# DEVICE FOR MONITORING THE INFLUENCE OF ENVIRONMENTAL WORK CONDITIONS ON HUMAN FACTOR

**DANIELA ONOFREJOVA, JAROSLAVA KADAROVA, JAROSLAVA JANEKOVA**

Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Special Engineering Processologies, Department of Safety and Production Quality, Kosice, Slovakia

Technical University of Kosice, Faculty of Mechanical Engineering, Institute of Management, Industrial and Digital Engineering, Kosice, Slovakia

**DOI: 10.17973/MMSJ.2021_10_2021034**

**e-mail: daniela.onofrejova@tuke.sk**

Industry 5.0 follows the idea of continuous digitization and transfer to digital factory. Industries must adopt the green and digital transitions to continue to be competitive. Besides the preservation of resources, climate change, the social stability is in the focus. Industries strive to become more resilient against external disturbances, such as Covid-19 crisis. Work environment considerably affects the productivity, health and safety of workers. Monitoring of the working environment with reliable miniaturized technology can guarantee suitable working conditions. In the line with the EU Strategic Framework on Health and Safety at Work 2014-2020, one of EU-OSHA's priorities is to fortify the prevention of work-related diseases.

**KEYWORDS**

*digital factory, digital production, human factor, safe and healthy working environment, productivity.*

## 1 INTRODUCTION

In the work environment, in addition to the "classic" harmful factors of the working environment, such as noise, dust, chemical factors, biological factors, etc. other factors that burden the human body and affect its physiological functions in particular have a negative effect on health; these factors include heat load and cold load at work, humidity factors, and others. New Decree of the Ministry of Health of the Slovak Republic No. 99/2016 Coll. takes into account practical knowledge, regulates in more detail the classes of work for the purposes of heat and cold load, conditions for ensuring permissible microclimatic conditions at the workplace, conditions for assessing heat and cold load at work, protective and preventive measures to protect workers' health, work and rest regime - breaks between individual work cycles, conditions of health risk assessment and requisites of documents - risk assessment and operating rules.

Results from the 6th European Working Condition Survey found that one in four European workers reported that work has a negative impact on their health [Holla 2019, Kubicek 2019]. Using the workplace as a setting to promote good mental health, not only helps protect employee's mental (and physical) health and wellbeing, but also makes good business sense. This article aims to provide the reader with an overview of the costs, the causes and consequences of mental ill health in the workplace; and provide an informed commentary on the methods and practices to develop and sustain psychologically safe and healthy workplaces.

According to the [Council Directive 89/391/EEC], employer is obliged to develope a coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment and thus avoid risks, evaluate the risks which cannot be avoided or combat the risks at source.

In production system, there are certain qualitative and quantitative requirements on human factor based on physical, physiological, and psychological aspects. Human needs to be adapted and ready for a given job and the workplace should allow maximum efficiency. The main idea is to adapt work and working conditions to a person, improve working conditions without endangering health, make the working environment comfortable and increase the efficiency of work activities. Work environment, as one of five factors (human, work process, workplace, work equipment, work environment), which influence the productivity and well-being can be adapted by elimination of disturbing factors that adversely affect human health, performance and safety.

Human has its abilities and limitations at work, therefore it is inevitable to adjust the workplace to his/her possibilities, abilities and knowledge. Human performance can be enhanced by the ergonomic approach to the design and adjustment of the work environment conditions, and thus reduce safety and ergonomics risks [Onofrejova 2020a].

The 3D printing technology and 3D designing are the inevitable skills for prototyping the industrial and household requirements. These are mainly the basic part design and part assembly for creating IoT (Internet of Things) prototypes, necessary casing to mount sensors and breakout boards [Kanagachidambaresan 2021] even biocompatible substitutes for human body parts (prosthesis) [Liacouras 2021]. [Liacouras 2021] compares the five printing technologies generally utilized for medical applications including material extrusion, vat photopolymerization, material jetting, binder jetting, and powder bed fusion for better radiologist understanding and appropriate use in their practices.

