Monika Metryka-Telka, Robert Kowalik, Nebojša Jurišević, Aleksandar Nešović
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ANALYSIS OF AIR QUALITY ASSESSMENT IN KIELCE IN RELATION TO THE COVID-19 PANDEMIC

ANALIZA OCENY JAKOŚCI POWIETRZA W KIELCACH W ZWIĄZKU Z PANDEMIĄ COVID-19

Monika Metryka-Telka, Robert Kowalik*
Kielce University of Technology
Nebojša Jurišević, Aleksandar Nešović
University of Kragujevac, Serbia

Abstract

Air pollution has a significant impact on citizens' well-being and overall life quality. In this regard, regular air quality monitoring aims to keep pollution levels within prescribed limits and to identify the factors (winds, traffic, seasons, ambient temperature, air humidity, and so on) that influence pollution levels. To carry out a preliminary analysis of the air quality in Kielce, a specialist detector of PM2.5 and PM10 particles Steinberg 10030389 SBS-PM2.5 was used. Besides, the analysis referred to pollutants such as SO_2; NO_2; C_6H_6, which were provided from the Chief Inspectorate of Environmental Protection. Controlling the above mentioned pollutants for monthly and hourly averages of the selected time period in 2020 and 2021, taking into account the epidemiological situation (lockdown), graphs with the results were prepared. Then the analysis was carried out, with the preliminary assumption that the air quality is worse when the population functions normally than when it remains indoors, and that air quality is usually better at night than during the day.

Keywords: air quality, particulate matter, pollution monitoring

Streszczenie

Zanieczyszczenie powietrza ma znaczący wpływ na samopoczucie obywateli i ogólną jakość życia. W związku z tym regularne monitorowanie jakości powietrza ma na celu utrzymanie poziomu zanieczyszczeń w wyznaczonych granicach oraz identyfikację czynników (wiatry, ruch uliczny, pory roku, temperatura otoczenia, wilgotność powietrza itp.), które wpływają na poziom zanieczyszczeń. Do przeprowadzenia wstępnej analizy jakości powietrza w Kielcach wykorzystano specjalistyczny detektor cząstek stałych PM2,5 i PM10 Steinberg 10030389 SBS-PM2,5. Ponadto w analizie uwzględniono takie zanieczyszczenia jak SO_2; NO_2; C_6H_6, które zostały udostępnione przez Główny Inspektorat Ochrony Środowiska. Kontrolując ww. zanieczyszczenia dla średnich miesięcznych i godzinowych z wybranego okresu w latach 2020 i 2021, z uwzględnieniem sytuacji epidemiologicznej (blokada), sporządzono wykresy z wynikami. Następnie przeprowadzono analizę, przyjmując wstępne założenie, że jakość powietrza jest gorsza, gdy ludność funkcjonuje normalnie, niż gdy pozostaje w pomieszczeniach zamkniętych, oraz że jakość powietrza jest zwykle lepsza w nocy niż w ciągu dnia.

Słowa kluczowe: jakość powietrza, pył zawieszony, monitoring zanieczyszczeń

*Kielce University of Technology, Poland, e-mail: rkowalik@tu.kielce.pl

1. INTRODUCTION

In modern day world, air quality monitoring is essential in the continuous efforts to reduce smog and enhance overall air quality. Every year, the intensity of traffic increases, as do the exhaust fumes emitted into the environment. This is frequently compounded by factory chimney smoke, which can also be harmful in composition. Because of that, relatively large cities, made continuous efforts to keep the rising dense fog, colloquially known as smog, at bay [1]. On the other hand, in relatively small towns where rural areas prevail, the air should seemingly be cleaner than in urban agglomerations. During the heating season, however, this is not a strict rule.

