RISK MANAGEMENT OF HEALTH HAZARDS IN RURAL AREAS IN ADAPTING PROCESS TO RAPIDLY CHANGING WORLD

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Abstract. The research is directed to the identification of hazards and health risk levels to workers in agricultural land. The comparison to the working conditions in other activities is presented. New machines (tractors, robots) can produce noise and vibration to workers. A high level of carbon dioxide (CO2) inside the rooms or cabins of tractors can influence the person's cognitive activities. The importance of chemical odours, including CO2 (carbon dioxide) and dust in (working) life have long been recognized as stressors for humans. Dust particles (2.5-10.0 microns) can be inhaled and enter the pulmonary system. Excessive sleepiness in the workplace and on highways is a serious safety hazard and can result in numerous accidents. Possible contact with chemicals and dust can happen everywhere, computers are used inside and outside. For measurements of noise and vibration, respectively TES 1358 and SV100, for measurements of chemicals, CO2 and dust, spectrometer FTIR-300-X, TESTO 435 and HazDust EPAM-5000, were used. Outdoor measurements of CO2, dust, vibration, noise in country-places were carried out and as a comparison, the data from big towns, airports, aeroplanes, schools, offices, living quarters were fixed. Main results: the vibration levels were highest created by lawn-mowers (over 3 m·(s2)-1), noise levels raised from 27 dB(A) in quiet rural areas to 85 dB(A) created by lawn tractors, 80 dB(A) in big towns, outside the houses; the concentration of CO2 was varying from 247 ppm in rural areas to 1933 ppm at airports; the dust levels were ranging from 3-7 $\mu g \cdot m^{-3}$ in airports to 2-4 $mg \cdot m^{-3}$ in wood processing units. The five-step health risk assessment model created by the authors, was used. Decrease of noise, vibration and carbon dioxide levels help people stay healthy. There is a necessity and possibilities to decrease the concentration of CO2 in the ambient air in rural areas.

Keywords: rural area, safety and health hazards, risk assessment.

Introduction

The research is dedicated to the identification of safety and health hazards and determination of health risk levels to workers in agronomic units and people in other rural areas. The agricultural activities in Estonia and Latvia have declined. The comparison to the working conditions in other premises and working and living places are presented in the current paper.

The work and living environment can be described as the whole surrounding where the person is staying (including airports, plains, railway and bus stations, green-offices in country-places, etc.). Computers are used everywhere (Fig. 1). New machines (including tractors, robots) can produce noise and vibration for the workers. The high level of carbon dioxide (CO_2) inside the rooms (schools, offices of small-scale enterprises, etc.) can influence the person's cognitive activities. Bad working conditions restrict employees to portray their capabilities and attain full potential. The main occupational risk factors over the world are: carcinogens, airborne particles, noise, ergonomic stressors and risk factors for injuries.

The country-side population is decreasing. Only some big farms near big towns are sustainable existing in Estonia and Latvia. The summer cottages are concentrated in one place, near the sea, for example. They can be located close to each other and as the landscaping includes the work with noisy machines then the problems can be created between the neighbours. The lawn-movers make noise and pollution. For the person, sitting on the lawn tractor or using a lawn-mover, the vibration on the body occurs.

The broken agriculture activities in Estonia, Latvia, have to be rebuilt. Many job tasks within agricultural work are commonly referred to as 3-Ds: "dirty, "dangerous" and "demanding". Agriculture is one of the most hazardous industries [1]. Agriculture work takes place primarily outdoors, in all kinds of weather. The average age of workers in agriculture work is increasing [2]. Not only the nature of the work is the factor that drives the progress of robotics. A large variety of other factors are driving the development of robotics and automation in agriculture activities, related to household and cottage maintenance: workforce shortages, economic, climatic, technological, political and social factors [3].

The research on the air quality in the driver's cabin has mostly been focused on the means of public transport and privately owned cars. During the tests of the air in the cabin, the pollutants from the fuel exceed the allowed numbers by the norms. The most frequent criticism reported due to the lengthy exposure to whole body vibration include stomach discomfort and disorders of the spine. The exposure of operators during agricultural tasks (both whole-body and hand-arm) has been studied in depth by Cutini et al., 2017 [4].

The aim of the study is to illuminate the health hazard risks in the rural areas and help reorganize safely organized agricultural work back into countryside.

