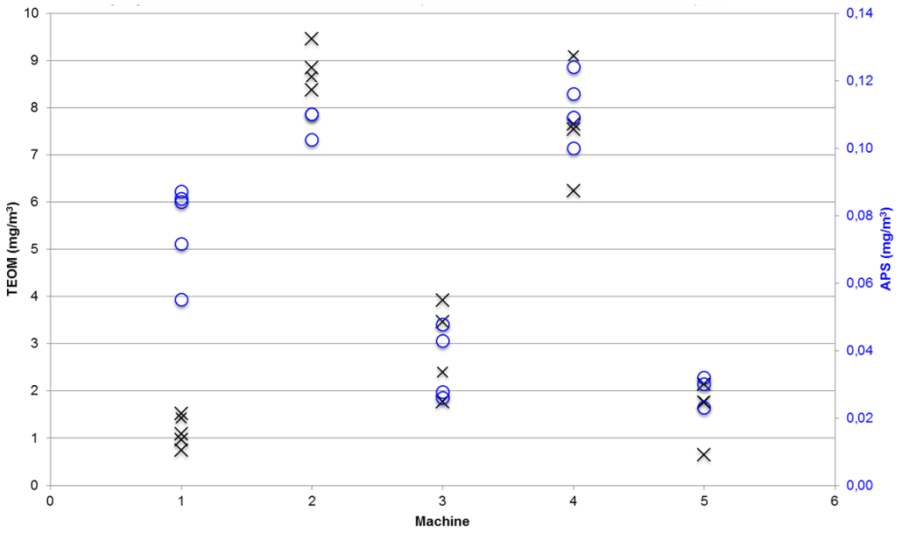

FIGURE 8: Results for 5 circular saws.

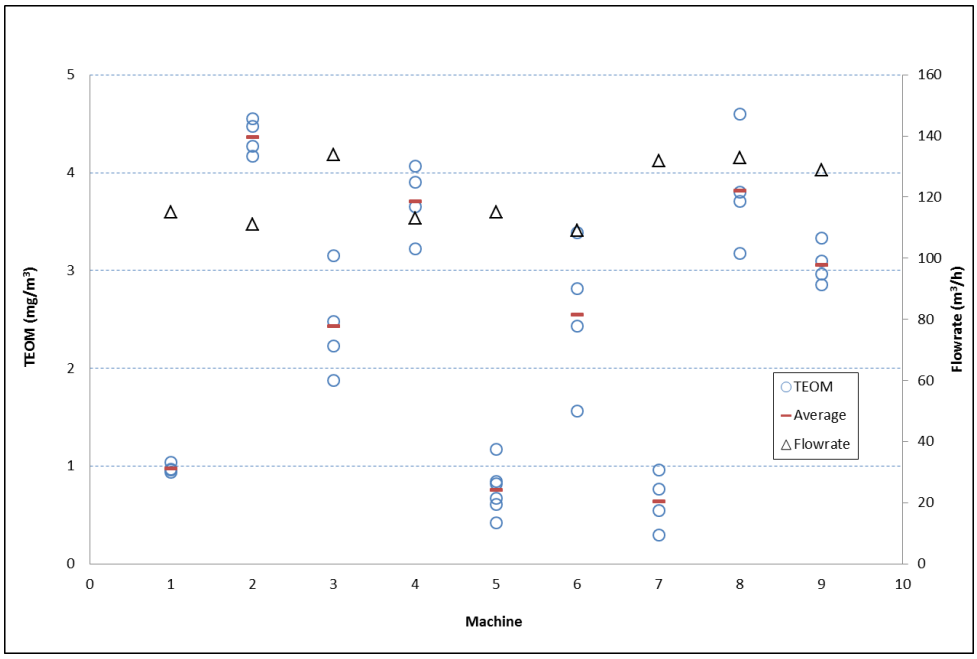

FIGURE 9: Concentration measurements and vacuum flow rate for 9 circular saws.