Technology is evolving rapidly in the twenty-first century. As a consequence, there are numerous outdoor and indoor sensors on the market, as well as numerous mobile applications that allow anyone to monitor air pollution. This gives citizens the ability to control whether the air quality parameters are within proscribed limits throughout the day, and thus whether it is safe to be outside or open a window at home without fear of harmful substances entering our bodies from outside. Due to the fact that the most common sensors on the market are PM10 and PM2.5 particulate matter detectors, the PM2.5 and PM10 SBS-PM2.5 particle detector, which is also a professional air quality meter, was used to measure these particles in Kielce during the total shutdown caused by the outbreak of the pandemic and a year later in the same period of time when the society was functioning normally. Using publicly available measurements from the Chief Inspectorate of Environmental Protection in order to read the measurements related to the levels of CO, NO_2, C_6H_6.

2. MATERIALS AND METHODS

In order to make a preliminary analysis of air quality in Kielce, this study utilized a specialist detector of PM2.5 and PM10 particles shown in Figure 1, and used data obtained from the Chief Inspectorate for Environmental Protection in the period from 15 March 21 to 15 April 21. That after, the study calculated daily and monthly averages and did a detailed comparison for one selected week in March of the year 2020 when coronavirus and the first lockdown occurred and for the same time period in the previous year were no restrictions.

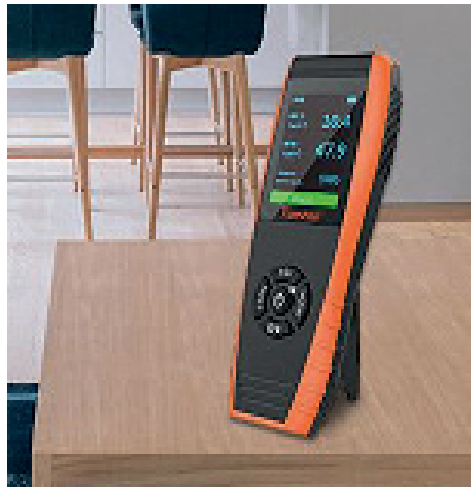

Fig. 1. SBS-PM2.5 and PM10 particle detector
Source: personal photo

This detector is a practical air quality meter by Steinberg Systems, which detects harmful airborne dust with its sensitive sensors. It is relatively easy to use and can be easily moved, which makes it possible to measure practically in any place. The measurement takes place in real time, hence the measurement is very up-to-date. The detection ranges for PM10 and PM2.5 is from 0 to 999.9 μg/m^3 [3].

3. IMPACT OF PM10, PM2.5, CO, NO_2, SO_2 AND C_6H_6 ON THE HEALTH OF SOCIETY

Studies show that concentrations of PM10 and PM2.5 particulate matter usually exceed their norms in winter due to the fact that it is the heating season and smog phenomenon, dangerous to health, is often observed [4]. Pollutants from road traffic weigh on air quality assessment especially in larger towns, while those from residential heating in suburban and rural agglomerations, where the air should generally be cleaner. WHO has shown that NO_2, PM10 and benzoapirene that enter the environment through traffic and from biomass burning were often unacceptably high compared to urban agglomerations. Hence, toxicity tests of PM extracts with lung epithelial cells showed higher toxicity for stations from smaller towns [5, 6]. In order to reduce air pollution and what effects it has on the health of the community, it is necessary to have a good understanding of its source [7]. Studies show that ambient air pollution contributes to millions of deaths worldwide (up to 4.2 million). This is because when inhaled, pollutant particles can penetrate deep into the lungs [8]. A potential measure of the health effects associated with a particular exposure in ecological studies is the relative risk of

Table 1. Assessment of air quality in relation to acceptable standards of pollution

Air Quality Index	PM10 [µg/m³]	PM2.5 [µg/m³]	NO_2 [µg/m³]	SO_2 [µg/m³]	C_6H_6 [µg/m³]	CO [µg/m³]
very good	**0-20**	**0-13**	**0-40**	**0-50**	**0-6**	**0-3**
good	20.1-50	13.1-35	40.1-100	50.1-100	6.1-11	3.1-7
moderate	50.1-80	35.1-55	100.1-150	100.1-200	11.1-16	7.1-11
sufficient	80.1-110	55.1-75	150.1-200	200.1-350	16.1-21	11.1-15
bad	110.1-150	75.1-110	200.1-400	350.1-500	21.1-51	15.1-21
very bad	**>150**	**>110**	**>400**	**>500**	**>51**	**>21**
no index	an air quality index is not determined due to the lack of measurement of the dominant pollutant in the province					

