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August 2021

Environmental management, land use, biodiversity

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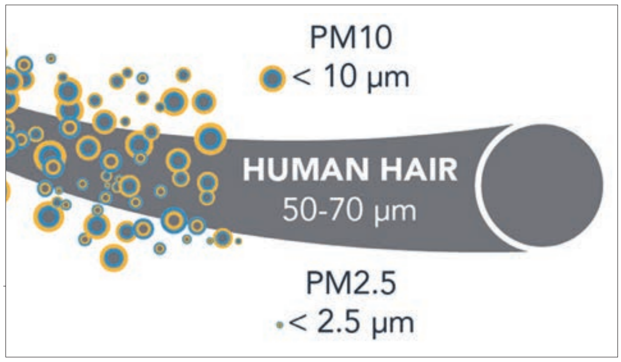

THE NITROGEN DIOXIDE (NO_2) AND PM_{10} POLLUTION LEVEL IN DEBRECEN, MISKOLC, AND NYÍREGYHÁZA HUNGARY IN THE PREVIOUS 4 YEARS

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ABSTRACT

Air quality represents a big concern all over the world, especially in urban areas. The level of air quality is controlled by determining the level of concentration of air pollutants, and it should be according to the air quality standard. The level of concentration of nitrogen dioxide (NO_2) and PM_{10} were analysed in this study for the cities of Debrecen, Miskolc, and Nyíregyháza in Hungary in the previous four years (2017, 2018, 2019, and 2020). The level of NO_2 and PM_{10} pollution was higher in 2017 than the other years, specifically for the PM_{10} where the daily average concentration was critical and reached 200 µg/m3, 358 µg/m^3, and 256 µg/m^3 in Miskolc, Debrecen, and Nyíregyháza respectively as daily average concentration. While the NO_2 level of concentration decreased in 2018, 2019, and 2020 with no exceedance of the daily limit value, the PM_{10} concentration continued to register higher daily average concentration, and surpass the daily limit value and the number of exceedances permitted each year by the European Union commission, particularly in Miskolc and Nyíregyháza. Thus, the level of PM_{10} pollution is relatively high in the three cities and can cause harmful effects to plants, and reduction in growth of numerous plants can occur.

keywords: NO_2, PM_{10}, Debrecen, Miskolc, Nyíregyháza

INTRODUCTION

Air pollution is the primary cause of the decline in air and environmental quality in many places across the world nowadays, with negative consequences for people's health. According to the most recent World Health Organization (WHO) report, more than 91% of people in urban areas are exposed to air quality levels that exceed the emission limits for air pollution (WHO, 2021). Carbon monoxide (CO), particulate matter (PM), nitrogen oxides (NO_x), volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), ozone (O_3), and sulfur dioxide are the primary atmospheric pollutants (SO_2). The rapid industrialization and urbanization of developing countries have increased the number of pollutants emitted (Fu & Chen, 2017, Hermanucz, 2018). Because of the strong relationship between air pollution exposure and increased harmful short- and long-term effects on human health, the scientific community, and public opinion are both concerned about the deterioration of air quality in urban environments (Masiol et al., 2014, Benécs et al., 2018). Aside from the health dangers posed by gas and particle inhalation, urban air pollution causes other issues such as faster corrosion and deterioration of materials, damage to historical monuments and structures, and damage to plants in and around the city (Vlachokostas et al., 2011).

Particulate matter (PM) is a broad word that refers to a mixture of solid particles and liquid droplets (aerosols) whose size and composition change depending on time and place. PM is composed of numerous constituents, including elemental or black carbon (BC) and organic carbon (OC) molecules, sulfate (SO_4^{-2}), nitrate (NO_3^-), trace metals, soil particles, and sea salt. PM comes in a variety of sizes (Figure 1), including PM with a diameter that is less than or equal to 10 µm (PM_{10}), PM with a diameter of less than or equal to 2.5 µm ($PM_{2.5}$), also known as fine particles, PM with a diameter of less than or equal to 0.1 µm ($PM_{0.1}$), also known as ultrafine particles (UFP), and PM with a diameter of less than or equal to 0.05 µm ($PM_{0.05}$), also known as nanoparticles. PM can be di-

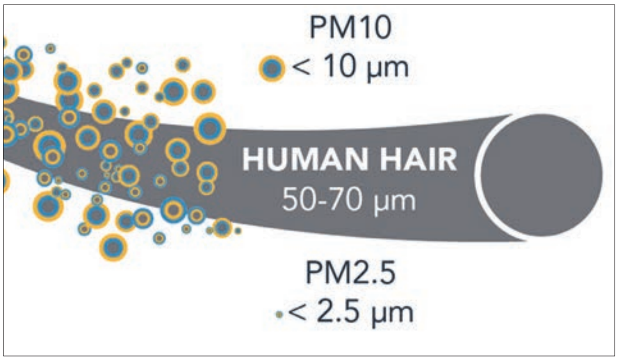

Figure 1: Particulate Matter (PM) size comparison (California Air Resources Board)

rectly emitted from anthropogenic (man-made) or natural sources (i.e., primary PM), or formed in the atmosphere from chemical reactions of numerous gaseous such as volatile organic compounds (VOCs), ammonia (NH_3), oxides of sulfur (SO_x), and oxides of nitrogen (NO_x) (i.e., secondary PM) (Harrison et al., 2016).
When agricultural crops are exposed to high concentrations of various air pollutants, they can be harmed. Injury can range from visible markings on the foliage to reduced growth and yield to the plant dying prematurely. The onset and severity of the injury are determined not only by the concentration of the specific pollutant, but also by a number of other factors. Which include the duration of exposure to the pollutant, the plant species and phase of growth, as well as environmental factors that promote pollutant formation and preconditioning of the plant, making it either sensitive or resistant to damage (Figure 2) (Heather, 2003).

Figure 2: Cement-dust coating on apple leaves and fruit (Heather, 2003)

Pollutants in the atmosphere have a negative impact on plants; they can be toxic directly or indirectly by changing soil pH, which leads to the solubilization of toxic salts of metals such as aluminium. Particulate matter has a negative mechanical impact. They cover the leaf blade, reducing light penetration and obstructing stomatal openings. These impediments have a significant impact on the photosynthesis process, causing the rate to drop dramatically. Also, the leaves of trees play a key role in particulate matter retention; they are most affected when wet and dry atmospheric deposition increase. The vegetation plays a vital role mostly in purifying of the atmosphere and the reduction of air pollutants. Plants, as primary producers, play an important role in biogeochemical cycles. Photosynthesis, respiration processes, and the final stage of litter decomposition, mineralization, all allowed vegetation to exchange some of the atmospheric gases. Photosynthesis by plants contributes significantly to the reduction of atmospheric CO_2 content. This reduction in atmospheric CO_2 content plays an important role in the reduction of greenhouse gases, thereby contributing to the reduction of the greenhouse effect and its consequences for climatic changes. Plants store carbon as a result of a balance between carbon fixed by photosynthesis and carbon released into the atmosphere through respiration (Gheorghe & Ion, 2011).
The EU established limit values that apply both in urban background areas and hotspots (traffic or industrial), as well as from north to south and west to east Europe, attempting to protect citizens from various socioeconomic backgrounds and development areas from air pollution. All of these efforts resulted in significant reductions in emissions and levels of air pollutants in the environment. However, in the last ten years, the rate of emission reduction has been much faster than the rate of decrease in pollutant levels in ambient air (Minguillón et al., 2013).
The purpose of this paper is to evaluate the level of PM_{10} and NO_2 pollution in the following 3 cities in Hungary: Debrecen, Miskolc, and Nyíregyháza during the previous four years.

