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Development of microclimate in the New Holland T6.165 tractor

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Abstract: A number of stimuli lead to what is termed "seasonal fatigue", where the only firm interconnection is the fact that this form of fatigue only occurs during a certain period of the season. The interior of the cabin and its effect on the machine operator is notable. The microclimate of the environment in which the operator works has a direct impact on his/her condition and, consequentially, the extent of his/her fatigue. The development of microclimate in a modern agricultural machine must be identified, and based on such findings, recommendation should be given regarding procedures for improving the current situation in agricultural technology. For testing, the New Holland T6.165 tractor was therefore selected. The individual measurements show that a certain drop of oxygen occurs in the cabin during the first half hour of driving. This leads to an increase in CO_2, which is in turn caused by the higher ventilation of the given individuals present in the vehicle. To eliminate said drops in O_2, the use of oxygen concentrators may be recommended.

Keywords: agriculture machinery; carbon dioxide; operator; oxygen; seasonal fatigue

It is estimated that fatigue behind the wheel, which presents itself as drowsiness or microsleep, is one of the main causes of automobile crashes (National Highway Traffic Safety Administration 2017, 2018, 2019). Consequences of fatigue are even more noticeable in the case of occasional "seasonal" activities, also often found in the environment of agricultural establishments. A large number of stimuli lead to "seasonal fatigue", where the only firm interconnection is that the fatigue only occurs at certain times of the season.

There exists seasonal fatigue, i.e. allergic fatigue, much prevalent in the general population. When exposed to an allergen, allergic persons may develop a fatigue condition, their attention might be reduced, mood worsened, or dysphoria (a state of anxiety, sullenness, subjectively felt discomfort) may become evident (Marshall et al. 2002). Fatigue may occur, for instance, in a variant caused by an affective disorder (mood disorder), which may also be seasonal in nature (Baars et al. 2008).

Seasonal fatigue considered in the general sense usually means fatigue caused during seasonal work, such as the operation of ski resorts, holiday resorts, etc. An example of seasonal work, where significant fatigue conditions from overexertion occur, is the work of the elite firefighters "interagency hotshot crew", which fights fires across the United States of America (Belval et al. 2018). However, focusing on the work where seasonal fatigue conditions most typically occur would lead us to operations in the agricultural sector (Irwin et al. 2019).

A large number of studies have already been carried out in the area of fatigue onset during the

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operation of agricultural machinery. Various methods of tackling problems connected with fatigue and safety improvement have been examined from different perspectives, which has opened up many alternative solutions to be used in effective combat against seasonal fatigue. The problem remains that when questioned, agricultural machinery operators reveal that they work "overtime" and very often also at night. They argue that these conditions make them fatigued. Regardless of these claims, they continue to work on their tasks (despite being fatigued) since they are under pressure in terms of tasks and finances (Irwin et al. 2019).

Cabin interiors and their influence on machine operators are notable. The microclimate of the environment where the given operator works has a direct impact on his/her condition and consequently also on the fatigue condition. Inside an agricultural machine, there is very often a high temperature, usually controlled by operators via air conditioning, which leads to a growth in CO_2 and hence directly to increased fatigue. Given the enormous dustiness, it is usually impossible to resort to frequent ventilation and air exchange inside the cabin. Fatigue is also induced by such interoperations as handling interventions in the outdoor environment (shock caused by the temperature difference between the air-conditioned cabin and the outside temperature), the difficulty of the route (driving in a rough terrain – shakes) or stress caused by monotonous and stereotyped work (Zewdie and Kic 2015, 2016).

The quality of air in the vehicle cabin is one of the most important variables with a potential to affect traffic safety (Zewdie and Kic 2015, 2016). A change in the operator's comfort may lead to fatigue which may in turn result in an emergency situation or accident due to reduced responsiveness on the part of the operator. The highest number of accidents usually take place in the first 30 min of the journey. Needless to say, it is questionable whether the reason for this is that shorter journeys are taken more frequently than long ones, or whether this is due to, for instance, changes in the air quality in the vehicle cabin. The level of CO_2 is the main indicator of air quality. (Zewdie and Kic 2015, 2016). A high level of CO_2 may act as an accelerant for fatigue and drowsiness and may reduce responsiveness (Zewdie & Kic 2015, 2016). Goh et al. (2016) together with Kilic and Akyol (2012) argue that the critical CO_2 level of 1 200 ppm may be exceeded in a vehicle, while Goh et al. (2016) measured an exceeding of this level after only 10 min of driving. Furthermore, Constantin et al. (2016) point out that CO_2 concentration in a vehicle cabin may reach levels which, as new data suggest, are thought to affect individuals' cognitive capacity. In addition, Galatsis et al. (2000) bring attention to the risk present in the vehicle when the internal air recirculation circuit is switched on. These authors claim that during conventional ventilation, the oxygen concentration drops below 20.5%, and during internal recirculation the oxygen concentration falls below 19.5% in a mere 15 minutes. This level affects the operator's judgment directly and leads to an increased risk of accidents (Galastis et al. 2000). Accordingly, such parameters as CO_2 and O_2 must be monitored.

