Agronomy Research **15**(3), 745–750, 2017

Influence of air-conditioning on dust level in drivers' cabin during the harvest of grain

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Abstract. The period of grain harvest is characterized by dry and hot summer weather. During the grain harvest is generated large amount of dust which significantly influences surroundings, but mainly drivers are exposed to dust pollution. The aim of this paper is to present results of microclimatic research focused on dust pollution in drivers' cabin of tractors and combine harvesters of different construction used for harvest of grain. The machinery selected for this research includes the old but also very modern tractors and combine harvesters which are equipped with air conditioning. In the frame of this research the concentration of air dust was measured by exact instrument DustTRAK II Model 8530 aerosol monitor. Using the special impactors the PM_1, $PM_{2.5}$, PM_4, PM_{10} size fractions were also measured. Obtained results of measurements were evaluated and concentrations of different size of dust particles were analysed. Results of different indoor conditions measured in new and old machinery are generalized.

Key words: combine harvesters, grain dust, indoor of cab, measurement, tractors.

INTRODUCTION

Dust level is one of the factors that affect the global environment in which people, animals and plants spend entire life. The protection of people against high dust levels is solved mainly in terms of working conditions in mines, quarries, factories, workshops, transport systems and other workplaces where is the technological dust is produced. The problems of dust pollution is studied many scientific articles and papers.

The attention to dust is paid in many research works, e.g. Skulberg et al. (2004), Bouillard et al. (2005), Mølhave (2008), Boac et al. (2009), Mølhave et al. (2009), Buchholz et al. (2011), Nõu & Viljasoo (2011), Eherlich et al. (2013), Traumann et al. (2013), Traumann et al. (2014), Kic (2015), Kic (2016). The methodology and the results of measurements correspond to the research topic, especially to factors that are specific to studied space. There are studied e.g. the impact of outdoor particulates transferred into the indoor space, the impact of processed and handled material, the influence of floor surface, the influence of sports equipment, particles released from special plastic materials used indoor, dust produced in animal farms etc.

In agriculture, there is among other environmental problems a large amount of organic dust during the grain harvest and by handling in storing, cleaning, processing and packaging. The aim of this paper is to show the results of measurements of dust during the harvest of grain. Concentration of dust was measured outdoors near the fields where it was harvested grain by combine harvesters and where tractors were driving around. It has also been measured directly in the driving cabs of tractors and harvesters.

Problems of drivers comfort are one of very important factors to which producers of different vehicles pay attention. Microclimate composition rate is an important index factor affecting contentment of drivers in the cabin. Some publication have shown the effects of inappropriate working conditions on fatigue, which significantly applies to prolonged driver's working hours mainly to professionals. A suitable microclimate is necessary and the systems must ensure as it is one of the most important safety features of the vehicles (Zewdie & Kic, 2015; Zewdie & Kic, 2016a; Zewdie & Kic, 2016b; Zewdie & Kic, 2016c).

MATERIALS AND METHODS

This research work and measurements were carried out in agricultural company situated in the south part of Czech Republic. For research measurements were chosen harvesters and tractors, which differ in equipment for ventilation and air conditioning.

The combine harvester Fortschritt E 517 (CH1) is outgoing but still at use; the combine harvester which is not air-conditioned, but equipped with forced ventilation creating overpressure in the cabin and with filtration of the inlet air. It is compared with a modern combine harvester Massey Ferguson MF BETA Paralel (CH2), equipped with comfort air-conditioner (AC).

The tractor Zetor 7045 (TR1) is an old Czech brand, but still widely used in the country. Ventilation is only through opened windows during the summer. It is compared with a modern tractor Case (TR2), equipped with comfort AC.

According to the type of material, dust has specific characteristics to which respond the properties. According to Act Government Regulation No. 361/2007 Coll. the type of dust produced by the cereals has irritating effects (grain and straw). For this type of dust the prescribed Occupational Exposure Limits (OEL) is permissible exposure limit of total grain and straw dust concentrations 6,000 $\mu g\ m^{-3}$.

Measured dust is not aggressive, therefore, as a criterion for comparative evaluation of the measured values can be also used the limit level of outdoor dust. According to the Air Protection Act No. 201/2012 PM_{10} limit value in 24 hours is 50 $\mu g\ m^{-3}$, 1 year limit value is 40 $\mu g\ m^{-3}$ and 1 year limit value $PM_{2.5}$ is 25 $\mu g\ m^{-3}$. The 90 data of dust concentration for total dust as well as of each fraction size in each measured place were collected.

RESULTS AND DISCUSSION

Principal results of dust measurement are summarized and presented in the Tables 1–3 and Figs 1–4. Table 1 shows the results of dust measurement of external environment at a distances D1 = 400–600 m, D2 = 200–400 m, D3 = 20–40 m from working combines, and at a distance of D4 = 10 m of hayloft, where straw is stored in big bales.