Theoretical basis

Carbon dioxide and dust: it is needed to decrease the concentration of CO_2 inside and outside the rooms. Linear physiological changes in circulatory, cardiovascular, and autonomic systems on exposure to CO_2 at concentrations ranging from 500 to 5000 ppm are evident. Human experimental studies have suggested that short-term CO_2 exposure beginning at 1000 ppm affects cognitive performance including decision making and problem resolution [5]. According to the World Meteorological Organization, the globally averaged CO_2 concentration in the atmosphere reached the symbolic level 400 ppm for the first time in 2015 (WHO, 2016) [6; 7]. The typical outdoor CO_2 concentrations are approximately 380 ppm, although in urban areas these have been reported to be as high as 500 ppm. The increasing CO_2 concentration contributes to the greenhouse effect and accelerates global warming. The typical average indoor CO_2 quality guidelines have established an upper limit of 1000 ppm for CO_2 in non-industrial buildings (Japan, Canada, Norway, China etc.).

By WHO's estimation, in 2019, air pollution caused 4.1 million premature deaths worldwide. The most harmful are PM2.5 particles, which penetrate the blood through the aerogematic barrier causing cardiovascular and respiratory diseases and cancer. PM10 can pass deeply into the lungs, but they are not so harmful. People believe that rural air is healthy. Research at the University of Minnesota showed that 18 000 Americans die every year due to air pollution by agriculture, primarily, ammonia (NH_3) from decomposition of fertilizers and livestock waste, and PM2.5 particles. Agricultural waste management and optimization of landscapes are effective ways of solving the problem [8].

The trend of rising agriculture productivity and falling labour participation is expected to continue. [9]. The operation and maintenance of more technologically sophisticated agriculture equipment like sensors and robotic devices operating by artificial intelligence methods is requiring greater educational attainment for agriculture workers. The increased use of robotics, sensors, and artificial intelligence is driving the need for engineers, economists, software technologists and supply chain experts to join the ranks of the agriculture workforce. Robotic devices are being developed (also drones) for agriculture use. One positive possibility for the use of previously used grain or potato fields in the northern countries is to plant trees on unused agricultural land and thereby reduce the carbon dioxide content in the air (Fig. 2 a, b). Solar cells also can be built on these empty lands (Fig. 2 c).

Fig. 1. ***Green-office**

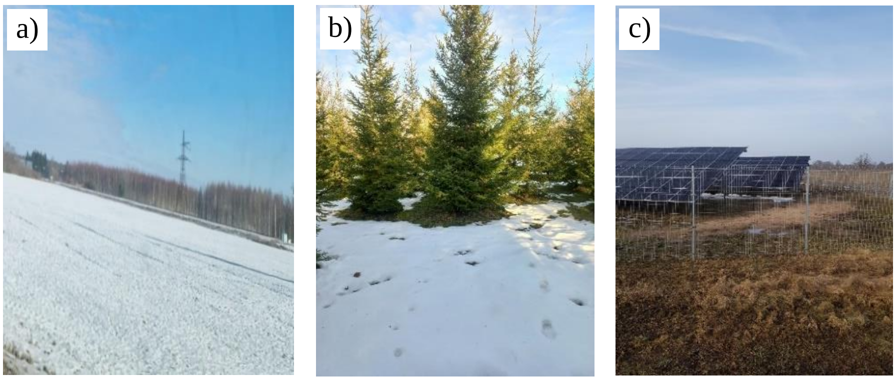

Fig. 2. **Unused land (a), planting trees there (b) or installing solar cells (c)** *Authors of all photos: M. Tint, V. Urbane, I. Vilcane