MATERIAL AND METHODS

Area of study

Hungary is a central European country that surrounds by seven countries (Austria, Slovakia, Slovenia, Ukraine, Romania, Serbia, and Croatia) with a population of 9,660,351 in 2020 (Worldometer, 2021). A big part of the country has an elevation of below 200 m above sea level which makes the country looks like a big flat area. Debrecen is the second-largest city in the country after the Capital Budapest, with a population of 201,112 in 2020 (Hungarian Central Statistical Office, 2020a), located in the Northern Great Plain of Hungary. Not so far from Debrecen, and about 50 km to the North, there is the city of Nyíregyháza, it is the seventh-largest city in Hungary with a population of 116,814 in 2020 (Hungarian Central Statistical Office, 2020c). Miskolc is a city known for its heavy industry, located in the North Hungarian mountains and classified as the fourth biggest city in Hungary after Debrecen and Szeged with a population of 152,901 in 2020 (Hungarian Central Statistical Office, 2020b).

NO_2 and PM_{10} data

The NO_2 and PM_{10} concentration data for the years 2017, 2018, 2019, and 2020 were retrieved from the Hungarian Air Quality Network platform (Országos Légszennyezettségi Mérőhálózat (OLM)), which is a platform that provides actual and historical air quality monitoring data throughout Hungary. Debrecen contains three air quality stations (Debrecen Hajnal u., Debrecen Kalotaszeg tér, and Debrecen Klinika). Same for Miskolc, that hosts also three air quality stations (Miskolc Alföldi, Miskolc Búza tér, and Miskolc Lavotta), while Nyíregyháza contains only one air quality station (OLM, 2021).

RESULTS

NO_2 level of concentration in Debrecen

In 2017, the limit daily value of 85 µg/m^3 for the NO_2 concentration was violated for 2 times, once in Debrecen Hajnal u station on the 30th of January registering a daily average concentration of 96.9 µg/m^3, and the second time was at the same date but in Debrecen Klinika reaching 88.6 µg/m^3. In 2018 the situation seemed to be controllable since there was no violation of the daily limit value.

In 2019 the daily limit value was violated 3 times in Debrecen Hajnal u station on the 19th of February, 18th, and 21st of October, and in the same station, the NO_2 concentrations were higher than the other 2 stations in Debrecen. And in 2020, no violation of the daily limit value occurred, and the highest NO_2 concentration registered at that year was 69.1 µg/m^3 in Debrecen Klinika on the 7th of January (Figure 3).

Debrecen Hajnal u station always had the highest yearly average NO_2 concentration, and that can be related to the location of the station, since it is located in the city center of Debrecen where the traffic is high.

PM_{10} level of concentration in Debrecen

In 2017 The PM_{10} daily average concentration exceeded the daily limit value for 35, 24, and 32 times in Debrecen Hajnal u, Debrecen Kalotaszeg tér, and Debrecen Klinika respectively, and the highest daily average concentration registered was 200 µg/m^3 on 30th of January in Debrecen Klinika. In 2018 the situation was better than in 2017. The PM_{10} daily limit value was exceeded for 25, 20 and 6 times in Debrecen Hajnal u, Debrecen Kalotaszeg tér and Debrecen Klinika respectively, with maximum concentration of 83µg/m^3 registered in Debrecen Kalotaszeg tér on the 8th of November. In 2019, the daily concentration reached 106 µg/m^3 on the 27th of October in Debrecen Kalotaszeg tér, which was the highest daily concentration registered that year. Also, the daily limit value was violated 24, 25, and 20 times in Debrecen Hajnal u, Debrecen Kalotaszeg tér and Debrecen Klinika respectively. In 2020 there was a slight decrease in the level of PM_{10} concentration and also the violation times where the daily limit value was exceeded. For 2020, 11, 15, and 5 were the number of times the PM_{10} concentration was higher than the daily limit value in Debrecen Hajnal u, Debrecen Kalotaszeg tér and Debrecen Klinika respectively, and the peak PM_{10} daily average concentration was 83 µg/m^3 on the 26th of March in Debrecen Kalotaszeg tér (Figure 4).

Figure 3: Debrecen NO_2 average daily concentration in 2017, 2018, 2019, and 2020

Figure 4: Debrecen PM_{10} average daily concentration in 2017, 2018, 2019, and 2020

Debrecen Hajnal u station always had the highest yearly average PM_{10} concentration in all the years, but the highest daily PM_{10} concentration was registered in Debrecen Kalotaszeg tér for 3 consecutive years (2018, 2019, and 2020) and in Debrecen Klinika one in 2017 and was the highest in all the four years.

NO_2 level of concentration in Miskolc

For Miskolc, only in 2017 the limit value of 85 µg/m^3 was violated 2, 4 and 2 times in Miskolc Alföldi, Miskolc Búza tér and Miskolc Lavotta respectively, while 2018, 2019 and 2020 no violation occurred. The highest NO_2 daily concentration was registered in Miskolc Búza tér in the 30th of January 2017 and was 127 µg/m^3, for 2018, 2019, and 2020 the highest concentration occurred in Miskolc Alföldi and was 71.9 µg/m^3, 63.8 µg/m^3, and 63.8 µg/m^3 respectively. The average yearly concentration of NO_2 was decreasing each year, while Miskolc Búza tér always had the highest yearly average concentration since it is located in the city center of Miskolc (Figure 5).

PM_{10} level of concentration in Miskolc

The PM_{10} level concentration in Miskolc is in a critical situation. The EU air quality standard states that the daily PM_{10} concentration limit value of 50 µg/m^3 should not be exceeded throughout the year more than 35 times. In 2017, the daily PM_{10} concentration limit value was violated for 64, 66, and 39 times in Miskolc Alföldi, Miskolc Búza tér and Miskolc Lavotta respectively, besides that the highest concentration was at the level of 358 µg/m^3 registered in Miskolc Alföldi on the 30th of January 2017 which shows the terrible situation at that year. In 2018, the maximum PM_{10} daily concentration decreased to 118µg/m^3 registered in Miskolc Búza tér on the 22nd of December, while, the number of times where the daily limit value was exceeded reached 62, 83, and 30 in Miskolc Alföldi, Miskolc Búza tér and Miskolc Lavotta respectively. In 2019, no big improvement from the previous year with maximum daily PM_{10} concentration of 122 µg/m^3 registered also in Miskolc Búza tér, and 70, 68, and 30 times where the PM_{10} daily limit value was violated in Miskolc Alföldi, Miskolc Búza tér and Miskolc Lavotta respectively. In 2020, the situation was slightly better than the 2 previous years, with a decrease of the average yearly concentration in all the stations in Miskolc and also the number of violations of the daily limit value concentration (48,42, and 18 for Miskolc Alföldi, Miskolc Búza tér and Miskolc Lavotta respectively) (Figure 6).