Monitoring the environment of a certain area provides information that is useful in knowing climate change, level of pollution, the effect on human health and their way of life. Researchers [Chowdhury 2019] strive and propose design, and implementation of a low-cost and portable environment monitoring system, [Farooqui 2017] focuses on large area environmental monitoring by disposable, compact, dispersible 3D-printed wireless sensor nodes with integrated microelectronics (Fig. 1). The proposed systems are designed and built exploiting Internet of Things (IoT) architecture. This will help the user to monitor the current weather and air quality of the surrounding area through the use of a mobile and/or web application. [Karlsson 2013] aimed to validate two measures of production loss, health-related and work environment–related production loss, concerning their associations with health status and work environment factors. They concluded, that measure of work environment–related production loss can be used to screen for production loss due to work environment problems as well as an outcome measure when evaluating the effect of organizational interventions.

Over the past few years, a number of different types of sensors have been implemented in the industry and so far. Sensors in the IoT (Internet of Things) platform collect, share data on a network of devices at a level that brings a kind of intelligence making the entire "ecosystem" smarter with time [Zou 2018].

The aim of the article is to introduce the prototype for environmental condition measurements, made by additive manufacturing. The developed device is able to measure these specific environmental factors as **temperature, relative humidity, atmospheric pressure, the amount of $CO_2$, volatile organic compounds**. Obtained data by indicative measurements in conformity with the Slovak legislative can be used for the regular preventive maintenance of operating conditions at the factory. The device can be used alone for local measurement (directly plugged into the computer through USB port), or data can be stored in the cloud when the devices are located in different places in the factory, thus creating a network of measuring devices.

## 2 WORK ENVIRONMENT AND ITS EVALUATION

### *2.1 3-D Manufactured Prototype Node With Sensor For Area Environmental Monitoring*

The difference between conventional and digital factory involves new sensors, innovative technical devices, new platforms and interconnection and communication of technical devices. The intelligent automation systems offer solutions for those customers who consider and aim for safe, convenient, cost saving, smart environment and can control following events: lighting and dimming, shades, outdoor / indoor blinds, opening / closing windows, unlocking/ locking the doors (electrical lock), garage doors and gates opening/ closing, heating, cooling (Air Conditioning), Fan-coil Units. Sensor systems can:

- Measure: Temperature, Humidity (Dew Point), Light Intensity, Concentration of Gases, etc.
- Detect: Motion, Respond to closure of any switch
- Optional device controlled by contactor or power relays
- Any device, which can be operated via communication standard RS 232, RS485, Ethernet, Infrared port and many others [Onofrejova 2014].

[Chowdhury 2019] proposes IoT system consisting of an IoT device and user interface software. The prototype device measures temperature, humidity, dust, UV index and different types of harmful gases and sends the data to a web server. The information is provided to the user like a weather app but with more insightful information. The device has the capability to gather and store data for a longer period which can be used to analyse changes over time.

Similar device for measuring the air quality of the working environment was developed by additive manufacturing as prototype intended for measuring local environmental changes, which are intended to use as complementary feedback when analysing human work behaviour with and without exoskeleton (Fig. 1). While wireless data transfer is reliable for a short distance, these devices features with direct measurement to PC, connection is secured by USB port. Basic IoT device with data storage in the IoT cloud can measure temperature, relative humidity, atmospheric pressure, the amount of $CO_2$, volatile organic compounds (TVOC), and dispose with adjustable atmospheric pressure offset, adjustable temperature correction (linear 2nd point), adjustable relative humidity correction (linear 2nd point), export data to a CSV file. Measurement period is every 10, 15, 20, 30 seconds and 1, 5, 10, 15, 20, 30 minutes. Measurement period with IoT module is set for 20 minutes, afterwards the measurement is sent to and stored in the cloud.

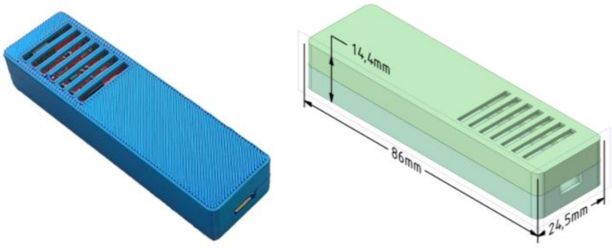


**Figure 1.** Equipment for measuring the air quality of the working environment

Before starting application, measurement mode can be adjusted in Settings, see Fig. 2. The sensor settings allow correction of temperature, pressure, humidity; also allow number format setting.

For the 3D design of the device case was used CAD software DesignSpark Mechanical and the firmware of device is programmed in the C and Assembler programming language.