Source: Chief Inspectorate of Environmental Protection. Air quality portal. Available online: http://powietrze.gios.gov.pl/pjp/archives.

increased illness or death in response to an increase in the concentration of a particular pollutant. Table 1 shows the WHO recommended concentration limits for each pollutant in the air.

3.1. PM10 and PM2.5 – harmful to health

Considering total suspended particulate matter (TSP), one can distinguish fractions with grain sizes above 10 µm and those with grain diameters below 10 µm. Regarding, PM10 fraction there is a fraction with the diameter of grains below 2.5 µm (PM2.5 particulate matter, whose particles are very hazardous to health) [9, 10].

According to the World Health Organization (WHO), as well as independent studies, there is a huge impact of particulate matter on human health with a special emphasis on PM2.5 [11]. Having a longer contact with this dust such as this, especially its finer fractions, one can shorten the life length by a year [12]. These dusts have particularly harmful effects on the respiratory system [13]. They may contribute to bronchial asthma, chronic obstructive pulmonary disease or common respiratory infections, including pneumonia. Exposure especially to PM2.5 in pregnant women may translate into poor respiratory function in the child later in life [14]. Lung cancer is an increasingly common effect of particulate air pollution, the risk of cancer can be 20-40% higher for areas with elevated dust concentrations compared to those places where these concentrations are low [15, 16]. Another negative effect of dust exposure is the dangerous effects on the cardiovascular system. PM2.5 and even smaller dust particles get from the alveoli to the circulatory system and subsequently to the internal organs causing undesirable health conditions from inflammation, oxidative stress and secondary activation of the sympathetic nervous system may result in damage to the vascular endothelium, destabilization or formation of new atherosclerotic plaques [17]. The occurrence of strokes, hypercoagulability of blood, formation of venous and arterial thrombosis are other possible consequences of the effects of particulate matter on the human body [18]. The nervous system is also exposed to dust penetration. Neurodegenerative diseases may occur leading to more frequent depressive states and acceleration of the aging process for the nervous system [19].

3.2. Carbon monoxide – harmful to health

Carbon monoxide (CO) is a highly toxic and odorless gas. Hence, it is often referred to as the silent killer. Apart from the fact that it can escape in a poorly ventilated apartment as a result of heating we also have to deal with it on a daily basis as it is one of the components of smog. However, it is not as dangerous to health in this form as the one we come into contact with in a closed room. Carbon monoxide very easily combines with red blood pigment, which means that it impedes the delivery of oxide molecules to tissues. Depending on the force with which it acts on the body it results in more or less hypoxia. If the volumetric concentration of carbon monoxide in the air is 100-200 ppm (0.01-0.02%) after the contact with it the symptoms for the human body are insignificant (headache, burning on the face), but if the concentration is 400 ppm (0.04%) it causes a strong headache already after about an hour of breathing the contaminated air. If the concentration is about 800 ppm (0.08%) it will cause dizziness or vomiting in a similar time. The higher the concentration the more severe the symptoms. A concentration of more than 1% will cause unconsciousness after just a few breaths, and may lead to death after a few minutes of breathing such polluted air [20].

3.3. Nitrogen dioxide – harmful to health

Nitrogen dioxide NO_2 is a highly reactive variety of nitric oxide. The source of its origin is mainly the fuel combustion of cars or heavy machinery. Only 5-10% of NO_2 is that emitted directly from nitrogen oxides. NO_X are directly involved in chemical transformations resulting in formation of particulate matter which is very harmful to health [21]. If we are briefly exposed to with exceeded permissible concentrations of NO_2 in the air can result in respiratory irritation, chemical inflammation, and pulmonary edema because NO_2 reacts with body fluids to form nitric acid and nitrous. If the exposure to high concentrations of NO_2 is prolonged, it may lead to the development of asthma, decrease the immunity of the respiratory system, and thus cause its more frequent viral and bacterial infections; in the case of people already suffering from asthma, it may contribute to increased mortality [22].