NO_2 level of concentration in Nyíregyháza

The concentration level of NO_2 in Nyíregyháza showed improvement between 2017 and 2020. In 2017 the violation of the daily limit value happened 2 times, on the 30th and 31st of January 2017. However, in 2018, 2019, 2020 the average daily concentration was below the daily limit value all the year, and the level of NO_2 pollution was decreasing, as the annual average concentration was decreasing also (Figure 7).

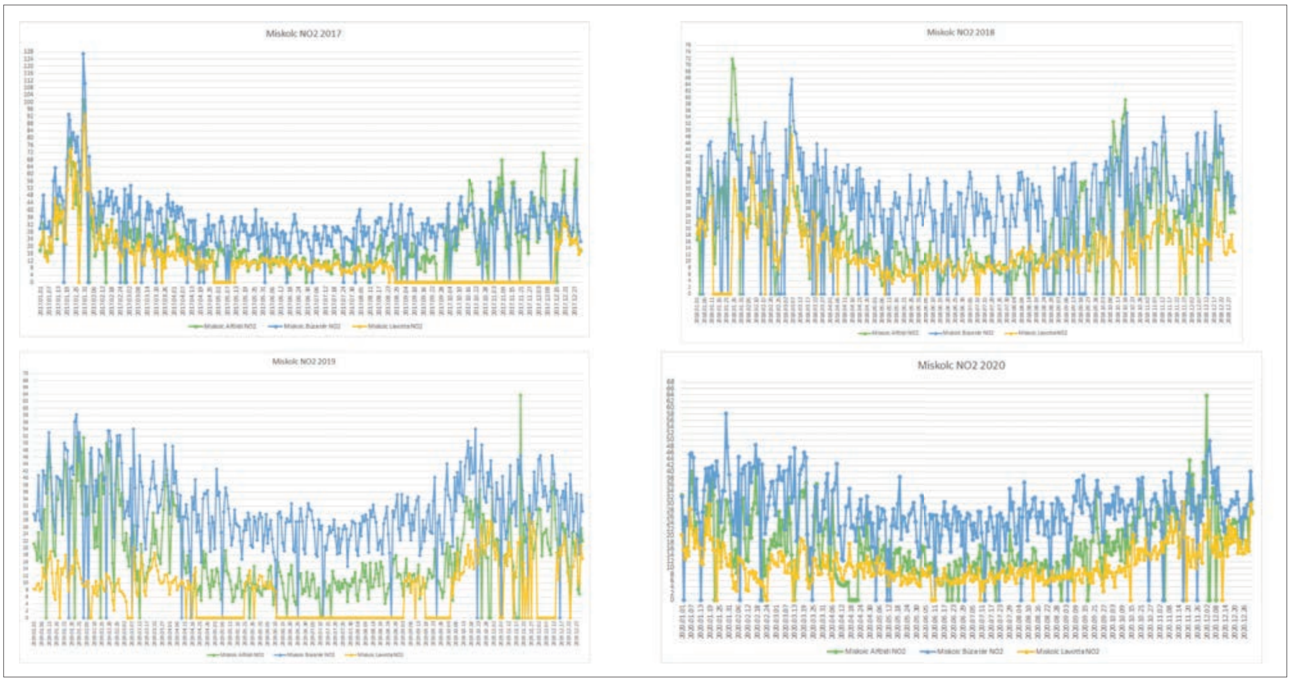

Figure 5: Miskolc NO_2 average daily concentration in 2017, 2018, 2019, and 2020

Figure 6: Miskolc PM_{10} average daily concentration in 2017, 2018, 2019, and 2020

PM_{10} level of concentration in Nyíregyháza

For the PM_{10}, 2017 was awful, especially during winter. The PM_{10} average daily concentration exceeded the daily limit value 43 times, which is higher also than the number of times of permitted exceedance each year allowed by the European Union Commission, while the highest PM_{10} average daily concentration was 256 μg/m^3 registered on the 31st of January. In 2018, the same number of the exceedance of the daily limit value (43 times) as in 2017 was registered, with the highest daily average concentration lower than 2017, accounting for 108 μg/m^3. In 2019, the level of PM_{10} concentration showed no improvement, the peak daily concentration reached 126 μg/m^3, and the exceedance of daily ceiling concentration occurred 42 times. However, in 2020, the PM_{10} concentration level slightly improved. The number of violations of the daily limit value dropped to 32 times, and the highest concentration reached that year was 77μg/m^3 (Figure 8).

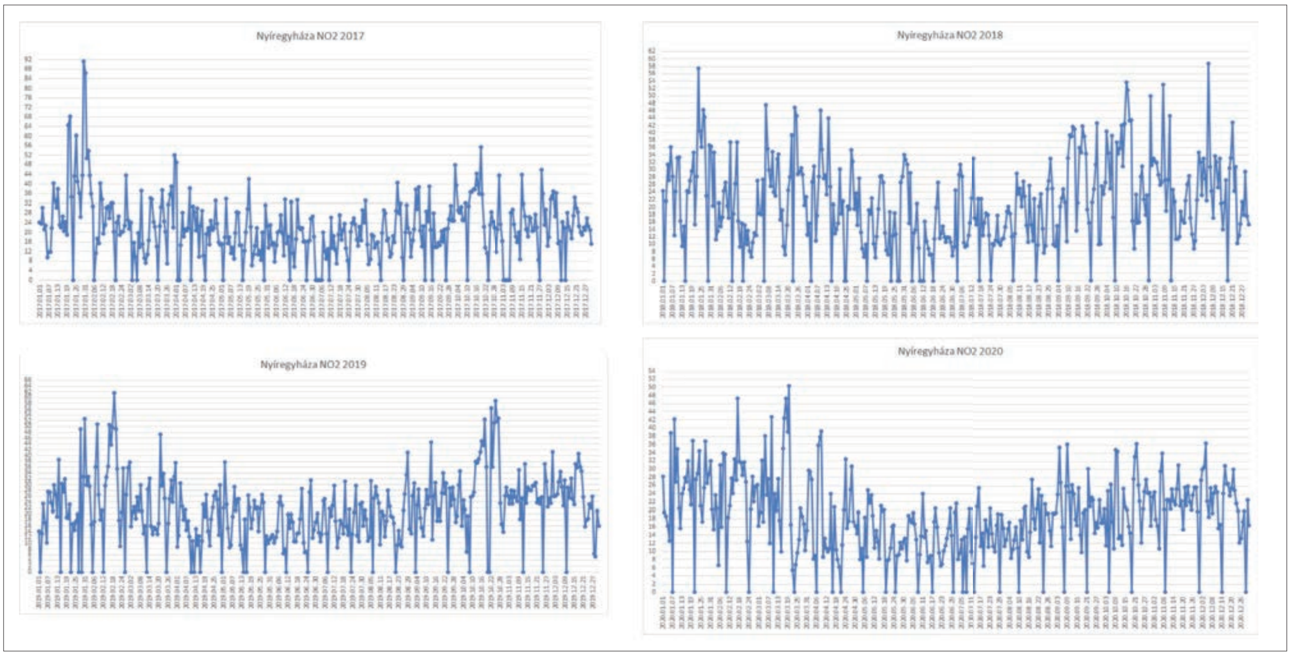

Figure 7: Nyíregyháza NO_2 average daily concentration in 2017, 2018, 2019, and 2020