### *2.2 Choosing filament for desktop 3D printing*

For desktop 3D printing, universal, easily achievable, easy to use depending on physical properties, 3D printer filament was used. The choice can be made from several types of filaments, depending on whether we rely on functional product like prosthetics or recreational like chess figures. The raw printing material of 3D printer filament vary from the everyday 3D printer filaments, such as PLA and PETG, to the tougher engineering-grade materials like Conductive PLA, Carbon Fiber and the exotics material supporting creativity like Flexible/TPE, Glow in The Dark. In addition to the likes of nylon, polycarbonate, carbon fiber reinforced, and polypropylene, there are also special blends with unusual properties like electrical conductivity and luminescence.

With such variety, it's easy to create functional, durable, and high-performing prints/prototype.

In the realm of consumer 3D printing, polylactic acid (PLA) is the most frequently used filament. Although it's often compared to ABS – the next most used – PLA is easily the most popular 3D printer filament type with its properties (see Tab. 1).

**Table 1.** Properties of the 3D printer filament type PLA

| 3D printer filament properties: PLA | |
|---|---|
| **Strength** | High |
| **Flexibility** | Low |
| **Durability** | Medium |
| **Print temperature** | 175 – 230°C |
| **Print bed temperature** | 50 – 60°C |
| **Shrinkage/warping** | Minimal |
| **Soluble** | chloroform, hot benzene |
| **Food safety** | yes |

PLA has a low printing temperature, and it doesn't require a heating bed (although it definitely helps). Another benefit of using PLA is that it doesn't give off an odour during printing, although depending on the type of PLA, there was reported some smelling. PLA is available in a wide range of colours and styles. Even many of specialty filaments use PLA as the base material, such as those with conductive or glow-in-the-dark properties or those infused with wood or metal [Locker 2021].

PLA is more environmentally friendly than many 3D printer filaments. The combination of biodegradability and low temperature resistance means that PLA prints are not ideal for outdoor use, even due to low UV resistance. PLA is only soluble in chemicals such as chloroform or hot benzene.

Compared to other types of 3D printer filament, PLA is brittle, so using it should be avoided when making items that might be bent, twisted, or repeatedly dropped, such as phone cases, high-wear toys, or tool handles. Also avoid using it with items that need to withstand higher temperatures, as PLA tends to deform around temperatures of 60°C or higher. For all other applications, PLA makes for a good overall choice in 3D printer filament.

Common prints include models, low-wear toys, prototype parts, and containers [Locker 2021].

### *2.3 Environmental Factors Measurement*

The work environment is a set of material and sensory and emotional values that create the conditions under which the work is performed. It is an environmental subsystem and is intended and used to perform the work. The work environment is made up of workers and factors which occur in the workplace or are related to the work performed and may affect health and wellbeing of the worker [Onofrejova 2020b].

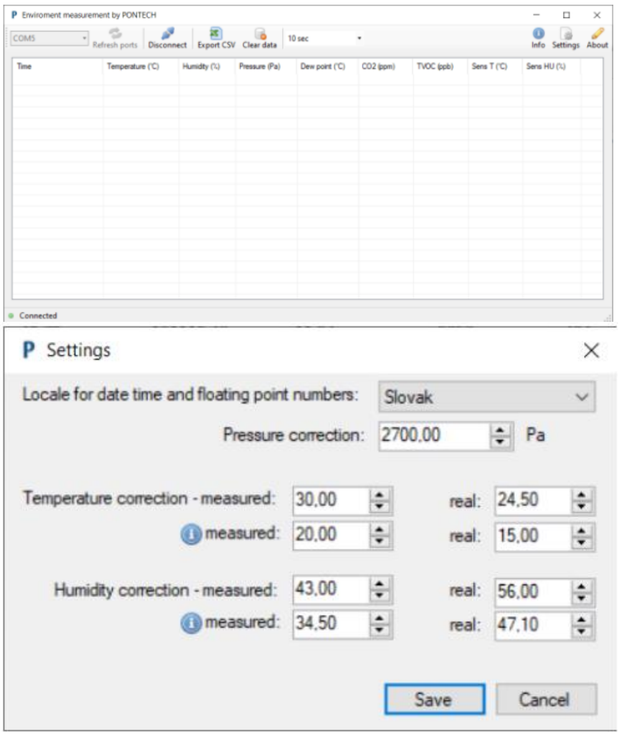


**Figure 2.** Setting the software application for measurement

Based on the consequences of working conditions the following are recognized in humans:

- **unpleasant working conditions:** do not cause a reduction in work performance, but often changes the employee's attitude to a certain reality (change of the subjective evaluation of a certain situation from pleasant to unpleasant),
- **disruptive working conditions:** result in reduced work performance (insufficient lighting, inappropriate socio - psychological factors),

- **harmful working conditions:** there is damage to the body - injury, occupational disease (extreme noise, high temperatures, chemicals, etc.).