3.4. Sulfur dioxide – harmful to health

Sulfur dioxide in the air comes mainly from the commercial power and heating industry, as well as various technological processes. Its level in the air is also significantly influenced by what we heat our homes with. To the smallest extent, SO_2 enters the air from exhaust of car engines [23, 24]. If its permissible concentration is exceeded, it shows toxic effects [25]. According to the results of environmental epidemiology studies, such pollutants as particulate matter and sulfur dioxide suggest that they may affect the occurrence of cardiovascular diseases and increase mortality especially in people over 65 years old [26, 27]. Further ailments associated with prolonged exposure to particulate matter with NO_2 may be increased permeability in lung tissue and with it the appearance of pulmonary edema especially in people with damaged heart muscle [28]; increased left atrial pressure may occur [29]; pneumonia or bronchiolitis [30]; congestive heart failure (with comorbidities [31]. If there is a reduction in nitrogen dioxide in the air we breathe it may contribute to a decrease in cardiovascular problems among the public [32].

3.5. Benzene – harmful to health

Benzene C_6H_6 like other air pollutants may have a natural origin, e.g. as a result of forest fires or anthropogenic origin, i.e. tobacco smoke, burning of fuels and processing of petroleum products, industry or building materials. Benzene C_6H_6 like other air pollutants may have natural origin, e.g. as a result of forest fires, or anthropogenic origin, i.e. tobacco smoke, burning of fuels and processing of products of petroleum origin, from industry or building materials. Long-term contact with benzene of higher than permissible concentration may cause mutagenic changes and even lead to leukemia [33]. Benzene is characterized by the fact that it is a colorless liquid, flammable with a sweet smell (it can be smelled at the gas station) [34]. It is said that "the only absolutely safe concentration of benzene is zero", which means that even small amounts of C_6H_6 can be harmful for our body. Unfortunately, due to the fact that benzene is one of the fuel components, its presence in the air we breathe is almost unavoidable [35]. It attacks mainly the liver, lungs, heart, kidneys and even the brain so abnormalities in the nervous system may also occur. Symptoms after prolonged exposure to benzene may be narcotic in nature, the person may behave as after alcohol intoxication, they are visible, characteristic and may signal that something wrong is happening in the body. And the most dangerous are the ones we don't notice. They can lead to chronic bone marrow damage [36].

4. RESULTS

Figures 2-3 show the average daily concentrations of PM10 and PM2.5 in the air in Kielce for 32 days from 15.03-15.04 for 2020 and 2021. In the studied period in 2020, the highest concentrations were: PM10 – 90 µg/m³; PM2.5 about 65 µg/m³, which as shown in Table 1 are at sufficient level. Mostly on those days it did not exceed 50 µg/m³ for PM10, and 30 µg/m³ so the air quality was generally good. As for 2021, the highest recorded value of PM10 is 140 µg/m³, PM2.5 is 60 µg/m³. For the most part of the study period PM10 level was moderate.