Vibration: tractors have made the work of agricultural operations easy but created the health hazards to the worker. Tractor drivers are exposed to many harmful influences: noise, snow, rain, high relative humidity, dust, chemicals, high and low temperatures, etc. One of the important negative factors is vibrations. Vibration is transferred from the cab floor to the seat and to the whole body of the driver. Especially evident it occurs in the older models of tractors. Cushions are used in vibration measurements at the tractor seat (compressed sponge, air, water). Vibration is transmitted to different parts of the body. Types of mechanical equipment that produce a lot of vibration force can cause hand-arm vibration in the tractor operator, also discomfort of the soft tissue, calcium loss in the hand and arm joints and the vascular damage. Some beneficial facts also happen: reduction of chronic back pain. The design of a tractor using the traditional method takes a long period and is a high-cost process. Conduits are important elements of the fuel system of cars, tractors, ships, planes, etc. Their vibrations often cause drumming, leading to discomfort for crew members and passengers [10]. The problems in human body, due to agriculture tractor vibrations, are seating discomfort and muscle fatigue. The adverse health effects from whole-body vibration (WBV) deals with the musculoskeletal system, in particular the lumbar spine. There is strong epidemiological evidence that occupational exposure to WBV is associated with an increased risk of low back pain (LBP), and degenerative changes in the spinal system, including lumbar intervertebral disc disorders. The main problems in human body, due to agriculture tractor vibrations, are seating discomfort and muscle fatigue [11; 12].

Noise and chemicals: often the co-influence of noise and chemicals (dust) can be observed [13]. The Nordic Expert Group [14] published a comprehensive review of occupational exposure to chemicals and hearing loss summarizing the writings on this topic from 1950 to November 2007. The chemicals were chosen based on the widespread indication on their ototoxicity. The review included medications, organic solvents, metals, pesticides, and polychlorinated biphenyls. Contacts near or below the present occupational exposure limits (OEL) resulted in hearing deficiencies for the following chemicals: styrene, toluene, carbon disulphide, lead, mercury and carbon monoxide. They also described animal evidence presenting that exposure to p-xylene, ethylbenzene and hydrogen cyanide (at or below the OEL) are related to hearing loss but there is a lack of human statistics. Another assessment of animal and human work with ototoxic substances through 2009 was conducted and the results showed that “lead, styrene, toluene and trichloroethylene are ototoxic and ethyl benzene, n-hexane and p-xylene are possibly ototoxic at concentrations that are related to the occupational location”. Construction activities in the rural land use a lot of chemicals. Sometimes the toxicity of these chemicals (even in small concentrations) is not shown on the Safety cards, but these minor amounts can be hazardous to humans. The authors also noted that carbon monoxide possibly interrelates, and toluene interacts with noise exposure to worsen hearing loss [15].

Risk assessment

The 5-step simple/flexible risk assessment model connecting the risk levels and health complaints, worked out by the Tallinn University of Technology (Fig. 3, [16]), was used in the current study.

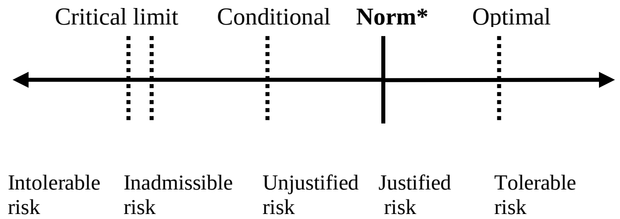

Fig. 3. **Five-step flexible risk assessment method**

*Norm (EN 16798-1:2019): CO_2 in schools: 1500 ppm, in industry: 5000 ppm; noise: in industry: 85 dB(A), in dwellings, schools: 50 dB(A); vibration [17]: local: 2,5-5.0 $m\cdot(s^2)^{-1}$ (simple lawn-mover); whole-body: 0.5-1.15 $m\cdot(s^2)^{-1}$ (tractors, ride-on movers)

For vibration, the limits between the steps worked out by the authors previously [12] are presented here: in the case of simple lawn-mowers, 1) tolerable risk: (acceleration, $w < 1.0$ $m\cdot(s^2)^{-1}$), possible fatigue of hands, blood pressure rise, exposure < 2 hours per day; 2) justified risk ($w < 1.15$ $m\cdot(s^2)^{-1}$): possible fatigue of hands, blood pressure rise, exposure < 4 hours per day; 3) unjustified risk ($w <$ 8-12 $m\cdot(s^2)^{-1}$): reversible blood circulation disturbances in fingers, < 8 hours per day; 4) inadmissible risk w = 12-16 $m\cdot(s^2)^{-1}$, white finger syndrome possible, non-reversible blood circulation disturbances in fingers, exposed < 4 hours per day; 5) intolerable risk ($w \geq 16$ m·(s^2)$^{-1}$): white finger syndrome, non-reversible blood circulation disturbances in fingers, ≥ 8 hours per day [12]. The last is not to allowed to happen.