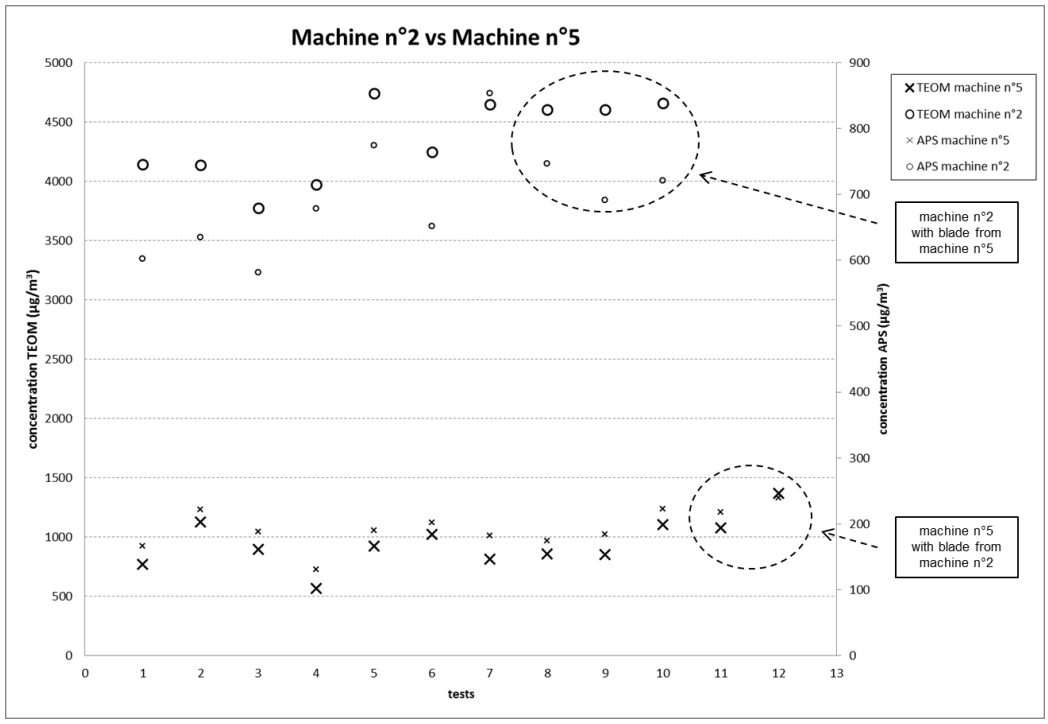

FIGURE 10: Average concentrations for 2 circular saws.

TABLE I: Sanders tested

Brand	Reference	Diameter (mm)	Grit type
Festool	WTS150/7	150	P120
Bosch	GEX150	150	P120
Black and Decker	KA191E	125	P120
Makita	BO5041	125	P120

TABLE II: Circular saws tested

Brand	Reference	Blade diameter (mm)	Blade thickness (mm)	Number of teeth	Power (W)	Max. rotational speed (tr/min)
Festool	TS75EBQ	210	2.4	Z36	1600	3550
Hitachi	C7BUY	190	2.0	Z18	1300	5500
Mafell	KSP55F	210	2.4	Z36	1600	4400
Metabo	K555	160	2.2	Z18	1200	5600
Bosch	GKS65	190	2.0	Z18	1300	5000
Makita	SP6000	165	2.2	Z48	1300	5800
Ryobi	RWS	190	2.2	Z24	1600	5000
Virutex	SRI174T	160	2.8	Z28	1150	5500
Dewalt	DW5520	165	2.0	Z48	1300	4200

TABLE III: Dust concentration emitted as a function of the suction flow rate – Machine n°2

Suction flow rate (m^3/h)	Min Concentration ($\mu g/m^3$)	Max Concentration ($\mu g/m^3$)	Mean Concentration ($\mu g/m^3$)
80	10	30	15
40	100	300	200
0	1000	10000	5000

TABLE IV: Average concentrations and wood mass removed for 9 circular saws

Machine	Mean Concentration (mg/m^3)	Wood removed (g)
1	1.0	76
2	4.4	83
3	2.4	91
4	3.7	76
5	0.8	68
6	2.6	83
7	0.6	76
8	3.8	106
9	3.1	83

TABLE V: Measurement values for 9 circular saws

Machine	Nomber of test	Concentration mg/m^3	Mean concentration mg/m^3	Standard deviation	LEV Q (m^3/h)
1	1	1,04	0,98	0,046	115
	2	0,97			
	3	0,96			
	4	0,94			
2	1	4,47	4,37	0,176	111
	2	4,27			
	3	4,17			
	4	4,55			
3	1	3,15	2,43	0,537	134
	2	2,23			
	3	2,48			
	4	1,88			
4	1	3,65	3,71	0,369	113
	2	4,07			
	3	3,90			
	4	3,22			
5	1	0,42	0,76	0,255	115
	2	0,61			
	3	0,67			
	4	1,17			
	5	0,84			
	6	0,82			
6	6	1,57	2,55	0,765	101
	6	2,44			
	6	3,39			
	6	2,82			
7	1	0,96	0,64	0,286	132
	2	0,77			
	3	0,55			
	4	0,30			
8	1	4,60	3,82	0,588	121
	2	3,80			
	3	3,71			
	4	3,17			
9	1	3,33	3,06	0,206	129
	2	3,10			
	3	2,85			
	4	2,97			

TABLE VI: Additional measurement values for 2 circular saws

Machine	Number of test	Concentration TEOM µg/m^3	Mean concentration TEOM µg/m^3	Standard deviation	Concentration APS µg/m^3	Mean concentration APS µg/m^3	Standard deviation	LEV m^3/h
2	1	4144	4353	340	602	694	83	110
	2	4136			635			
	3	3774			582			
	4	3973			679			
	5	4744			775			
	6	4247			652			
	7	4647			854			
	8	4603			747			
	9	4605			691			
	10	4658			721			
5	1	769	948	207	166	193	30	110
	2	1126			221			
	3	896			188			
	4	567			130			
	5	923			190			
	6	1019			202			
	7	813			182			
	8	858			174			
	9	851			184			
	10	1102			222			
	11	1078			218			
	12	1368			239			