4.1. Average results of PM10, PM2.5 measured in the period 15.03-15.04.2020 and 15.03-15.04.2021

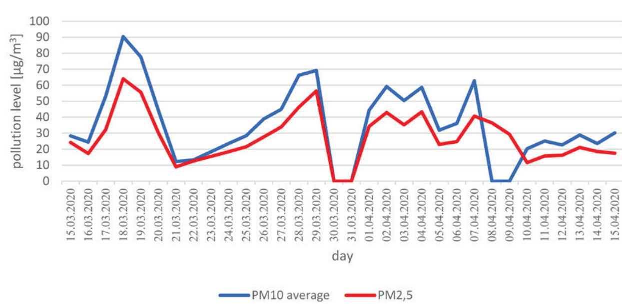

Fig. 2. Average daily PM10 and PM2.5 results Kielce 2020

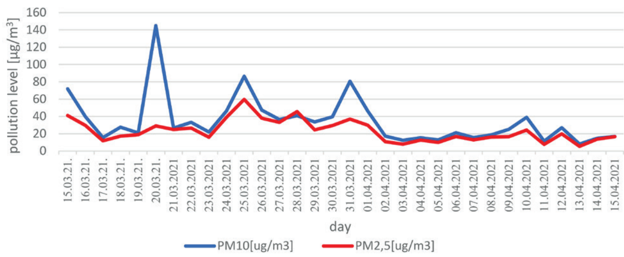

Fig. 3. Average daily PM10 and PM2.5 results Kielce 2021

In terms of the remaining pollutants, SO_2 concentrations were at a maximum of approximately 20 µg/m³ for both of the study periods in 2020 and 2021, that is relatively acceptable concentration. In 2020 the average value for NO_2 was 38 µg/m³; for C_6H_6 2.5 µg/m³ and for CO no values were recorded. In 2021 NO_2 averaged around 22 µg/m³; C_6H_6 – 2 µg/m³ and carbon monoxide was not detectable in the air and remained at the level equal to 0 µg/m³. For these pollutants, the concentration values remained at a very good level for the whole study period. Hence, they had no excessive harmful effects on citizens' health.

4.2. Results of PM10, PM2.5, NO_2, SO_2, C_6H_6, CO. Measurement at 04:00 a.m. in the period 16.03-22.03.2020 and 16.03-22.03.2021

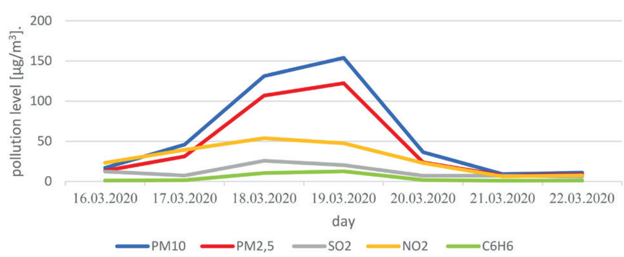

Fig. 4. Results of PM10, PM2.5, SO_2, NO_2. Measurement at 4:00 a.m. Kielce 2020

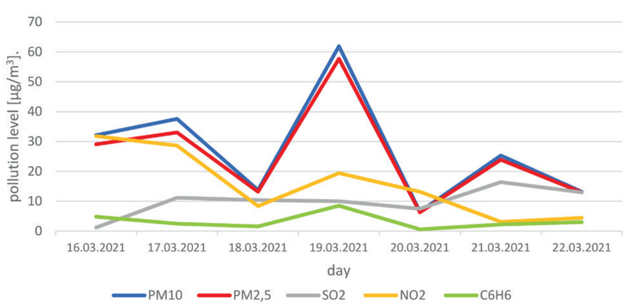

Fig. 5. Results of PM10, PM2.5, SO_2, NO_2. Measurement at 4:00 a.m. Kielce 2021

Figures 4 and 5 show the results of measurements for all sampled pollutants in the air measured at 4:00 a.m. for 2020 and 2021 during the period from March 16 to 22. The highest values during the study period for 2020 were: PM10 – 150 µg/m³; PM2.5 – 120 µg/m³; SO_2 – 25 µg/m³; NO_2 – 55 µg/m³; C_6H_6 – 12 µg/m³ and CO – 2.1 µg/m³. These values, as can be seen from Table 1, varies the levels of air quality – from very good to very bad, which results in moderate air quality. It is worth mentioning that concentrations of pollutants were the highest on 18th and 19th of March. The values on the graphs increase up to those days, and then they start decreasing. Before and after reaching the maximum value they remain at good and very good level. Analyzing 2021 we can see that the highest values are: PM10 – 60 µg/m³; PM2.5 – 58 µg/m³; SO_2 – 16 µg/m³; NO_2 – 30 µg/m³; C_6H_6 – 8.5 µg/m³ and CO – 0 µg/m³. Unlike in 2020, in Figures 10, 12, 14, 16 and 18 we can see that the line does not form a "parabola" but the values on it increase and decrease alternately, not giving worse air quality as good. Assuming a pandemic broke out in 2020, one would expect the pollutant values to be lower as for 2021, but for most pollutants they are higher.

