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Exposure to audible and infrasonic noise by modern agricultural tractors operators

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A B S T R A C T

The wheeled agricultural tractor is one of the most prominent sources of noise in agriculture. This paper presents the assessment of the operator's exposure to audible and infrasonic noise in 32 selected modern wheeled agricultural tractors designed and produced by world-renowned companies in normal working conditions. The tractors have been in use for no longer than 4 years, with rated power of 51 kW to up to 228 kW (as per 97/68 EC). Audible and infrasonic noise level measurements and occupational exposure analysis to noise were performed according to ISO 9612:2009 (strategy 1 – task-based measurements). The measurements were made in different typical work conditions inside and outside of tractors cabs.

The results indicated that exposure levels to noise perceived by the operators ($L_{ex,Te}$ between 62,3 and 84,7 dB-A) and can make a small risk of potential adversely effects on hearing during tasks performed inside the closed cab. It should be remarked that uncertainty interval is wider and in in some conditions can occur transgression of audible noise occupational exposure limits. The measured audible noise levels can potentially develop the non-auditory effects. Analysed tractors emit considerable infrasonic noise levels that tend to exceed the occupational exposure limits (both inside and outside the driver's cab). The levels of infrasound: 83,8–111,4 dB-G. All tractors introduced for sale should be subjected to tests in terms of infrasonic noise levels. The applicable standards for low frequency noise and its measurement methods for vehicles, including agricultural tractors, should be scientifically revised. In the last years there has been a noticeable technical progress in reduction of audible noise exposure at the tractors operators workplaces with simultaneously lack of important works for limitation of exposure to infrasound. Author discuss possible health and ergonomic consequencies of such exposure.

1. Introduction

Audible and infrasonic noise is the very significant hazard in the working environment of agriculture. Workers employed on large farms and individual farm owners are exposed to the multiple-sourced noise (tractors cooperating with farming machines, self-propelled farming machines, e.g. combines of various types, moving machines, chaff cutters, stationary farming machines, e.g. threshing machines, grain mills, crushers, mixers and milking machines, as well as workshop and construction machines and equipment) (Solecki, 1999, 2000, 2002a,b 2005a,b, 2006). Characteristic is high variability of exposure to noise at the workplaces in agriculture -depending on seasonality of work, the type of farm, seasonality of work, mechanization level, work organization, weather conditions etc.

The wheeled agricultural tractor is the most commonly used vehicle on farms (there are about over 29 million tractors in the world), and one of the most prominent sources of noise in agriculture. Operators-perceived audible noise levels have been reduced due to considerable technical progress in the last years. Many authors exampled that the noise generated by the old-generation of agricultural tractors significantly exceeded noise exposure limits and may cause high risk of noise-induced hearing loss (Adamczyk, 2005; Kumar et al., 2005; Solecki, 1998–2006; Depczynski et al., 2011). Solecki reported that the average daily (8 h) exposure level to audible noise ($L_{eq,8h}$) in the driver's seat in medium- and high-powered tractors was between 89.6 and 96.6 dB-A (Solecki, 2001). To the noise-reduction methods in cabs of tractors belong "active" (reduction of audible noise generated by the tractor engine) and "passive" methods (ergonomic cabs structures have further limited the driver's exposure) (Aybek et al., 2010; Cieślikowski and Ślipek, 2007). The noise levels are paradoxically lower in the operator's cab than outside it- even at a distance of 7.5 m from the tractor (according to the measurement method set out in the European Union Directive) (Directive, 2009).

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The noise levels generated by engines vary considerably in individual vehicles, depending on various factors, including the type and power of engine, design solutions, and the type of work being done, whereas high fluctuations in the noise level can be identified during a specific type of work in progress, which can be attributed to different engine loads, vehicle and rotational speeds, vehicle speeds, weather and soil conditions, and operator's skills (Solecki, 1999). The accompanying whole-body vibration (especially when the exposure to whole-body vibration is high, which is common in old-generation tractors) can result in damage of the vestibulocochlear organ. It might also act in synergy with noise for potentially development of noise-induced hearing loss (Bovenzi, 2005; Seidel, 1993; Solecki, 2007, 2010; Sorainen et al., 1998).

Apart from audible noise, agricultural machines are an source of infrasound. Infrasound consists of acoustic oscillations whose frequency is below the low frequency limit of audible sound (16 Hz- or more commonly considered as 20 Hz) (IEC, 1994), but this definition is incorrect, as sound remains audible at frequencies well below 16 Hz. The exposure levels to infrasound generated by different wheeled agricultural tractors and other wheeled vehicles have already been examined in the past, but there are no analyses concerning technological progress which could contribute to the reduction of exposure to this hazard. (Nowacki et al., 2008).

This paper presents the assessment of the operator's exposure to audible and infrasonic noise in selected 32 modern wheeled agricultural tractors designed and produced by world renowned companies with the examples of possible health and ergonomic consequences caused by such exposure.