Figure 8: Nyíregyháza PM_{10} average daily concentration in 2017, 2018, 2019, and 2020

DISCUSSION

Stations like Debrecen Hajnal u, Miskolc Búza tér and Nyíregyháza are considered as traffic stations and always register higher concentration of NO_2 and PM_{10}, and even rural stations like Debrecen Klinika and Miskolc Lavotta register high concentrations specifically for PM_{10}, which increase the influence on agricultural activities, as the deposition of the PM particles on vegetation can interfere with the leaf's normal respiration and photosynthesis mechanisms and inhibit the action of a pre-harvest crop spray.

CONCLUSIONS

Air pollution is still a serious problem in today's society. The level of NO_2 pollution concentration showed improvement in Debrecen, Miskolc, and Nyíregyháza, and the NO_2 daily average concentration was a decreasing year after year, also the level of NO_2 was controllable and better from 2018. For the PM_{10} pollution level, the concentration is still high and the number of violations surpasses the permitted exceedance allowed each year by the European Union Commission, especially in Nyíregyháza, Miskolc Alföldi, and Miskolc Búza tér, in addition, the level of PM_{10} concentration is higher in Miskolc and Nyíregyháza than Debrecen.

The hotspot stations in Debrecen and Miskolc (Debrecen Hajnal u and Miskolc Búza tér) always registered higher concentration than the other stations, along with Nyíregyháza air quality station. Moreover, during the winter the concentration of NO_2 and PM_{10} was higher than the other seasons, due to the high probability of occurrence of a temperature inversion that traps the air pollutants near the ground surface, and for most of the times, the highest daily average concentration for both NO_2 and PM_{10} occurred on the 30th or the 31st of January. Furthermore, the worse year was 2017 with critical concentration levels that surpassed 200μg/m^3 (200μg/m^3, 358μg/m^3, and 256μg/m^3 registered in Miskolc Alföldi, Debrecen Klinika, and Nyíregyháza respectively).

Finally, the NO_2 pollution level is improving over the years in the three Hungarian cities, while, the PM_{10} pollution level is still hard to be controlled, mainly because of the long- and short-range transportation of the atmospheric particles. Moreover, high concentration of PM_{10} increase its influence on the agricultural activities because the deposition of particles on vegetation can disrupt the normal photosynthesis and respiration processes of the leaf, and can raise soil pH to levels that are detrimental to crop growth.

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SIMULATION AND EXPERIMENT OF APPLE FRUITS IN DOMESTIC FRIDGE

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ABSTRACT

The fridge is considered as the most important item in the food store chain and considered as the most used electrical appliances in the world, where many farmers store their harvested fruit or vegetables from one season to another, aiming to get higher prices and to ensure the availability of the item all around the year. To stop or reduce the duplicating process of the bacteria in the food, the fruit and vegetables must be stored in appropriate temperature and humidity. In inappropriate temperature conditions like between 5 - 60 °C, bacteria can get doubled every twenty minutes. In this paper, apple fruits with different sizes are analysed in a small-medium size storing fridge, to check the temperature fluctuation due to on/off working behaviour of the motor. And the thermal distribution due to the big fridge dimensions in height mainly. All these measured parameters are compared to simulated calculations using ANSYS. The open-close door influence is measured on the apple crispy taste and visual parameters using colour sensors in the small-scale house fridge. The results show that modelling using convection mode is the closest to the real-time experiment compared to the non-conviction model, and the colour measurement for 5 days does not show a significant difference from this aspect. On the other hand, the three-shelves fridge showed crucial temperature difference in the lower shelf.

keywords: Apple, ANSYS, Bacteria, Temperature

INTRODUCTION

Huge amounts of apple are harvested annually, in 2010 the number was about 69 million tonnes (Brennan et al. n.d.). Considering that consumption does not follow mass production and people consume the fruit all around the year, storing is the best solution and can get more profit if sold out of the season. Also, countries, where large amounts of this fruit cannot be locally cultivated, due to expenses or climate conditions, so they have to import it. Therefore, cooled cargo containers are needed (Farkas, et al. 2019). The main parameter of storing the harvested production is to be picked correctly and stored in appropriately. Stored apples need to be harvested at the minimum maturity point and the storing period varies a lot according to the cultivar species from 1-2 weeks to 3-6 months. If the storing period is exceeded, the apple starts to develop an off flavour because the fruit starts to feed on the sugar, starch, and the acid content after losing the nutrients from the tree. The good storing apple depends a lot on the cultivars, maturity picking stage, how soon the fruit was cooled, and finally the storing conditions (temperature and humidity). Where the appropriate conditions are from 0 to 5 °C with 90-95 humidity ratio and with 0.2% loss of moisture per month,
If the humidity is not accurate, apples will be dehydrated and shrivelled (Naeve, et al. 2008). To enhance the food compartment for the fresh or storing, the thermal behaviour must be improved by many methods in the domestic and commercial refrigerating field. Estimating the best solution must be done by comparing the simulation results with the experiments and to understand the risk in it. Garrido et al. (2010) did a measurement of a ham slice in 33 domestic refrigerators in Spain showing that after just three days of two storage temperature 5 and 9, the ham reaches a dangerous level of pathogens. Also, they focus on building a colour model graph where the appropriate position of the shelf can be determined. Many approaches have focused on the energetic aspects; however, thermal distribution and air flow is essential as well (Ding, et al. 2004), where the appropriate temperature condition will result in better storing (Brown, et al. 2014). Better interior designs are needed, since the temperature variation is prejudiced in the fridge (Gupta, et al., 2007)
Refrigeration represents a share of around 28% of all usage of electricity in domestic scenarios. This number use can be intensified or diminished by refrigerator efficiency, as well as its open-close door dynamic throughout time. An experiment carried out in Bangladesh revealed

that opening a refrigerator door can increase the energy consumption by 7-30% depending on the frequency of the opening (Hossen Khan, et al. 2014; Géczi G., et al. 2019). Another research made in Malaysia corroborates this conclusion, the scholars found an increase of 40% of energy usage in an open-door refrigerator (Hasanuzzaman, et al. 2008). This process also impacts on the compressor on-off cycling, as shown at the same study, it is increased by 2-5 times, increasing loss in the refrigeration system and therefore, decreasing refrigerator lifespan and increasing hazardous waste. In addition, the fluctuation of inside temperature can lead to lower food quality, which is the investigation point for this present study.
In this paper, we aim to analyse the temperature fluctuation on the apple fruits (core and shell) due to on/off working behaviour of the motor in the domestic fridge environment, as well as the influence of the apple rigidity and colour. The specific goals are: ANSYS simulation of thermal distribution; measure real temperature of the apples (core and shell), compare results from ANSYS simulated calculation and real data. The resulting apple fruit will be measured according to colour measurement based on the green and yellow dyes on the skin of the apple. In usual conditions of temperate zones, harvested apples do not need pre-cooling; however, if the apples temperature is high, it must be precooled quickly.