At work, a person is exposed to many harmful influences. The role of ergonomics is analysing the harmful effects of a working environment, eliminating them and creating a higher comfort for a person during work. Some factors of the work environment are affecting others too. The detrimental effect of one may be initiated or attenuated by another factor.

The coexistence of factors can be:
- synergistic are mutually active cooperation,
- antagonistic have adverse effect,
- potentiating factors complement each other.

According to the character, the individual factors of the working environment are divided into the following subsystems: physical, chemical, biological, psychosocial, economic and other. Physical factors represent a significant risk factor in the work environment. Their risk depends on their **intensity, length** and **frequency** of action. Most of these factors significantly affects the human senses, burdens the nervous system and can have a negative effect on the overall human health.

The most frequent factors of the working environment include: lighting, noise, vibrations and shocks, workplace microclimate, dustiness, toxic substances, radiation. Evaluation and assessment of the state of the working environment requires a comparison of the findings with the requirements of standards and applicable regulations. Approaches to job evaluation environment can be:

- **subjective evaluation** of unmeasurable or difficult to measure factors, at of which only an informative assessment of the state of the environment on the basis of which measures will be taken to improve the current situation;
- **objective evaluation** of measurable factors using current methods and techniques measurements. This method is mainly used when subjective evaluation reveals the need for more detailed measurement of work environment factors.

The result of these evaluations is such an adjustment of the working environment that workers brings improvements in working conditions, elimination or mitigation harmful environmental factors, increasing safety at work, reducing the possibility of occurrence accident, resp. reducing the incidence of occupational diseases.

## 3 DIGITAL FACTORY TRANSFORMATION PROCESSES

Production sphere aims toward Intelligent Factories with cyber-physical systems monitoring the factory's physical processes and making decentralized decisions. Physical systems become the Internet of Things, communicate and collaborate with each other and with people in real time over a wireless web.

Acquiring these technologies is key to developing modern and intelligent manufacturing processes, which also include products, machines, production modules that communicate with each other, exchange information, run operations, and control each other through intelligent manufacturing environments [Fusko 2019]. This concept connects the physical and virtual worlds, enabling a radical increase in productivity and production efficiency and innovation and strengthen business in an integrated, data-driven production environment [Onofrejova 2014 and 2020b]. Smart factories are a step ahead of traditional automation, a system that is flexible, fully connected to the Internet, and can work with the constant flow of data coming from production systems or operations to learn and adapt to new requirements [Burke 2017].

### 3.1 *Legislative Obligations For Processing The Environmental Data For Ergonomic Purpose*

Decree of the Ministry of Health of the Slovak Republic from 26 June 2019, which amends the Decree of the Ministry of Health of the Slovak Republic No. 99/2016 Coll. on details of the protection of health against heat and cold at work provides work class according to the total average energy expenditure at the employee's work, optimal and permissible values of the factors of the thermal-humidity microclimate of the indoor working environment, tolerable load of heat and cold at work, protective and preventive measures in case of heat and cold load at work, permissible surface temperatures of solid materials and temperatures of liquids with which it comes into contact skin of the employee, drinking regime of the employee, health risk assessment, operating rules.