Material and methods

The measurements of vibration, noise, CO_2 and dust were conducted. For measurement of vibration the standard methods were used: ISO 2631-4:2001. Mechanical vibration and shock – evaluation of human exposure to whole-body vibration and EVS-EN 5349-2:2001. Mechanical vibration. Measurements and evaluation of human exposure to hand-transmitted vibration. For measurements of carbon dioxide, the following method was used: EVS-EN-ISO 7726:2003. Ergonomics of the thermal environments- instruments for measuring physical quantities. The measurement methods for noise are presented in ISO 9612:2009. Guidelines for the measurement and assessment of exposure to noise in a working environment and ISO 1996-2: Acoustics – description, measurement and assessment of environmental noise. Part 2: Determination of sound pressure levels. The measurement equipment used for noise was TES 1358 (ranges 30-100 dB and 50-130 dB) and for vibration SV100 (range for acceleration 0.01-200 m·(s^2)$^{-1}$). For the chemicals, CO_2 and dust, the following equipment was used, respectively: 1) spectrometer FTIR-300-X, 2), TESTO 435 (measurement range for the CO_2 concentration from 0 to 10,000 ppm) and 3) HazDust EPAM-5000. EPAM-5000 is a portable air monitor designed for measuring the trace level for ambient air pollution. The unique sampling design allows for real-time data and filter gravimetric analysis directly behind the optical sensor. EPA-5000 offers a weather tight carrying case, temperature compensated electronics, an easy to clean optical sensor and a standard 24-hour battery or continuous sampling with a solar power panel accessory. The universal measuring equipment (CO_2, dust, microclimate) used in Latvia, was Temtop M2000C (measures PM2.5, PM10, number of particles, CO2 concentration, temperature and humidity). The places for investigation were: houses in the country-place, schools, outdoor environment; houses and outdoor environment in a big town (Riga), inside and outside of cars, in airports, aeroplanes. The number of driving cars (mainly private cars) has been counted for 5 minutes (N = 225). The houses, where the noise and CO_2 level were investigated, where residential type in towns and old village houses. The number of investigated schools in Latvia was 20 (including 2 high-schools) and four in Estonia (including one high-school). A one-way analysis of variance (ANOVA) has been conducted by using sensitivity scores of each of noise, vibration and carbon dioxide levels.

Results

The results of measurements of noise, vibration and CO_2, dust in 2024, are presented in Table 1.

Table 1

Results of measurements and risk levels of noise, vibration and carbon dioxide/dust

Object (time-based measurements)	**Noise level, dB(A), ±1 dB***	**Vibration acceleration level *w*, m·(s^2)$^{-1}$ ±0.01**	**CO_2 level, ppm*** ±10 ppm/ dust (D), mg·m^{-3} or µg·m^{-3} ±0.2/ ±0.2**	**Risk level**
Houses in the ountryside:				
West-**Estonia**	28.0-29.0	0.02	700-800^{ppm}	Justified risk
South-**Latvia**	29.0-30.0	0.01	1308^{ppm}	
Environmental data around the houses in countryside	29.0-30.0	0.02	240-250^{ppm} **D:** 1-2 mg·m^{-3}	Tolerable risk Temperature: 24.4 °C; humidity: 34%
Machines for grass cutting	Until 88	0.94-3.72*	**D**: 2-4 mg·m^{-3}	Unjustified risk **Noise**: protective means needed **D**: Unjustified in wood processing activities, weeding in agriculture

Table 1 (continued)

Object (time-based measurements)	Noise level, dB(A), ±1 dB*	Vibration acceleration level w, m·(s2)-1 ±0.01	CO2 level, ppm*** ±10 ppm/ dust (D), mg·m-3 or µg·m-3 ± 0.2/ ± 0.2	Risk level
Riga, centre, inside the houses	35.0-55.0	0.05	530-540ppm	Justified risk
rooms against the drive road	30.0-33.0**; with opened window: ≤ 60	0.02	628ppm	Unjustified risk, **Noise**: Double windows needed
rooms against the courtyard	30.4-31.1	0.03	622ppm	Justified risk
environmental data, bus traffic	74.0-79.0	0.03	449ppm	Justified risk
Schools in **Latvia** inside the classrooms	50.0-60.0	-	513-850ppm	Depending on the season, in summer, the concentration is higher
Small car: noise from wheels and music	45.0-55.0	0.23	1348ppm	**CO_2:** Unjustified risk, air-conditioning needed Temperature inside: 18 °C; humidity: 51%
Outside the car	65.0-66.0	0.02	487pm	-
At an airport	45.0-50.0	0.02	1933ppm **D**: 3-7 µg· m $^{-3}$	**CO_2**: Unjustified risk
On an aeroplane	60.0-65.0	0.25	1490ppm	**CO_2**: Unjustified risk