MATERIAL AND METHODS

In order to carry out the experiment were used the following materials: a small-scale storage fridge (Gorenje) with nominal power 73 W; an electrical clamp meter (Chauvin arnoux); a power monitor socket type “EM 231”; data logger, type Almemo 2590-9; and temperature sensors NiCr-Ni type.
The scale storage fridge has 3 roof levels, small drawer, and freezing compartment and the specifications. The electrical consumption of the fridge is measured by the electrical clamp meter, working as an amperage of the fridges socket, which will be multiplied by the average voltage, in order to determine the final power consumption.
The power consumption was determined by obtaining the results of the power monitor, which shows the voltage, amperage, and the Phi angle and calculated as in the Equation 1.

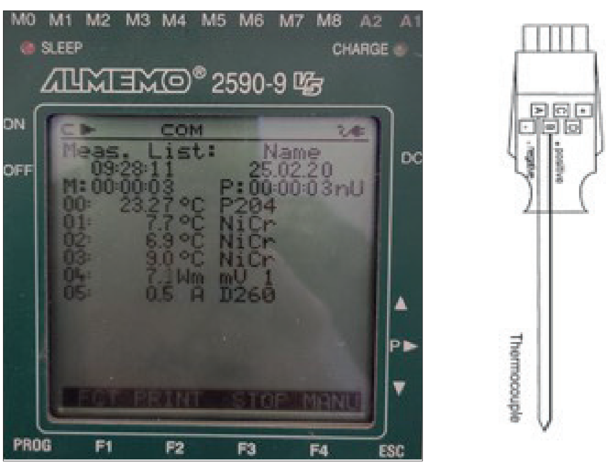
$$P = I \cdot U \cdot \cos(phi) = 0.58 \cdot 230 \cdot 0.54 = 72.04\ W \qquad (1)$$

The data was stored and transferred to the data logger with large graphical display and 8 input channels as in Figure 1. The temperature sensors are NiCr-Ni type measures from –200.0 to +1370.0°C with 0.1 K accuracy rate.

The measurements were performed in the food technology laboratory at the Hungarian University of Agriculture and Life Sciences for two days and a half continuously with step time one reading per minute.

RESULTS

The data of the real measurement revealed a behaviour of fluctuation, which is repeated frequently for all the measured parameters; therefore, 12 hours of 16 repeated cycles were taken, since it is representative for all the data as in Figure 2.
The noted results regarding T_1 and T_3 (upper roof and drawer) was stable and consistent with less than 2 °C difference between maximum and minimum, as well as the electrical consumption matching the on-off working period of the compressor motor. The unusual data was regarding the T_2 (lower roof), where the fluctuation in the temperature was high for more than 7 °C . The well-known advice regarding the food storing, that the coolest part shall be above the drawer, is correct regarding the obtained results. However, the fluctuation was more than three times higher compared to the fluctuation on the other two spots, which makes the decision of storing such fruits like apple in the lowest part not recommended, because of the temperature fluctuation, as well



Channel	Description
M0	Ambient temperature outside the fridge
M1	T_1 at the top roof of the fridge
M2	T_2 at the lower roof of the fridge
M3	T_3 at the middle space of the drawer
M4	Q_hf the heat flux on the side wall of the fridge
M5	I_current the electrical current of the power consumption imported from the clamp meter

Figure 1: Almemo data logger 2590-9 and temperature sensor NiCr-Ni type.

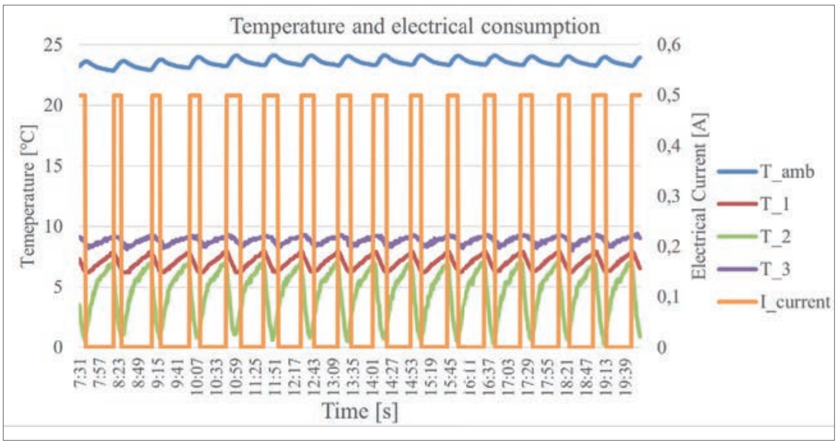


Figure 2: Thermal and electrical performance of the fridge.

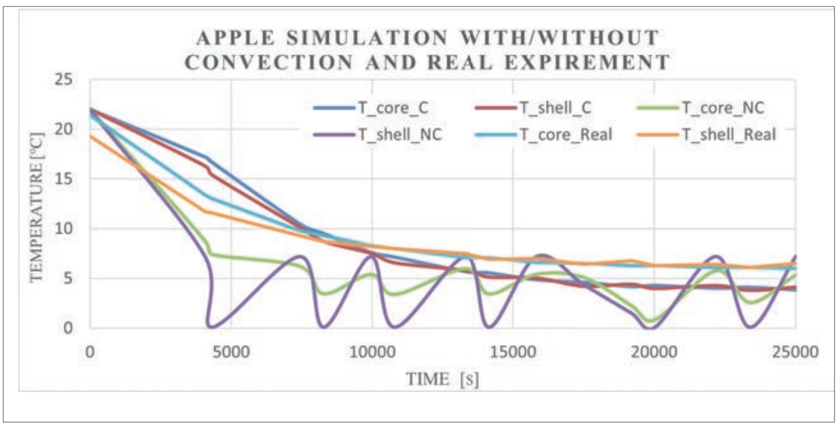


Figure 3: Simulation results with and without convection compared to real experiment

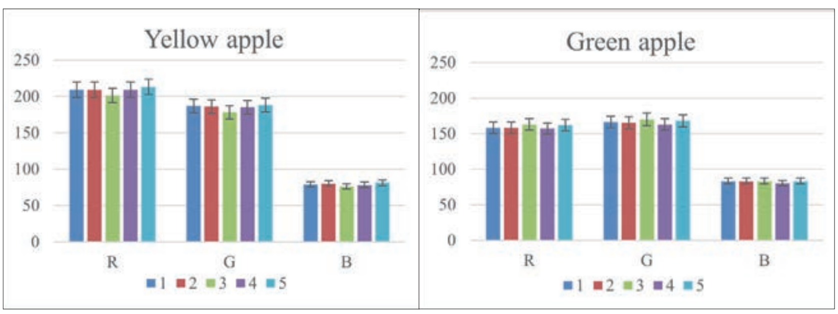


Figure 4: Colour specification of both samples

as exceeding the appropriate storing temperature limit of 5 °C .