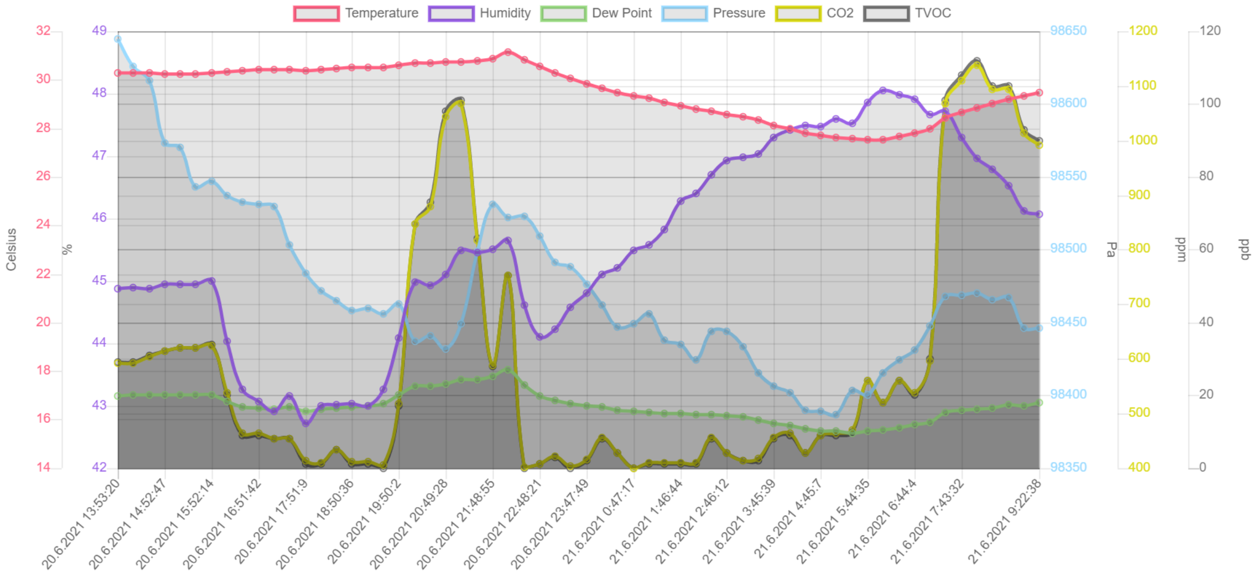


**Figure 3.** Output of measured local environmental data in the factory (Temperature, Humidity, Dew Point, Pressure, $CO_2$, TVOC)

Excessive heat exposure can cause health problems and damage to health in the form of fatigue to heat exhaustion, overheating of the body with increased body temperature, malaise, drowsiness, headache, dizziness, nausea, cramps, unconsciousness, but also skin damage in terms of burns. Damage to health caused by excessive heat stress at work is not part of the list of occupational diseases; they are classified as work-related illnesses.

Employers are obliged to ensure in particular to protect the health of employees during heat stress:

• Health risk assessment for activities where the assumption of heat load in the indoor workplace for technological reasons or during long-term work in the outdoor workplace on extremely hot days (the day during which the outdoor air temperature measured in the shade reached a value higher than 30 ° C). The assessment of the health risk at the workplace is performed by the occupational health service, which, according to the degree of risk, proposes measures to the employer to reduce or eliminate the risk. The employer is obliged to ensure the assessment of the health risk by the occupational health service at least once a year, as well as in the event of any significant change in working conditions. The heat load when working indoors is evaluated according to the operating temperature or the resulting temperature of the ball thermometer in conjunction with the relative humidity and the air flow rate.

New in the Decree of the Ministry of Health of the Slovak Republic no. 99/2016 Coll. In contrast to the current legislation, which required only objective measurement, it is possible to use data obtained from the state hydrological or meteorological service or data obtained by indicative measurements for the operational implementation of preventive measures during extremely hot days, when heat load is assumed. However, this data or indicative measurement cannot be used for the purpose of identifying hazardous work.

• Adherence to the permissible values of the heat-humidity microclimate factors during long-term work at the indoor workplace, if it is not possible to ensure the optimal values of the heat-humidity microclimate factors by technical measures.

### 3.2 *Processing The Measured Environmental Data For Ergonomic Operational Implamentation*

Output sample data from designed and implemented measuring device can be seen in Fig. 4.