The results indicate that the OEL values of 6,000 $\mu g\ m^{-3}$ were never exceeded. Far away from the harvest place in distances D1 and D2 the limits applicable to the external environment were not exceeded. Near the harvesters in distance D3 the values of PM_{10} and $PM_{2.5}$ were sometimes slightly exceeded. The highest concentrations of dust were measured near the storage of straw D4. The measured total concentration of dust was very high and also measurement $PM_{2.5}$ exceeded the limit value of 25 µg m^{-3}.

Table 1. Total dust concentration and concentration of dust fractions PM_{10}, PM_4, $PM_{2.5}$ and PM_1 in in external conditions at distances D1, D2, D3 and D4

Place	Total	PM_{10}	PM_4	$PM_{2.5}$	PM_1
	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD	µg m^{-3} ± SD
D1	20.6 ± 7.9	20.3 ± 9.0	14.6 ± 3.5	14.5 ± 3.9	13.4 ± 2.6
D2	29.4 ± 8.0	29.1 ± 7.4	24.2 ± 1.1	22.6 ± 1.0	20.9 ± 0.4
D3	51.1 ± 46.3	50.4 ± 47	37.3 ± 22.4	24.3 ± 10.2	12.5 ± 2.4
D4	238.5 ± 213.3	42.3 ± 8.0	33.8 ± 1.1	33.0 ± 1.8	32.5 ± 2.7

SD – Standard deviation.

The Fig. 1 presents graph of a size distribution of dust particles in outside air. The main parts (65%) of dust in the external air in distance D1 are the particles smaller than 1 µm (PM_1) and 28% are the particles bigger than 4 µm and smaller than 10 µm. The air contains the biggest dust particles in very low percentage (1% of the particles bigger than 10 µm). The situation in the external air in distance D2 is very similar, PM_1 is 71% and 17% are particles bigger than 4 µm and smaller than 10 µm. The air contains the biggest dust particles in very low percentage (1% of the particles bigger than 10 µm).

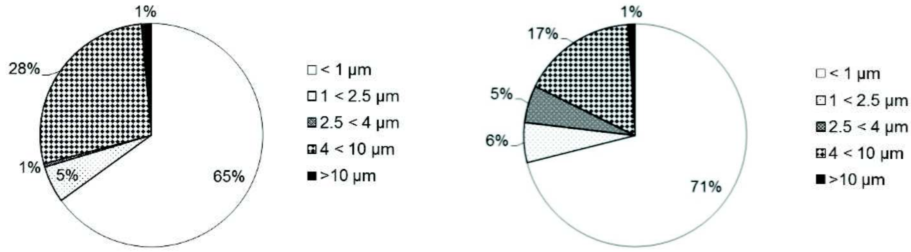


Figure 1. Percentage of dust fractions in the outside air in distances D1 (left) and D2 (right).

The Fig. 2 presents graph of the size distribution of dust particles in outside air in distances D3 and D4. The size distribution of dust in the external air in distance D3 is rather uniform, only the content of the biggest dust particles in very low (1% of the particles bigger than 10 µm). The situation in the external air in distance D4 is very different. There are 82% of the biggest dust particles and 14% the smallest PM_1.

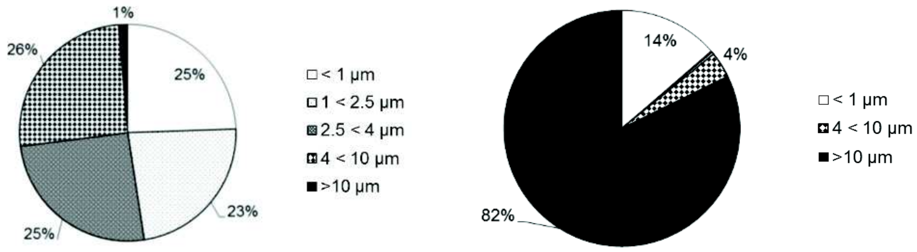


Figure 2. Percentage of dust fractions in the outside air in distances D3 (left) and D4 (right).

The results of measurement show that the eternal air in big distances from the fields with combine harvesters and tractors contains mainly small dust particles and the highest concentration of big dust particles is near to the source of pollution (D4).

Table 2 shows the results of measurement in the cabins of combine harvesters CH1 (E 517) and CH2 (Massey Ferguson). Results show a significant effect of air filtration in ventilation and air conditioning on clean air in the cab. The limit values for PM_{10} or $PM_{2.5}$ were never exceeded. Both combine harvesters have ventilation with forced air supply and pressure filtration. The results showed that the total dust level in the new modern harvester CH2 was approximately 6 times lower than in the older combine CH1 without air-conditioning. There are not smallest particles PM_1 in CH2.

Table 2. Total dust concentration and concentration of dust fractions PM_{10}, PM_4, $PM_{2.5}$ and PM_1 in cabins of combine harvesters CH1 a CH2 (AC)

Place	Total	PM_{10}	PM_4	$PM_{2.5}$	PM_1
	$\mu g\ m^{-3} \pm SD$	$\mu g\ m^{-3} \pm SD$	$\mu g\ m^{-3} \pm SD$	$\mu g\ m^{-3} \pm SD$	$\mu g\ m^{-3} \pm SD$
CH1	22.4 ± 8.3	22.3 ± 7.2	15.3 ± 2.7	11.9 ± 1.9	8. 8 ± 2.4
CH2	5.1 ± 2.9	2.6 ± 1.3	2.2 ± 1.7	2.0 ± 0.6	0 ± 0

SD – Standard deviation.