The maximum, minimum, and average rate are also listed in Table 1, where the difference between maximum and minimum in T_1, T_3, and T_amb, are 2, 1.4, 1.28 °C respectively, while T_2 has the highest difference by 7.1 °C , which shows the importance of this case, since if the average temperature was only considered as 4.17 °C it will be a good choice, while in fact this fluctuation may have real effect on the stored items, mainly shelf time and changing in the colour.

Table 1: Maximum, minimum, and average parameters' rate.

	T_1	T_2	T_3	T_amb	Q_hf	I_current
Max	8	7.2	9.4	24.14	13.1	0.5
Min	6	0.1	8	22.86	4.9	0
Average	6.976	4.37	8.82	23.48	7.762	0.12

The measurement is compared to a simulation process using ANSYS simulation program. Since the measurement concern is thermal with time, so the Transient thermal process was chosen. The apple item was added to the material library as in Table 2. The chosen size of the apple is 5 cm mounted in the lowest roof which has the fluctuation between 7.2 and 0.1 °C with starting temperature 22 °C supposed as room temperature. The heat convection coefficient is determined from literature 3.28 W/m²·K (Inan, et al. 2000; Laguerre, et al. 2012).

Table 2: Apple specifications

Density	960	kg/m³
Isotropic thermal conductivity	0.406	W/m·K
Specific heat	1760	J/kg·K
Diameter	5	cm

The results of the simulation are in two different ways, the first one assuming that the apple's shell temperature is the same as the surrounding temperature, which means no conviction is happening, while the conduction between the shell and the core is the main phenomena. The second method is using a heat convection coefficient 3.28 W/m²·K. The two methods show different results, where the convection makes more realistic results, as in Figure 3. The C labelled graphs mean using convection, while NC means no convection. The measurement duration is 7 hours for 6 on-off cycles till it is stable, where it is noted that the core temperature reaches 4.58°C and the shell 4.54°C for the convection results.

While from colour aspect as we see in Figure 4, we can see that for five continuous days there is no significant change in the colour components in both samples. This indicates that for a short-term storage process, the colour specification of green or yellow apple do not change dramatically in proper temperature and humidity conditions.

CONCLUSIONS

People aim to store their food for a specific period so they can consume it out of its season. Apple fruits are harvested and stored from a season to another one ensuring its availability all around the year. The main question is how long we can store our apple in domestic fridge, and what is the real temperature of the core and shell of the fruit compared to the fridge temperature. In this paper we made 60 hours of a real experiment of two types of apples (yellow and green) to measure its real temperature. In the meanwhile, we conducted a simulation using ANSYS program with two approaches, with and without conviction. The results show that the conviction model is closer to the real experiment. After that, we conducted five days of colour measurement to check the changing of the red, green, and blue factors in the skin of the apple. Nevertheless, it shows that the colour components remain relatively the same during the experiment.

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RELEVANCE OF MACHINE TESTING IN PLANT PROTECTION

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ABSTRACT

An important element of crop production technologies is plant protection, which enables safe production and high-quality crops. It plays a significant role in economic and efficient production and deserves special attention because of its impact on the environment. The technical standard and technological development of plant protection machines play an important role in reducing the agricultural use of pesticides and thus their impact on the environment. Our paper presents the legal environment for the distribution and operation of plant protection machines and their impact on the technical quality of the machines.

keywords: plant protection machines, sprayer testing, sustainable agricultural

INTRODUCTION

The Testing Laboratory of Plant Protection Machines of the University Laboratory Center of the Hungarian University of Agricultural and Life Sciences (MATE) places great emphasis on the development and testing of plant protection technologies and tools, and on facilitating the innovation processes of the field through its services to machine manufacturers, distributors and producers. Recognising the importance of crop protection machines in crop security, MATE's legal predecessors conducted in the early 1950s, with their capabilities, conducted very extensive studies with manual, knapsack, horse drawn sprayer, motorised, and tractor-driven machines (Erdei et Flesch, 1969).

Besides research, the rapid development of the Hungarian agricultural machinery industry in the 1970s also led to the design and development of plant protection machines. In the late '80s and early '90s, chemical-free plant protection methods were already being researched as alternative plant protection options, including technical solutions for thermal weed control. Once again, mechanical weed control has become of great importance with the development of machines suitable for combined treatment processes. During these times, chemical-saving, environmentally friendly plant protection technologies were also established. Among the chemical-saving technical solutions, electrostatic spraying technology had practical significance. In plantations the so-called tunnel spraying, where the spray liquid can be recovered using semi-enclosed equipment.

In 1987, the 271 m^2 steel-structured laboratory building was built to meet the increased demand for machine manufacturers and to meet the specific requirements of testing and machine development orders, in which the inspection of plant protection machines could be carried out in compliance with the strictest environmental regulations until the early 2000s.

To improve the technical condition of plant protection machines, from the mid-1990s, based on the practice of western, more technically advanced countries, a system of requirements for type certificates, test methods and the necessary instruments and equipment were developed.

Taking these proposals into account, the responsible Ministry has gradually incorporated them into legislation since the 2000s, making their application compulsory for machinery manufacturers and distributors. In doing so, it enforced the requirements of international law and the application of standards based on them. Because of the introduced measures, the current Testing Laboratory of Plant Protection Machines was established at the Institute of Agricultural Engineering, which is suitable for testing plant protection machines and their components (pump, blower, armature, nozzle). Furthermore, the laboratory fulfils its legal obligation to perform the pre-market type-approval procedure for plant protection machines with a tank larger than 5 dm^3.

In October 2009, EU Directive 2009/128/EC required the Member States to achieve the sustainable use of pesticides. As a result, an action plan had to be drawn up, and a deadline was set for the introduction of inspection of plant protection equipment in use for the production and service of goods. The basic objectives of the National

Plant Protection Action Plan include the promotion of the sustainable use of plant protection products: to reduce or keep to a minimum the risks to human health and the environment arising from the use of plant protection products and plant protection technologies; reduction of soil, surface and groundwater, air pollution; reduction of risk factors during aerial spraying. For this reason, in April 2010, the responsible Ministry, in line with the EU Directive, issued a decree on plant protection activities and regulated the inspection of plant protection equipment in use.