4.3. Results of PM10, PM2.5, NO_2, SO_2, C_6H_6, CO. Measurement at 10:00 a.m. during the period 16.03-22.03.2020 and 16.03-22.03.2021

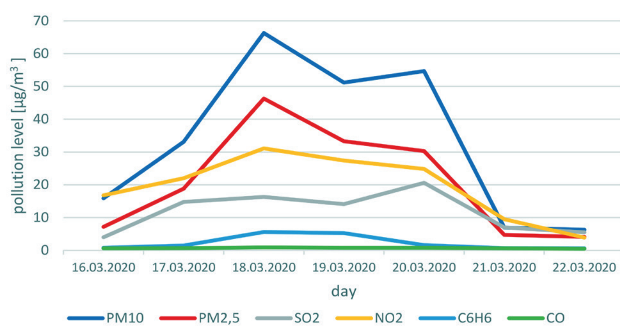

Fig. 6. Results of PM10, PM2.5, SO_2, NO_2. Measurement at 10:00 a.m. Kielce 2020

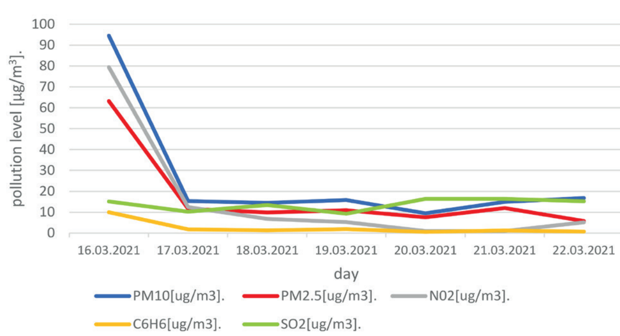

Fig. 7. Results of PM10, PM2.5, SO_2, NO_2. Measurement at 10:00 a.m. Kielce 2021

Figures 6 and 7 show the results of measurements for all tested pollutants in the air measured at 10:00 a.m. for 2020 and 2021 during the period from March 16 to 22. The highest values during the study period for 2020 were: PM10 – 65 µg/m^3; PM2.5 – 45 µg/m^3; SO_2 – 20 µg/m^3; NO_2 – 30 µg/m^3; C_6H_6 – 5.5 µg/m^3 and CO – 0.9 µg/m^3. These values, as can be seen from Table 1, are at different levels of air quality from very good to moderate which results in good air quality.

4.4. Results of PM10, PM2.5, NO_2, SO_2, C_6H_6, CO. Measurement at 4:00 p.m. in the period 16.03-22.03.2020 and 16.03-22.03.2021