The objective of this paper is to consolidate the existing individual measurements (Galastis et al. 2000; Kilic & Akyol 2012; Zewdie & Kic 2015; Constantin et al. 2016; Goh et al. 2016; Zewdie & Kic 2016) by combining the measurements of CO_2 and O_2 in a modern tractor cabin, verifying whether the development of O_2 and CO_2 poses a risk even in modern agricultural technology. It is therefore necessary to identify the development of microclimate in the cabin of a modern agricultural machine, and, based on such findings, to recommend procedures for improving the current situation in agricultural technology.

MATERIAL AND METHODS

As a first step, the tractor ordinary route taken by the tractor on a regular basis was identified for measurement purposes. Next, air quality was measured by means of individual analysers (Table 1).

All journeys were made by one driver. For the tests (with the view of availability and compliance with

Table 1. Range of measurements

A	B	C	D
Aquasol® PRO OX 100	O_2	0.01 to 21%	+/– 0.25%
Testo 315-3	CO_2	0 to 10.000 ppm	+/– 10 ppm

A – instrument name; B – wuantity measured; C – instrument range; B –instrument accuracy; ppm – parts per million

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requirements for modern agricultural technology), New Holland T6.16 (New Holland, Czech Republic) tractor was selected, equipped with a standard roof and a new air-conditioning system, which makes use of a dual-zone technology, guaranteeing a high performance. The aforementioned air-conditioning system is furnished with 12 air vents. The air recirculation filters were replaced in the given tractor before the individual tests (in order to measure the optimal condition) were carried out. The measurements were performed in 10 cycles in total. Testing was conducted with the normal air-conditioned ventilation setting and the setting with the internal air-conditioned circuit (air recirculation in the cabin).

The procedure of the test was as follows:

(*i*) The vehicle was left stationary to stabilise (without operation for at least 3 h, in a shaded outdoor location).

(*ii*) Installation and checks of the gauges: the wiring of all probes was checked; sampling was set up for every 5 sec; the gauges were installed in the mounting system inside the cab.

(*iii*) Enter the operator.

(*iv*) Engine and ventilation started up: ventilation was turned on to the medium level by all exhausts; air conditioning was turned on; air temperature in the cabin was set at 21 °C.

(*v*) The operator drove the route prepared in advance.

(*vi*) The vehicle was parked, and the measurement was completed.

(*vii*) Data for the subsequent analyses was downloaded from the individual analysers.

All measurements were executed by averaging the values derived from the individual journeys. In total, 10 half-hour cycles were carried out, and the measurements as such were conducted under pre-determined conditions (Table 2). The measurements at all times strictly followed the methodological procedure. The measurements were taken under the conditions (Table 1) which were monitored the whole time and for all measurements.

RESULTS AND DISCUSSION

Results of the individual journeys were processed in a form of an arithmetic average of the individual journeys, where, for clarity's sake, the results were provided in one graph at all times, and projected to show the development of air quality in the vehicle cabin over time (Figures 1 and 2).

The research in the development of air quality in the cabin of the New Holland T6.165 reveals that a certain drop in oxygen occurs in the cabin in the first half hour of driving virtually at all times. The reason for that is a slow onset of ventilation of the vehicle, while the individual present in a reduced oxygen environment ventilates more. The higher ventilation of the individuals present in the vehicle induces an increase in CO_2. This effect is reflected, in particular, in Figure 1, where an increase in CO_2 follows the area of a drop in O_2.

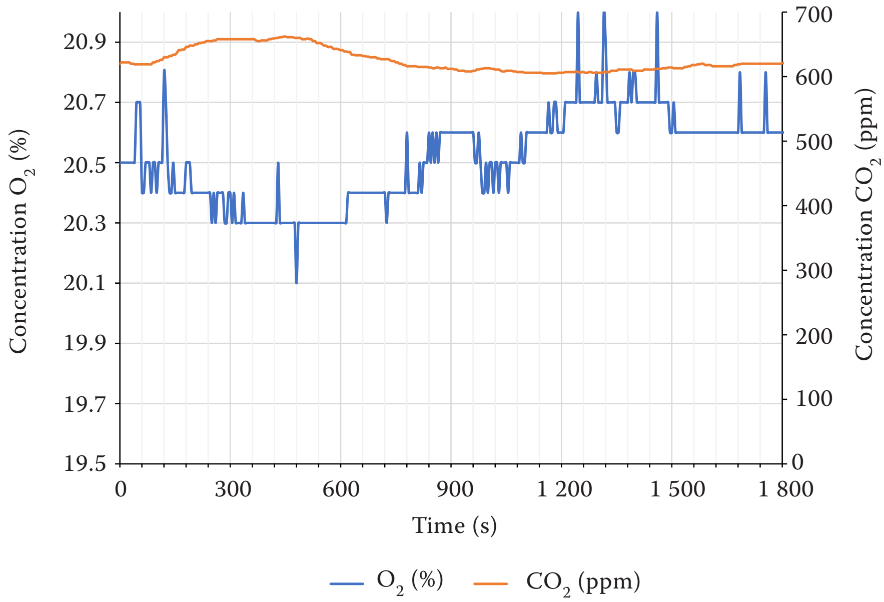

Figure 1. Results of measurements of O_2 and CO_2 volumes for the normal ventilation setting with air conditioning