MATERIAL

The Plant Protection Testing Laboratory has had an accredited status since 2004 to determine the technical and environmental characteristics of horizontal boom sprayers and sprayers for bush and tree crops. Horizontal boom sprayers are tested according to MSZ EN ISO 16119-1: 2013 and MSZ EN ISO 16119-2:2013, while sprayers for bush and tree crops are tested according to MSZ EN ISO 16119-1:2013 and MSZ EN ISO 16119-3: 2013. When spraying in the field, the effectiveness and utilisation of the chemicals depend largely on how uniformly the spray applies to the target surface. Therefore, the most important requirement for sprayers is a sufficiently uniform spread. According to the standard, the transverse distribution uniformity must be determined on a groove line with a pitch of 100 mm along with the boom. The coefficient of variation (CV) for new machines may not exceed 7%, and the measured values may deviate from the mean by a maximum of ± 15%. In the test with the PESSL Sprayertest 1000 mobile spray scanner (Fig. 1), the measuring car with ten grooves performs measurements on 1 m sections moving along the track laid on the ground. After determining the amount of fluid collected in the grooves, the measuring car rolls to the next

Figure 1: PESSL Sprayertest 1000 mobile spray scanner for the measurement of the transverse distribution uniformity of a horizontal boom sprayer

Figure 2: PESSL 4500 vertical patternator used in the test

measurement stage. The device is suitable not only for the laboratory but also for mobile measurement. The test is automatic, and the computer evaluates the obtained results (Fig. 3/a).

With sprayers for bush and tree crops, the nozzles and the spraying device must be adjusted according to the location of the vegetation so that the droplets reach the target surface as much as possible and the spray does not fall, drift or evaporate (Dimitrievits et Gulyás, 2011). The vertical spread pattern of the sprayers should be adjusted to the dimensions of the plantation and leafage. The uniformity of coverage and the amount of losses depend on the location and direction of the nozzles, the size of the nozzles, the operating pressure, as well as the amount, speed, and direction of the airflow delivered by the blower. Besides determining the vertical distribution, the PESSL 4500 vertical patternator (Fig. 2) helps to optimise the sprayer based on the characteristics of the plantation being treated. During the test, the spray carried by air flows through the lamellas placed up to a height of 4,5 m. Meanwhile, the droplets separate and, depending on the height, the amount of liquid collected per 15 cm sector is determined. The spray pattern is modelled by a computer (Fig. 3/b).

The adequacy of performing the nozzles influences the distribution uniformity of sprayers. A maximum deviation of ± 15% from the nominal flow rate specified by the manufacturer is acceptable. With sprayers for bush

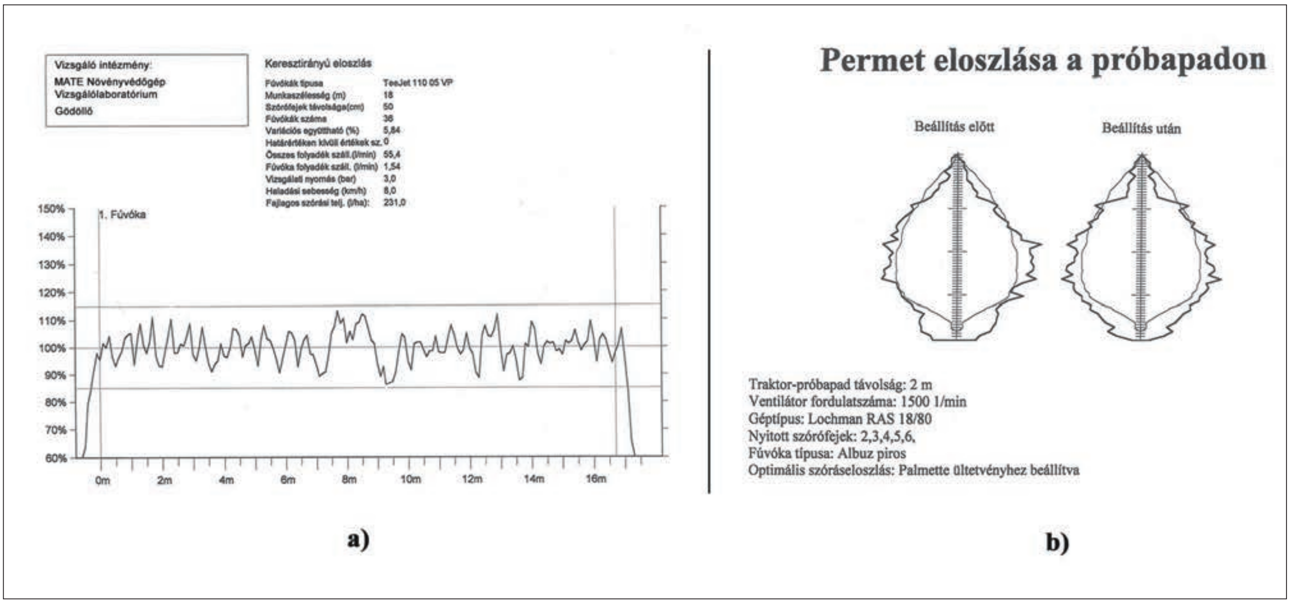

Figure 3: Results of the distribution uniformity of an (a) air assisted sprayer, and a (b) horizontal boom sprayer

Figure 4: PACHLER EP-570 nozzle test bench

and tree crops, the spray pattern is determined with a PACHLER EP-570 nozzle test bench (Fig. 4). For horizontal boom sprayers, it is possible to determine the nozzle's flow rate using a manual flowmeter.

Besides above, the laboratory performs tests on the residual volume, the control equipment of the sprayers, the accuracy of the manometer, the volume of the tanks, the surface roughness, the efficiency of the mixing equipment and the pressure drop.

As part of a non-accredited activity, the laboratory also tests horizontal boom sprayers and sprayers for bush and tree crops. Furthermore, operational testing of the increasingly popular spraying drones (Fig. 5) and portable sprayers, pesticide application equipment for seed treatment and granulate applicators, covers, among others, the determination of relative coverage, specific droplet number and sedimentary deposition.

Reflecting on the present challenges, the activities performed by machine tests and in cooperation with machine manufacturers promote the development of modern plant protection machines and plant protection technologies, improve their efficiency, and ensure the operation of machines under environmental regulations.

Market participants are assisted by professional consultancy on the proper set-up of plant protection machines, their operation, the prac-

Figure 5: Work quality inspection of spraying drone

tice of spraying techniques that take environmental and economic aspects into account, and the quality of work.

RESULTS

The laboratory also performs sprayer tests in accordance with the requirements of ENTAM (European Network for Testing of Agricultural Machines). The test reports are also available to farmers, providing decision-making information for machine investments, and it facilitates the cross-border expansion of agricultural machinery manufacturers and distributors.

The laboratory tasks include carrying out the licensing procedure for placing on the market of plant protection machines based on the criteria (droplet formation, spraying technique) determined under Decree 43/2010 (IV.23.) of the Ministry of Agriculture regulating plant protection activities. The results of the above tests will be used during the authorisation procedure. The procedure can be performed based on document evaluation and laboratory testing. Sprayers with a capacity of over 5 dm^3, i.e., besides horizontal boom sprayers and sprayers for bush and tree crops, including portable (motorised, non-motorised) sprayers, pesticide application equipment for seed treatment, microgranule applicators. The following table shows the list of authorised machines in Hungary (Tab. 1).