The Fig. 3 presents the graph of the size distribution of dust particles inside the cabins of combine harvesters. Dust in CH1 without AC contains main parts (39%) of dust the particles smaller than 1 µm (size fraction PM_1) and 31% are the particles bigger than 4 µm and smaller than 10 µm. The air in CH2 with AC contains 49% of the particles bigger than 10 µm and 39% bigger than 1 µm and smaller than 2.5 µm.

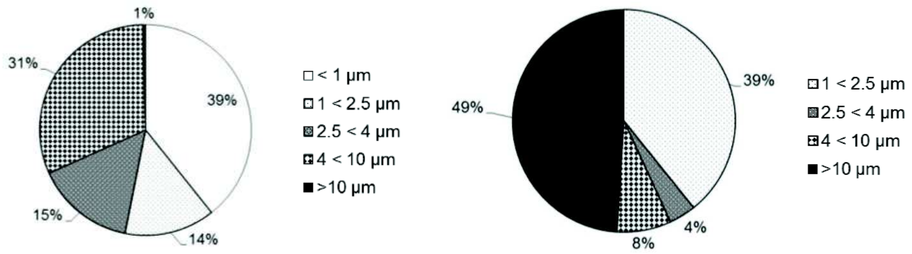


Figure 3. Percentage of dust fractions in the cabins of combine harvesters CH1 (left) and CH2 (AC) (right).

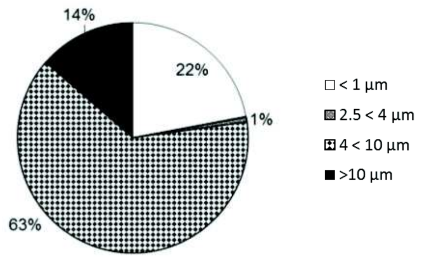
Table 3 shows the results of measurements in the driving cabs of tractors TR1 (Zetor 7045) and TR2 (CASE). The results show a very strong influence of air filtration on air purity. The internal environment of the tractor TR1 has been improved only by ventilation through open windows. The dust concentration was therefore very high and has exceeded the limit values for external environment PM_{10} and $PM_{2.5}$. Concentration of dust inside the tractor TR2 (CASE) equipped with AC with air filtration was very low.

Table 3. Total dust concentration and concentration of dust fractions PM_{10}, PM_4, $PM_{2.5}$ and PM_1 in cabins of tractors TR1 a TR2 (AC)

Place	Total	PM_{10}	PM_4	$PM_{2.5}$	PM_1
	$\mu g\ m^{-3} \pm SD$	$\mu g\ m^{-3} \pm SD$	$\mu g\ m^{-3} \pm SD$	$\mu g\ m^{-3} \pm SD$	$\mu g\ m^{-3} \pm SD$
TR1	282.4 ± 233.0	243.9 ± 171.2	64.4 ± 11.8	62.5 ± 7.4	62.2 ± 20.6
TR2	34.5 ± 14.5	9.2 ± 0.7	9.2 ± 0.6	9.1 ± 0.5	8.1 ± 0.2

SD – Standard deviation.

The Fig. 4 presents the graph of the distribution of dust size of particles inside the cabins of tractors. Dust in TR1 without AC contains 22% of dust particles smaller than 1 µm (size fraction PM_1) and 63% are the particles bigger than 4 µm and smaller than 10 µm. 14% are the particle bigger than 10 µm. Air in TR2 with AC contains 73% of the particles bigger than 10 µm and 24% smaller than 1 µm.



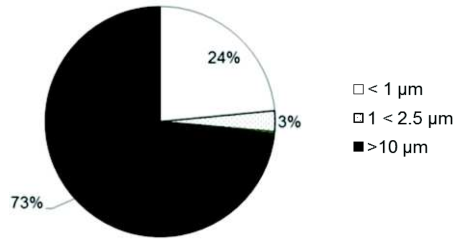


Figure 4. Percentage of dust fractions in the cabins of tractors TR1 (left) and TR2 (AC) (right).

CONCLUSIONS

The results of dust measurements have shown that the work and function of machines and manipulation with cereals during the harvest of grain and straw significantly increased the concentration of dust pollution near the source of the dust (harvesting, handling and transportation). Very high level of total dust concentration and also high concentrations of dust fractions is dangerous for the human health, mainly because of a lot of allergens. Dust concentration decreases with increasing distance from the place of harvest. The spread of dust into the environment is greatly influenced by wind speed and direction.

The created overpressure in driving cabins equipped with a pressurisation system and a dust filtration of all supplied fresh air has a positive impact on the indoor environment in driving cabs of tractors and combine harvesters, which is reflected especially in today's modern harvesters and tractors. The purity of the air in terms of dust in them is lower than inside other conventional indoor spaces as dwellings, schools and similar buildings.

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