| Time | Temperature (°C) | Humidity (%) | Pressure (Pa) | Dew point (°C) | CO2 (ppm) | TVOC (ppb) |
|---|---|---|---|---|---|---|
| 2.6.2021 7:42 | 24,66 | 39,27 | 102134 | 9,91 | 690 | 44 |
| 2.6.2021 8:02 | 24,81 | 41,59 | 102149 | 10,9 | 1389 | 150 |
| 2.6.2021 8:22 | 25,13 | 43,46 | 102155 | 11,85 | 1591 | 236 |
| 2.6.2021 8:42 | 25,31 | 43,23 | 102149 | 11,93 | 1572 | 224 |
| 2.6.2021 9:02 | 25,44 | 43,86 | 102141 | 12,27 | 1606 | 249 |
| 2.6.2021 9:21 | 25,5 | 43,1 | 102145 | 12,06 | 1520 | 185 |
| 2.6.2021 9:41 | 25,32 | 40,88 | 102158 | 11,1 | 780 | 57 |
| 2.6.2021 10:01 | 25,13 | 38,22 | 102156 | 9,92 | 588 | 28 |
| 2.6.2021 10:21 | 24,94 | 37,89 | 102163 | 9,62 | 485 | 12 |
| 2.6.2021 10:41 | 24,96 | 37,43 | 102147 | 9,45 | 577 | 26 |
| 2.6.2021 11:01 | 25,23 | 40,66 | 102125 | 10,94 | 780 | 57 |
| 2.6.2021 11:20 | 25,35 | 41,52 | 102121 | 11,35 | 923 | 79 |
| 2.6.2021 11:40 | 25,43 | 41,97 | 102120 | 11,59 | 964 | 85 |
| 2.6.2021 12:00 | 25,47 | 41,97 | 102138 | 11,63 | 964 | 85 |
| 2.6.2021 12:20 | 25,52 | 41,94 | 102132 | 11,66 | 964 | 85 |
| 2.6.2021 12:40 | 25,57 | 42,36 | 102129 | 11,86 | 1019 | 94 |
| 2.6.2021 13:00 | 25,56 | 41,95 | 102125 | 11,71 | 995 | 90 |
| 2.6.2021 13:19 | 25,36 | 40,69 | 102124 | 11,07 | 737 | 51 |
| 2.6.2021 13:39 | 25,32 | 39,19 | 102123 | 10,46 | 704 | 46 |
| 2.6.2021 13:59 | 25,34 | 39,03 | 102118 | 10,41 | 692 | 44 |
| 2.6.2021 14:19 | 25,41 | 38,77 | 102121 | 10,38 | 1053 | 99 |
| 2.6.2021 14:39 | 25,46 | 38,72 | 102120 | 10,41 | 885 | 73 |
| 2.6.2021 14:58 | 25,5 | 39,24 | 102128 | 10,64 | 844 | 67 |

**Figure 4.** Correlated measured data sample as output from designed and implemented measuring device

There are a few possibilities of displaying the measured data stored in the cloud via web interface, for example using software Java with Java Script, see Fig. 3.

Obtained data by indicative measurements in conformity with the Slovak legislative can be used for the operational implementation of preventive measures during extremely hot days, when the heat load is assumed. Data can be processed by standard software as MS Excel (Fig. 5), Anova, Minitab and others, as they have output in form of csv file.

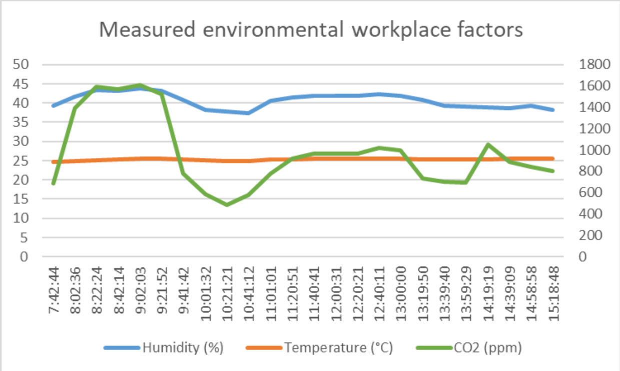


**Figure 5.** Processed real time measured data from the workplace category type 1c

The measurements in Fig. 5 were accomplished with the above mentioned device during beginning of July in the prototype centre with air-conditioning turned off, but with secured airflow through open windows and partly open back doors. The outdoor temperature reached at the noon 33 ˚C. As operators must wear working uniforms, our issue of interest was the level of indoor temperature and humidity. Are those factors set according to the legislative standards, or must an employer take action and thus eliminate the ergonomic risk?