Table 1: Distribution of marketing authorization plant protection products by type

Pesticide application equipment	Number of types
Mounted horizontal boom sprayers	175
Trailed horizontal boom sprayers	418
Self-propelled horizontal boom sprayers	77
Mounted sprayers for bush and tree crops	55
Trailed sprayers for bush and tree crops	171
Mobil and knapsack sprayers, manual	101
Mobil and knapsack sprayers, motorised	99
Pesticide application equipment for seed treatment	2
Granular applicators	8

It can be stated that plant protection machine types are available in a sufficiently wide range in the Hungarian market in most categories. However, based on the experience gained during the nearly twenty years of operation of the type rating system, the following technical problems have arisen:

For portable machines:

- the cover lid of the spray liquid tanks was not tight,
- sometimes the volume of the tanks did not even reach the nominal volume, thus they did not have reserve capacity,
- the current level of filling of the tanks, most times it could not be read from the level indicator on the tanks,
- a filter or pressure gauge is not always installed in the pressure pipe,
- the identification of portable machines and nozzles (type, year of manufacture, size of nozzles, fluid transport) was often incorrect.

For non-portable machines:

- spray tanks sometimes did not have the required minimum reserve capacity of 5% of the nominal volume,
- the division of the tank level indicators on some machines did not comply with the regulations and the accuracy of the level indicators did not meet the relevant requirements,
- the volume of the rinsing water and hand washing water tanks mounted on the machines was not adequate in all cases,
- the mixing equipment, due to their design, could not ensure the sufficient homogeneity of the applied spray,
- a higher than permissible pressure drop because of the use of improperly selected low- permeability filters, valves, pressure regulators and hoses with too small a cross-section,
- the division and accuracy of the manometers mounted on the machines were often not ensured,
- the blowers and nozzles of sprayers for bush and tree crops did not always meet the requirements for the symmetry of the application,
- several problems have arisen regarding transverse distribution uniformity due to inadequate boom design (distance between nozzles, length of sections with independent spray supply, inadequate nozzle attachment) and nozzles quality (nozzles from unknown manufacturers or aftermarket).

The applicants have corrected deficiencies and failures during the procedure, based on the laboratory's opinion. If it took longer to correct the defects, depending on the number and severity of the defects, provisional marketing authorisations valid for one year were granted, or the types concerned were not authorised.

Besides the procedure for placing new machinery on the market, a system for inspection of plant protection equipment in use has been introduced. Currently, the obligation applies to plant protection machinery used in the production of goods. The tests are performed by the test stations every three years according to the MSZ EN ISO 16122:2015 standard. According to the National Food Chain Safety Office (NÉBIH) records, in 2021, 104 testing stations provide nationwide coverage. The station staff's basic theoretical and practical training was carried out by the MATE Testing Laboratory of Plant Protection Machines organised by NÉBIH.

The development of high-quality, pesticide-saving, safe, least polluting and environmentally friendly application equipment significantly reduces the impact of plant protection on the environment. In addition to the certification procedures, the MATE Testing Laboratory of Plant Protection Machines also supports the innovation activities of the manufacturers with its R&D services.

CONCLUSIONS

Manufacturers and distributors have upgraded and improved their machines several times considering the requirements for plant protection machines set out in legislation and standards based on the certification procedures' results. Furthermore, the qualification system for new machines and the periodic inspection system for used machines contribute to the continuous improvement of the design and technical standard of the machines and the ensuring of the appropriate technical condition of the used machines. As a result, the effectiveness of plant protection interventions is improved, and unjustified and unnecessary chemical exposure to the environment is reduced.

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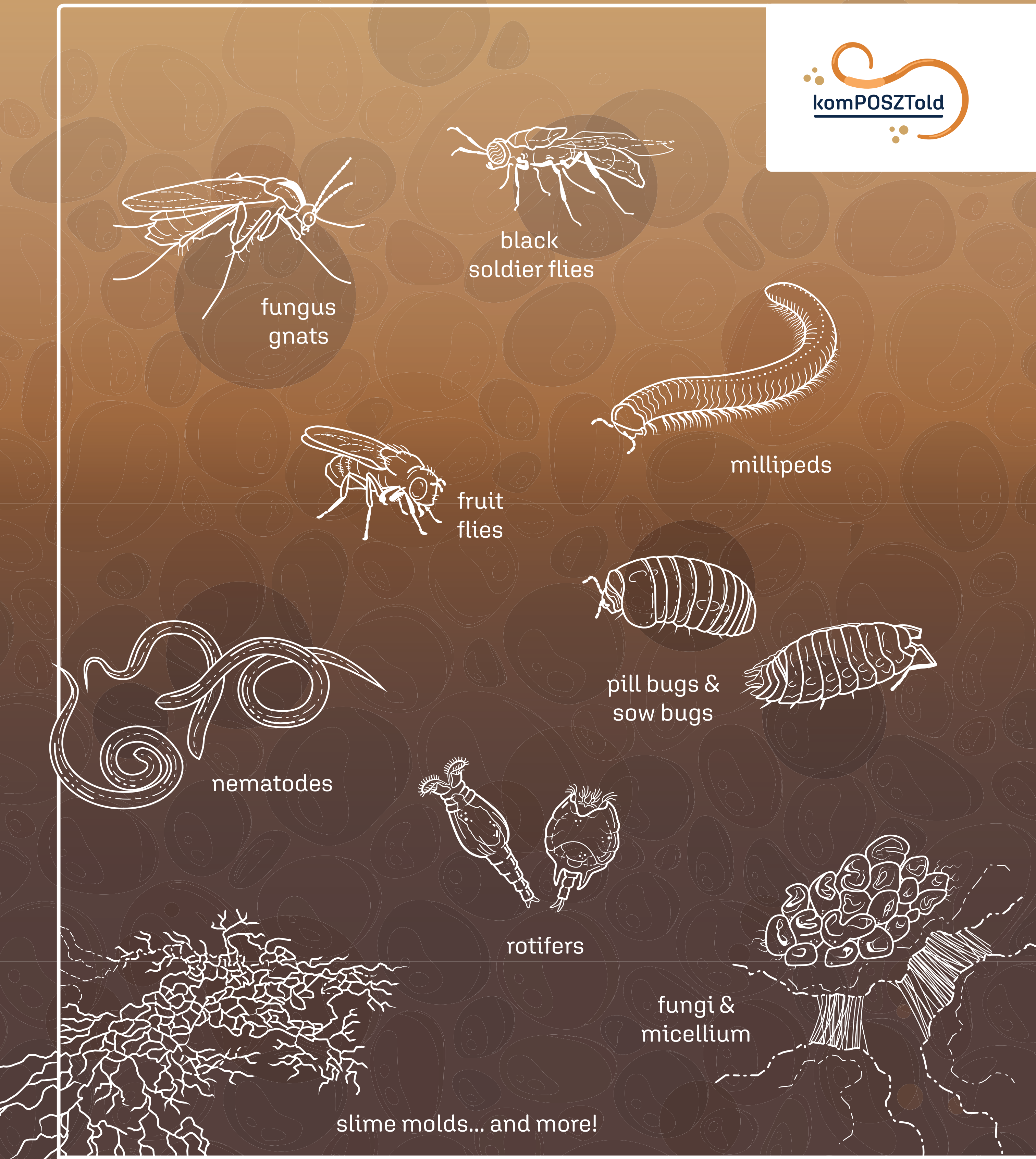

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