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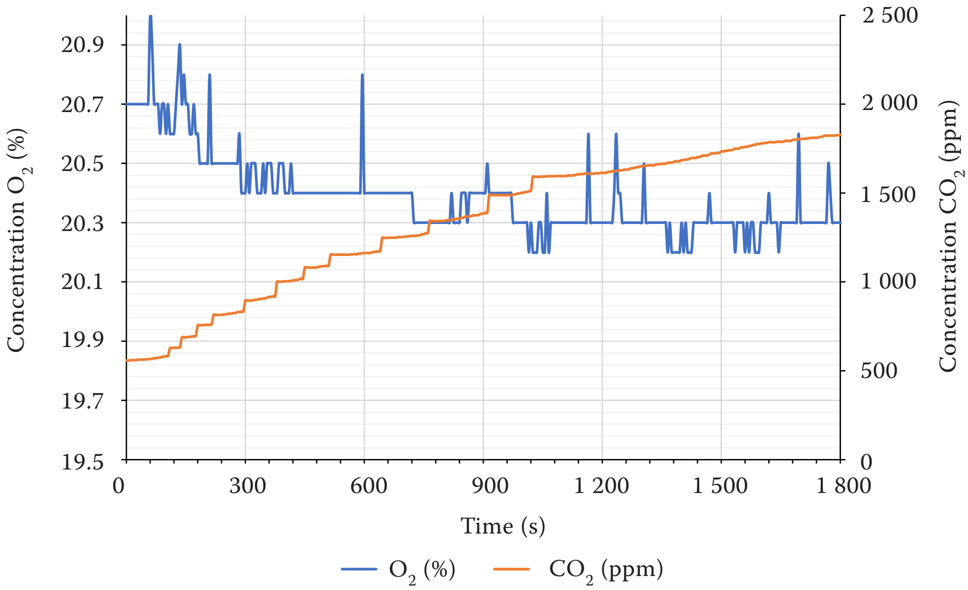

Figure 2. Results of measurements of O_2 and CO_2 for the setting of ventilation with the internal air-conditioned circuit (air recirculation in the cabin)

Galatsis et al. (2000) reached the conclusion that in the first fifteen minutes of driving, under normal circumstances, there is a decrease below the threshold of 20.5%, while this is true, in most cases, for the first ten minutes of driving. This claim has been partially confirmed.

The human body as such consumes about 250 mL·min^{-1} of oxygen at rest (360 L·day^{-1}). The real oxygen reserve in the human body is sufficient for cca. 5 minutes. Oxygen cannot be accumulated and used later, unlike other substances processed by the human body. Even the slightest drop in oxygen below the threshold of 21% leads to a negative response of the human body. However, the human body is able to adapt to this condition to a certain extent over time (Kilic & Akyol 2012; Constantin et al. 2016).

The reduction in the oxygen levels in the vehicle cabin gives rise to a risk of compromising the driver's responsiveness and concentration. Accordingly, the risk of microsleep grows, and there are more noticeable signs of the individual's fatigue compared to standard conditions (oxygen around 21%). One of the feasible recommendations is to equip the vehicle with an oxygen concentrator, which might eliminate the above risks and compensate for the aforesaid drops in O_2 at the start of the journey or during the recirculation of air in the cabin.

Table 2. Measurement conditions

A	B
Outdoor temperature	23 up 26 °C
Wind velocity	up to 12 km·h^{-1}
Weather	partly cloudy

A – quantity monitored; B – limiting values

CONCLUSION

An assessment was carried out of the development of air quality in the cabin of the New Holland T6.165 tractor in normal operation. The time course of the development of gases (CO_2 and O_2) inside the tractor cabin was determined through measurements. An undesirable decrease in the oxygen concentration was established, chiefly in the first 15 min of driving in the normal setting of ventilation with air conditioning, whereupon the given O_2 concentration increased again. In the setting of ventilation with the internal air-conditioned circuit (air recirculation in the cabin), a decrease in oxygen is evident, with no tendency to return to the original value, and unlike in the normal setting of ventilation with air conditioning, there is a significant increase in CO_2, up to 1 800 ppm. The use of an oxygen concentrator might be recommended to compensate for the above-mentioned drop in oxygen in the vehicle cabin.

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