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Quantifying the Volume of Particulate Matter at Bus Stations

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ABSTRACT

Congested urban traffic substantially contributes to air pollution in cities. While waiting at bus stops, passengers may be exposed to increased contamination caused by vehicles, including particulate matter (PM). The modern bus stop layout, position and design ignore air quality and allow excessive exposure to pollution. Particulate matter seriously harms the environment, threatening human health and severely damaging all living organisms. The research purpose is to monitor particle emissions at the bus station in the city of Žilina (Slovakia), amassing data on exhaust emissions released from buses at the station premises. As moving or running-engine vehicles incessantly produce atmospheric emissions, we measure air quality during peak hours at the bus station. The results indicate a direct interconnection between passing vehicles and produced particle emissions, when multiple times higher emission levels are revealed. During the morning rush hour, the particulate matter exceeded 360% for $PM_{2.5}$ and 420% for PM_{10}. The research showed PM released directly from the buses tends to accumulate in covered premises of the bus station, severely damaging the health of passengers and staff. Our study warns about possible risks of deteriorating human health as waiting passengers unknowingly inhale contaminated particles. Our results indicate the largest emission producers and suggest remedial measures.

KEYWORDS

air quality; emissions; particulate matter; vehicle; bus; station.

1. INTRODUCTION

There has been an enormous increase recently in exhaust emissions from road vehicles caused by human anthropogenic activities like industrial production and transport. The latter results from the distances between homes, workplaces, cultural establishments or shops. Road transport is a driver of environmental pollution and exhaust emission production. The sector is currently subject to strict emission limits [1]. Many studies suggest that, despite these restrictions, the number of registered cars has grown [2], leading to massively increased emissions [3, 4].

Numerous cars on roads during rush hours cause severe traffic congestion, seriously damaging air quality and public health. Overfull traffic corridors in municipalities largely contribute to urban air pollution [5, 6]. Frequent traffic jams and their impact on human health have forced governments to impose measures to support sustainable public transport, ease congestion and improve the environment [7]. Private transport has become a worldwide problem, causing massive atmospheric pollution [8]. Harantová et al. point out how frequent car accidents exacerbate the situation on busy roads, suggesting public transport promotion to alleviate the transport issues [9].

Bus stops are integral for public transport, allowing passengers to get on and off [10]. While waiting for the connection, commuters are vulnerable to increased pollution caused by oncoming traffic [11]. Although many studies have dealt with the layout, design, capacity and waiting time at bus stops, few have considered the impact of emissions on the environment [12, 13].

Public transport systems, widely used by low-income individuals, are essential for reducing traffic and improving the environment. Koushki et al. conducted an extensive study in Kuwait, revealing high public transport usage among labourers recruited from immigrants [14]. Sustainable transport development is vital for intelligent and eco-friendly urban growth [15], as many towns and cities suffer from congested roads, causing unexpected delays, high transport costs, increased emissions and threatening traffic safety [16]. Kwan et al. point to a massive decentralising trend in urban areas, resting heavily on private car transport [17]. This deplorable situation needs an efficient, intelligent and eco-friendly public transport system.

Ozener et al. suggests multiple factors behind increased emissions at bus stops, including drivers, passengers, transport bus conditions, the bus stop layout, the transport environment etc. Transport eco-friendliness depends heavily on the driver's behaviour, passenger load and number. Transport bus conditions involve the average speed, acceleration, load and engine performance. Bus stop characteristics include its layout, position, length, surrounding transport conditions and the roadway design. The transport environment encompasses humidity and temperature [18].

Experts have explored many emission reduction methods, including adding construction elements to the combustion engine or introducing electric motors. There are many ways of minimising air pollution in urban areas. Multiple studies [19, 20] indicate eliminating vehicles that run on fossil fuels. Another possibility is to encourage public transport in frequently congested traffic departments. Although numerous municipalities have already implemented hydrogen-driven buses or trolleybuses, suburban areas still use petroleum fuels burnt in the combustion engine [21].

Several studies examined air quality impaired by pollution, revealing flagrant violations of global regulations on air quality [22, 23]. Densely populated urban and industrial areas heavily depend on clean air, significantly improving the quality of life. Regular air quality check-ups largely contribute to urban sustainability and better life [24, 25], including monitoring and forecasting air quality to prevent environmental contamination. Many studies focused on various methods of measuring particulate matter [26, 27]. Numerous authors [28–30] explored the link between the number of vehicles and produced emissions, arriving at inconsistent conclusions. While some blamed increased traffic volumes in urban areas, others dismissed this claim for weak or zero correlations between variables [31–33]. The COVID-19 pandemic largely contributed to improving air quality by imposing severe restrictions on human activities [34, 35], leading to substantial global pollution abatement [36].

The specific aim of our research is to focus on assessing the relationship between the number of vehicles and produced particles, indicating various pollution levels depending on the number of oncoming cars. The investigation conducted during our research imitate the investigation carried out by the Slovak Hydrometeorological Institute, the only institution monitoring and evaluating air quality in Slovakia. The informative role of the Institute prevents taking any practical steps towards remedying the current situation in Slovakia. We classified the data according to quality, converting figures to words and assessing their public availability. *Table 1* illustrates individual classes of measured particulate matter, including the information about the air quality, marked in colours. The data on the particulate matter are available online.