For example, the results for chosen work category show, that according to the legislative [Decree No. 99/2019 Coll.], work indicated in category 1c, which is the type of work in sitting position as laboratory work, control, set-up of light objects; in standing position the type of work as drilling or milling of small parts, machining with low performance tools, temporary walking (speed up to 2,5 km/h). Optimum operative temperature at workplace is 20 – 24 ˚C, maximal allowed 26 ˚C, allowed relative air humidity 30 – 70 %. According to our measurements (see Fig. 4, Fig. 5), captured data are in accordance with directive, thus there is no need to propose corrective measures to the employer to reduce or eliminate the ergonomic risk at the workplace.

## 4 CONCLUSIONS

Now, industry inevitably needs infrastructure and tools to help it successfully transform. The support is depicted in the Recovery plan approved by the government of Slovak Republic in the area of education and health (wellbeing and active aging), energy/green economics, research, development, innovation, public management, sustainability of public finances, labour market, pensions, social inclusion.

Ambient intelligence will play a very important role in new effective production systems. Savings in costs, improving safety and the whole management in a factory will enforce its competitiveness. Implementation of intelligent systems, thus creating intelligent environments has growing tendency in increasing the efficiency and effectiveness of work. Companies want to manage the business intelligently and reduce costs, but they are already considering solutions to replace the shortage of employees. The transformation to digital factory involves new sensors, innovative technical devices, new platforms and interconnection and communication of technical devices. The intelligent automation systems offer solutions for those beneficiaries who consider and aim for safe, convenient, cost saving, smart sustainable resilient environment with smart control.

Work environment considerably affects the productivity, health and safety of workers. Monitoring of the working environment with reliable miniaturized technology can guarantee suitable working conditions. In the line with the EU Strategic Framework on Health and Safety at Work 2014-2020, one of EU-OSHA's priorities is to fortify the prevention of work-related diseases. Excessive heat exposure can cause health problems and damage to health in the form of fatigue to heat exhaustion, overheating of the body with increased body temperature, malaise, drowsiness, headache, dizziness, nausea, cramps, unconsciousness, but also skin damage in terms of burns. Damage to health caused by excessive heat stress at work is not part of the list of occupational diseases; they are classified as work-related illnesses.

Our simple IoT device with data storage in the IoT cloud can measure temperature, relative humidity, atmospheric pressure, the amount of $CO_2$, volatile organic compounds (TVOC) and is suitable for creating the stable system for performing indicative measurements for the operational implementation of preventive measures during extremely hot days, when heat load is assumed. The device can be used alone for local measurement (directly plugged into the computer through USB port), or data can be stored in the cloud when the devices are located in different places in the factory, thus creating a network of measuring devices.

## ACKNOWLEDGMENTS

This work has been supported by the Slovak Grant Agency KEGA 009TUKE-4/2020, and the Agency Supporting Research and Development APVV-19-0290.

## REFERENCES

[Balazikova 2019] Balazikova, M., Andrejiova, M., Wysoczanska, B. Methodology for Risk Assessment of Noise Effects at Workplace. MM Science Journal, 2019, Vol. 12, pp. 3426-3430.

[Burke 2017] Burke, R. et al. The smart factory: Responsive, adaptive, connected manufacturing [online]. 2017, [downloaded 2018-12-19]. Available from: https://www2.deloitte.com/insights/us/en/focus/industry-4-0/smart-factory-connected-manufacturing.html

[Council Directive 89/391/EEC] Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work [online]. Council of the European Union, 2008. [downloaded 03/03/2021]. Available from: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A31989L0391

[Chowdhury 2019] Chowdhury, A.H., Arabi, A.A., Amin, M.A. In Search of a Low-Cost IoT System for Real-Time Environment Monitoring. Computer Science. In: IEEE International Conference on Robotics, Automation, Artificial-intelligence and Internet-of-Things (RAAICON), 2019.

[Decree No. 99/2019 Coll.] Decree of the Ministry of Health of the Slovak Republic from 26 June 2019, which amends the Decree of the Ministry of Health of the Slovak Republic No. 99/2016 Coll. on details of the protection of health against heat and cold at work. [downloaded 03/03/2021]. Available from: https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2016/99

[Farooqui 2017] Farooqui, M.F., Karimi, M.A., Salama, K.N., Shamim, A. 3D-Printed Disposable Wireless Sensors with

Integrated Microelectronics for Large Area Environmental Monitoring. In: Advanced Material Technology, Vol. 2, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2017.