*uncertainty of measurements
** double windows
***ppm – parts (of substance) per million (parts of air)

The noise levels were from 30 dB(A) in rural areas to 80 dB(A) in big towns, outside the houses; the concentration of CO_2 was varying from 247 ppm in the rural areas to 1933 ppm at airports; the dust levels were ranging from 3–7 µg·m^{-3} in airports to 2–4 mg·m^{-3} in industrial settings (1-3 mg·m^{-3} in rural areas). The five-step health risk assessment method created by the authors was used. The concentrations of CO_2 in airports and airplanes, also in a car, respectively 1933 ppm, 1490 ppm and 1348 ppm have to be considered as unjustified risk as people often stay in these rooms for a long time. The air-conditioning helps. The local vibration on the workers hands, using the machines for grass-cutting (simple lawn drivers) over 3 m·$(s^2)^{-1}$ is also unjustified risk, the time for work with these machines has to be under 4 hours per day. Unjustified risk can also be emerged during weeding, in addition to the vibration, the used chemicals can be harmful.

Conclusions, discussion and future research

This article presents research aimed at identifying hazards and levels of health risks for workers in rural areas (whereas most studies focus on urban conditions) with comparisons to working conditions in other sectors. One of the potential new contributions of the article is the application and presentation of the five-step health risk assessment model developed by the authors. The article provides specific measurement data on noise, vibration, CO_2 and dust levels at specific locations in rural areas of Estonia and Latvia in 2024. In addition, the article highlights the changing nature of rural work, including the growing importance of robotics and automation in agriculture. It also highlights the need for OSH research in the context of new agricultural technologies that are still in the developing phase.

The hand-arm vibration disturbances are one of the two possible health hazards (besides whole-body vibration). Previously the risk assessment method is presented by Monarca et al. [19].

The simple lawn mowers showed the highest local vibration levels. There are many ways for employers and workers which can help reduce the workers' exposure to vibration. For the vibration caused damage rehabilitation WBV exercise was performed on a Galileo machine at an intensity of 12-20 Hz, for 72-year-old (range 59-86) workers. This study showed the beneficial effect of WBV exercise in addition to muscle strengthening, balance, and walking exercises in improving the walking ability in the elderly [12]. The decrease of noise, vibration and carbon dioxide levels help people staying healthy. There is a necessity and possibilities to decrease the concentration of CO_2 in the ambient air in rural areas. Noise above 60 dB in the houses situated in the residential district can cause cardiovascular diseases and nervous system disorders [13].

While some new robotics and automated machines are available, most are still developed. This provides OHS researchers an opportunity to mitigate risk and benefit health and safety of agriculture workers. The uncertainty of a changing climate as well as increased natural disasters such as floods, wildfires, and draughts has put an augmented financial load on agricultural manufacturers. Therefore, the country-place work is changing: the workplace, the workforce, and how work is accomplished, are changing. This is occurring to meet the increased demand for domestic food, and the demand for rapidly changing world. Some new agricultural robots and automated machines are currently in the market, meaning that 80% of them are still in the development phase. There are also training/education needs in safety and health for future workforce.

The computer work is enlarging also in the rural areas. Intensive computer work (also connected with the new machines that will be used in agriculture) has a lot of hazards to health: eye strain, trapezius muscle strain (also from tractors), forced posture, overloading of the arms and hands at work, fatigue [20]. Work with a computer outdoors or elsewhere in the rural area, can be influenced by environmental dust. On the hazards, connected with the computer-work in agriculture, enough attention has not been directed until now. There are a lot of future possibilities to improve the (working) environment. Artificial Intelligence (AI) technology can also be used in agricultural processes to improve the everyday working conditions [21].

Author contributions

Tint, P.: draft preparation; Urbane, V.: measurements; Vilcane, I.: measurements; Tint, M.: measurements. All authors have read and agreed to the published version of the manuscript.

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