2. Materials and methods

Operator-perceived audible and infrasonic noise levels (inside and outside the cab) were examined for 32 types of modern cab-type tractors during normal, different working conditions. The tractors have been in use for no longer than 4 years, with rated power of 51 kW to up to 228 kW (as per 97/68 EC), designed and produced by world-renowned companies (8 John Deere and 9 Case, 8 Fend and 7 New Holland). To account for the different types of farm work carried out in different seasons of the year, the measurement results were divided into task-specific noise levels ($L_{eq,Te}$) (strategy 1 (task-based measurements) as per ISO 9612:2009). Total exposure to noise ($L_{eq,8h}$ or $L_{eq,week}$) was omitted as it depended on both exposure to noise and its duration. The author decided to focus on aspects related to technical progress in noise reduction, instead of analysing farm-specific exposure to noise. Otherwise, as was the case in previous studies (Solecki, 2006), considerable season-, month-, day-specific variations in noise exposure would have to be taken into account (depending on the duration of different activities). Exposure to noise level is defined as driver-experienced noise levels and the duration of exposure. Noise level measurements and occupational exposure analysis to audible and infrasonic noise were performed according to ISO 9612:2009.

Task-based assessment was used in interpreting measurement results (strategy no. 1 – according to EN ISO 9612:2009). The values of equivalent noise levels weighted by frequency characteristics A and G during various operator-performed tasks ($L_{Aeq,Te}$, $L_{Geq,Te}$), the maximum noise levels A (L_{Amax}) and peak noise levels C (L_{Cpeak}) were determined for all tasks applicable. The uncertainty of measurements was assessed based on EN ISO 9612:2009. Noise levels were measured in cooperation with an accredited by an entity being a signatory to the International Laboratory Accreditation Cooperation (ILAC MRA) and the European Cooperation for Accreditation (EA MLA) laboratory for noise measurements and according to EN ISO/IEC 17025:2005. The equipment for measurements: DSA-50 digital sound analyser (class 1 instrument, manufacturer: SONOPAN (Poland) and a KA-50 acoustic calibrator (class 1 instrument, manufacturer: SONOPAN (Poland)) with calibration certificates. To be able to access exposure to audible and infrasonic noise, a typical measurement method was applied using A, C and G filters, with frequency specifications as set out in Fig. 1 (ISO, 1995, 2003). All measurements inside the cab were taken with cab windows closed (the study included tractors with a cab structure and air conditioning), in consideration of the fact that open windows significantly affect the levels of audible and infrasonic noise (Nowacki et al., 2008; Report, 2004). The noise levels measurements outside the cabs were performed 1 m from the fronts of tractors. Apart from measurements of noise levels using A, C, G filters were taken samples of the audible noise octave band spectrums.

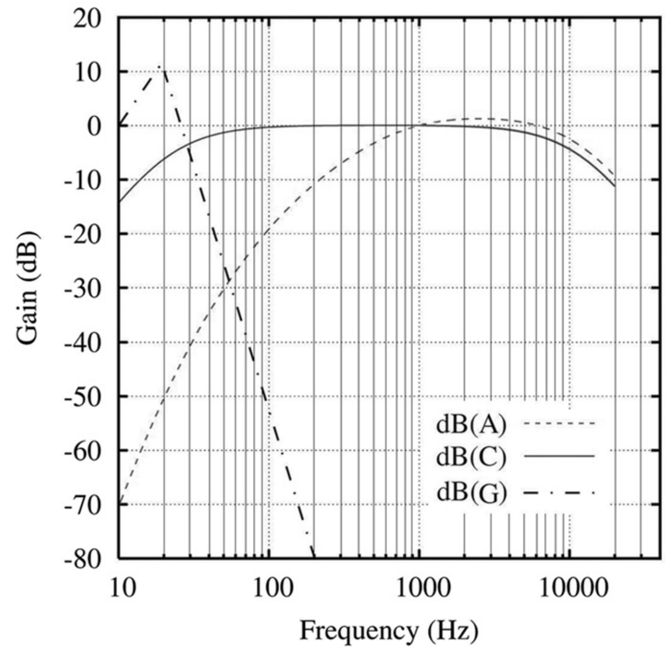

Fig. 1. Frequency characteristics of filters applied in audible noise (A and C curves) and infrasonic noise (*G* curve) measurements in working environments.

3. Results

The scope of driver-performed field tasks with the aid of the tractor models analysed in this study was considerably diverse on both crop and livestock producing farms. This analysis presents task-specific operator-experienced levels of audible and infrasonic noise. The applicable tasks are presented on Figs. 2 and 3: preparation of tractors and accompanying equipment for operation – tractor setting and start-up (inside the cab), ploughing (inside the cab), access and transport to the fields on hard-surfaced roads – the driver is (inside the cab), tasks performed outside the cab of the tractor at a standstill, with no exposure to other sources of noise, application of power transmission shaft when the tractor is at a standstill – mixing feed using a feed mixer/distributor (inside the cab).

3.1. Exposure to audible noise

The noise levels during an 8-h daily exposure were below maximum exposure limits for audible noise concerning hearing protection (LA eq, Te in range 62,8–84,7 dB-A) (for example: exposure limits in Poland: $L_{eq,8h}$ = 85 dB-A, L_{Amax} = 115 dB-A, L_{Cpeak} = 135 dB-C) (Regulation, 2002). Fig. 2 presents average task-