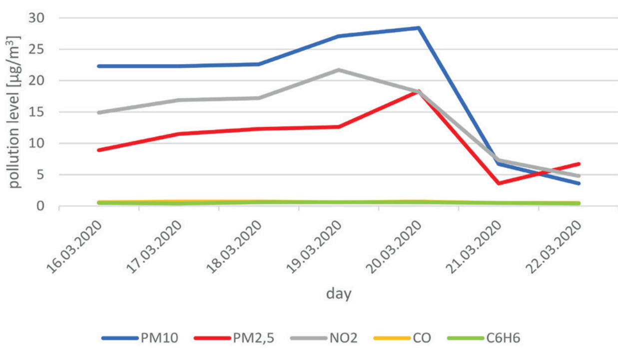

Fig. 8. Results of PM10, PM2.5, SO_2, NO_2. Measurement at 4:00 p.m. Kielce 2020

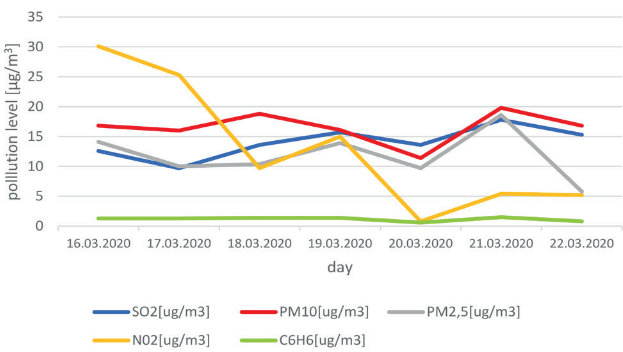

Fig. 9. Results of PM10, PM2.5; SO_2, NO_2. Measurement at 4:00 p.m. Kielce 2021

Figures 8 and 9 show the measurement results for all tested pollutants in the air measured at 4:00 p.m. for 2020 and 2021, during the period from March 16 to 22. The highest values during the study period for 2020 were: PM10 – 28 µg/m^3; PM2.5 – 45.18 µg/m^3; SO_2 – 18 µg/m^3; NO_2 – 22 µg/m^3; C_6H_6 – 0.6 µg/m^3, which remained at this level for 3 days and CO – 0.7 µg/m^3. These values, as it results from table 1 are on two levels of air quality – very good to good which as a result it gives us very good air quality. It is worth mentioning that the highest concentrations of pollutants do not exceed values below those indicating good air quality. The values on the graphs are distributed ascending to the highest concentration, then descending. Analyzing 2021, it can be seen that the highest values are: PM10 – 18 µg/m^3; PM2.5 – 18 µg/m^3; SO_2 – 18 µg/m^3; NO_2 – 5.5 µg/m^3; C_6H_6 – 1.5 µg/m^3 and CO – 0 µg/m^3. These values as for 2020 are on a scale from good to very good air quality. In Figure 8 one can notice how until 20th of March comparable values from two different time periods were nearly equal however on 20th of March for most of the pollutants the highest concentrations were recorded then a decrease is seen. Overall the results show very good air quality in the discussed hour.

4.5. Results of PM10, PM2.5, NO_2, SO_2, C_6H_6, CO. Measurement at 10:00 p.m. in the period 16.03-22.03.2020 and 16.03-22.03.2021

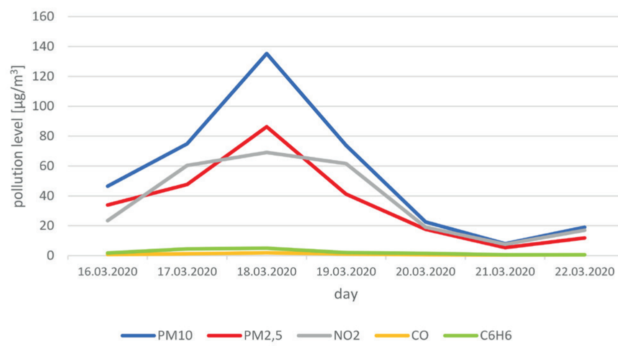

Fig. 10. Results of PM10, PM2.5, SO_2, NO_2. Measurement at 10:00 p.m. Kielce 2020

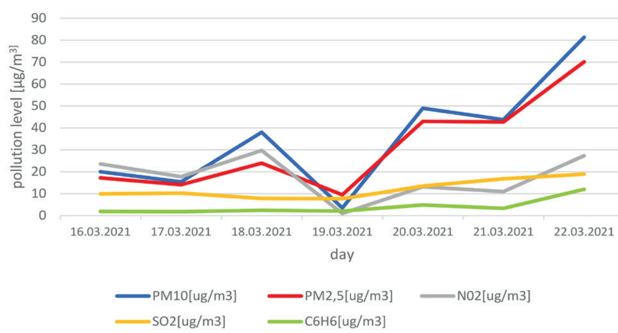

Fig. 11. Results of PM10, PM2.5, SO_2, NO_2. Measurement at 10:00 p.m. Kielce 2021