[Fusko 2019] Fusko, M. et al. Concept of long-term sustainable intralogistics in plastic recycling factory. Sustainability, 2019, Vol. 11, No. 23, pp. 1-27. ISSN 2071-1050. Available from: https://www.mdpi.com/2071-1050/11/23/6750/htm

[Holla 2019] Holla, K., Moricova, V. Specifics of Monitoring and Analysing Emergencies in Information Systems. In: 13th International Scientific Conference On Sustainable, Modern and Safe Transport (TRANSCOM 2019), 2019, Vol. 40, pp. 1343-1348.

[Kanagachidambaresan 2021] Kanagachidambaresan G.R. Introduction to 3d Printing and Prototyping. In: Role of Single Board Computers (SBCs) in rapid IoT Prototyping. Internet of Things (Technology, Communications and Computing). Springer, Cham, 2021. ISBN 978-3-030-72957-8.

[Karlsson 2013] Karlsson, L.M., Bergström, G., Björklund, Ch., Hagberg, J., Jensen, I. Measuring Production Loss due to Health and Work Environment Problems. Journal of Occupational and Environmental Medicine, 2013, Vol. 55, No. 12, pp. 1475-1483.

[Kubicek 2019] Kubicek et al. Working conditions and workers' health [online]. Eurofound, 2019. [downloaded 04/29/2021] Available from: https://www.eurofound.europa.eu/publications/report/2019/working-conditions-and-workers-health

[Liacouras 2021] Liacouras, P., Wake, N. 3D Printing Principles and Technologies, Chapter 5. In: 3D Printing for the Radiologist, Elsevier, 2021, pp. 61-73, ISBN 978-0-323-77573-1.

[Locker 2021] Locker, A. 3D Printer Filament – The Ultimate Guide. All3DP, 2021, Munich, Germany. [downloaded 30.04.2021] Available from: https://all3dp.com/1/3d-printer-filament-types-3d-printing-3d-filament/

[Onofrejova 2014] Onofrejova, D., Onofrej, P., Simsik, D. Model of Production Environment Controlled with Intelligent Systems. In: Proc. of Modelling of Mechanical and Mechatronic Systems MMaMS 2014: 25th-27th November 2014, High Tatras, Slovakia. Procedia Engineering, 2014, No. 96, pp. 330-337.

[Onofrejova 2020a] Onofrejova, D., Sebo, J. Ergonomics in Industry. Kosice, Slovakia: Technical University of Kosice, 2020, ISBN 978-80-553-3684-8 (in Slovak).

[Onofrejova 2020b] Onofrejova, D. et al. Simulation and Evaluation of Production Factors in Manufacturing of Fireplaces. In: International Journal of Simulation Modelling (IJSIMM). Wolkersdorf im Weinviertel (Austria): DAAAM International Vienna, 2020, Vol. 19, No. 1, pp. 77-88. ISSN 1726-4529.

[Panda 2019] Panda, A. et al. Development of the method for predicting the resource of mechanical systems. The International Journal of Advanced Manufacturing Technology, 2019, Vol. 105, No. 1-4, pp. 1563-1571. ISSN 0268-3768.

[Zou 2018] Zou, J. et al. Production System Performance Identification Using Sensor Data. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 2018, Vol. 48. No. 2, pp. 255-265. ISSN 2168-2216.

## CONTACTS

Ing. Daniela Onofrejova, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering
Institute of Special Engineering Processologies, Department of Safety and Production Quality
Letna 9, Kosice, 042 00 Slovakia
Telephone: +421 55 602 2513, e-mail: daniela.onofrejova@tuke.sk, web: http://www.sjf.tuke.sk/kbakp/

prof. Ing. Jaroslava Kadarova, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering
Institute of Management, Industrial and Digital Engineering
Park Komenskeho 9, Kosice, 042 00 Slovakia
Telephone: +421 55 602 3242, e-mail: jaroslava.kadarova@tuke.sk, web: http://www.sjf.tuke.sk/umpadi/

Assoc. Prof. Ing. Jaroslava Janekova, PhD.
Technical University of Kosice, Faculty of Mechanical Engineering
Institute of Management, Industrial and Digital Engineering
Park Komenskeho 9, Kosice, 042 00 Slovakia
Telephone: +421 55 602 3239, e-mail: jaroslava.janekova@tuke.sk, web: http://www.sjf.tuke.sk/umpadi/