Figures 10 and 11 show the results of measurements for all tested pollutants in the air measured at 10:00 p.m. for 2020 and 2021 during the period from March 16 to 22. The highest values during the study period for 2020 were: PM10 – 130 µg/m^3; PM2.5 – 70 µg/m^3;

SO_2 – 15 µg/m^3; NO_2 – 30 µg/m^3; C_6H_6 – 5 µg/m^3 and CO – 1.9 µg/m^3. These values, as can be seen from Table 1, fall within the levels of air quality – very good to poor which results in good air quality. In other cases, the results are mixed especially for PM10 where the discrepancy is from 10 to 120 µg/m^3 in the examined period. Analyzing 2021 it can be seen that the highest values are: PM10 – 50 µg/m^3; PM2.5 – 90 µg/m^3; SO_2 – 18 µg/m^3; NO_2 – 70 µg/m^3; C_6H_6 – 12 µg/m^3 and CO – 0 µg/m^3. These values are on a scale from very good to poor in terms of air quality, which results in the worst rating on 7 of the surveyed days at moderate level, while on the remaining days the quality is better.

5. CONCLUSIONS

The findings of the analyses dealing with major air pollutants for two selected periods in 2020, from the first days of the COVID-19 pandemic to the same period in 2021 when there was no lockdown, are quite surprising.

The average daily concentrations of the pollutants (PM10 and PM2.5) that determined air quality from 15.03 to 15.04.2020 remained good, while they were moderate in 2021. The improvement in air quality due to reduction of floating particulate matter in the year 2020, could be caused by forced isolation of residents in their homes, which resulted, among other things, in a significant reduction of motorized transport in the study area.

For the remaining pollutants NO_2, C_6H_6 and CO the results remained at least at moderate level and SO_2 was usually at very good level.

Subsequent measurements were made 4 times per day (4:00 a.m., 10:00 a.m., 4:00 p.m., and 10:00 p.m.) for a selected week from March 16 to 22 for 2020 and 2021. The first measurement at 4:00 a.m. for the period March 16 to 22 recorded higher concentrations for 2020. For 10:00 a.m., higher pollutants were already recorded for 2021 compared to 2020, due to work and remote education, which significantly reduced motorized transport between 6:00 a.m. and 8:00 p.m., which was already significantly noticeable for 2021, worsening air quality.

The 4:00 p.m. surveys for 2020 and 2021 showed values that were at least good. In 2020. PM10; PM2.5; NO_2 and C_6H_6 at 4:00 have the highest values and there is a decreasing trend in the following hours, but during the fourth hour at 10:00 p.m. they increase again. SO_2 concentration decreases until 4:00 p.m. then remains constant until 10:00 p.m. Analyzing 2021 we can see a little bit opposite situation as in 2020. PM10 and PM2.5 are higher with each measurement and at 10:00 p.m. they decrease, SO_2 increases, then at 4:00 p.m. it decreases and at 10:00 p.m. it is the same index, SO_2 decreases until 4:00 p.m. and at 10:00 p.m. it is higher. C_6H_6 initially increases, at 4:00 p.m. it has a low value, and at 10:00 p.m. it is high again.

6. DISCUSSION

The values of PM2.5 and PM10 pollutants are strongly correlated. In most cases PM10 slightly exceeds PM2.5. It is interesting to note that air concentrations of pollutants PM10 and PM2.5 did not turn out to be lower at all during the period, the first isolation in March 2020 compared to March 2021. NO_2 SO_2 CO and C_6H_6 concentrations also did not turn out to be lower during the pandemic period, but tests performed at 10:00 a.m. and 10:00 p.m. showed that concentrations were higher in March 2020. The degree of pollution at 4:00 a.m. was at a similar level. The initial assumption of the measurements was that air quality improved during social isolation; however, the study found that air quality was of similar or worse quality during quarantine.

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