Table 1 – Evaluation of air quality in the measurement of particulate matter [according to Slovak Hydrometeorological Institute]

Air quality evaluated according to Slovak Hydrometeorological Institute [μg/m^3]

Quality level	$PM_{2.5}$	PM_{10}
very good	0–14	0–20
good	14–25	20–40
worse	25–70	40–100
bad	70–140	100–180
very bad	>140	>180

The purpose of conducting similar research works is extremely important for several reasons. Practical investigation contributes towards a deeper understanding the resources and the extent of air pollution, which is crucial for developing effective policies and regulations. Based on the results, it is possible to identify the most endangered groups of the population and propose measures to protect them. The results of the research itself provide foundations for introduction of innovative technologies and approaches that can significantly contribute towards improving the air quality. Finally, similar research promotes sustainable development by showing the way to reduce negative environmental burden and improve public health.

2. METHODOLOGY

The research methodology involved measuring particulate matter emissions at the bus station in Žilina during the morning and afternoon rush hours, comprising two consecutive hours, 6:00 – 8:00 in the morning and 14:00 – 16:00 in the afternoon. We made four measurements for each period during the working days except Monday and Friday, given the massive upsurge of passengers that would bias our results. We did not include wind conditions, considering only the air quality at the bus station over specific periods during rush hours. *Figure 1* shows the number of outbound buses during the day, suggesting the same number of departing buses each day.

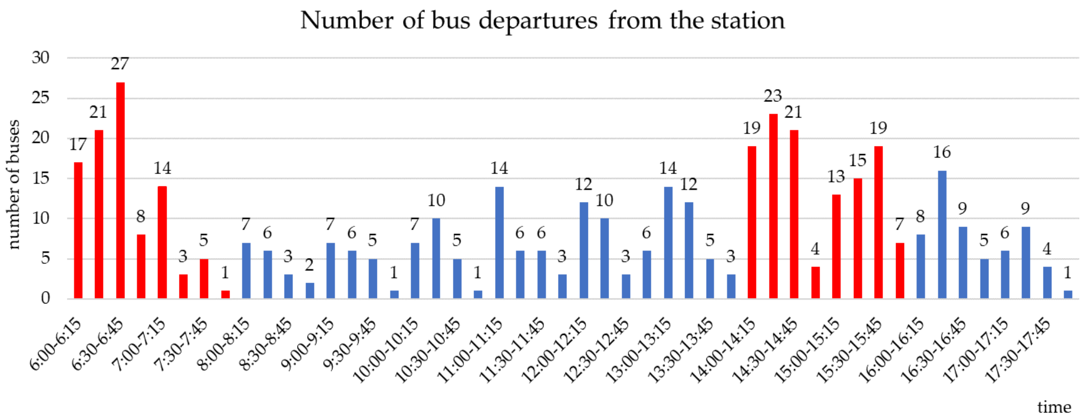

Figure 1 – Number of bus departures from the station [authors]

Figure 1 depicts the number of bus departures from the station. The red colour illustrates measured periods. The acquired data indicate the peak time of outgoing buses from 6:00 to 8:00 in the morning and from 14:00 to 16:00 in the afternoon, corresponding to our data collection on air quality. We changed the place of measuring within the premises every 15 minutes, always looking for the busiest platform. *Figure 2* illustrates the scheme of the bus station in Žilina.

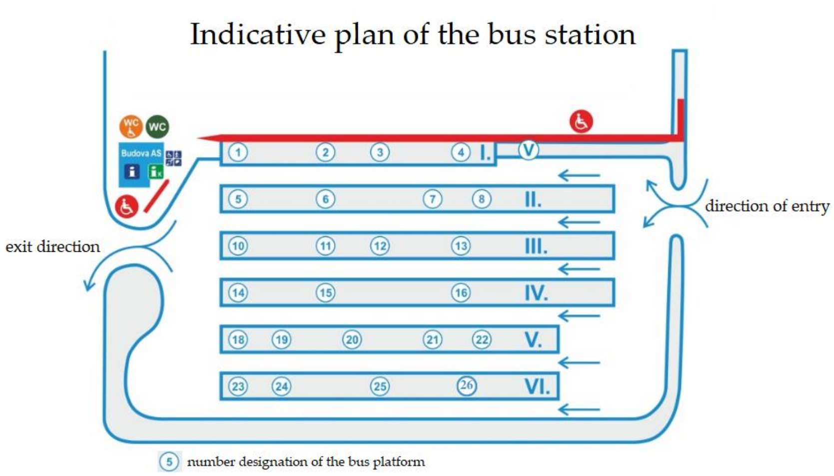

Figure 2 – Indicative plan of the bus station [authors]

Platforms 1 and 4 dispatch international coaches, indicating high numbers of departing buses. Platform 26 serves for irregular transport, showing similar numbers to the previous cases. Platforms 5, 6, 11, 14 and 15 have the highest number of outbound buses, exceeding 50 departures per day. Platform 24 tops the list, dispatching coaches to Kysucké Nové Mesto, Vadičov, Nesluša, Lodno, Nová Bystrica and Snežnica. Other platforms are not as busy.

2.1 Measurement devices

We used the PCE-PCO 2 measurement equipment to detect particulate matter emissions. This portable device monitors particulate matter in the atmosphere, measuring the amount of exhaust gases, fumes and other pollutants in the air. We positioned the device at one spot 160 cm above the ground throughout the measurement periods, mimicking the head height of a walking pedestrian. As our research aimed to quantify the amount of particulate matter emissions and assess the threat to human health, we collected data from the average height of human nostrils. The equipment sucks air through its upper part (*Figure 3*).

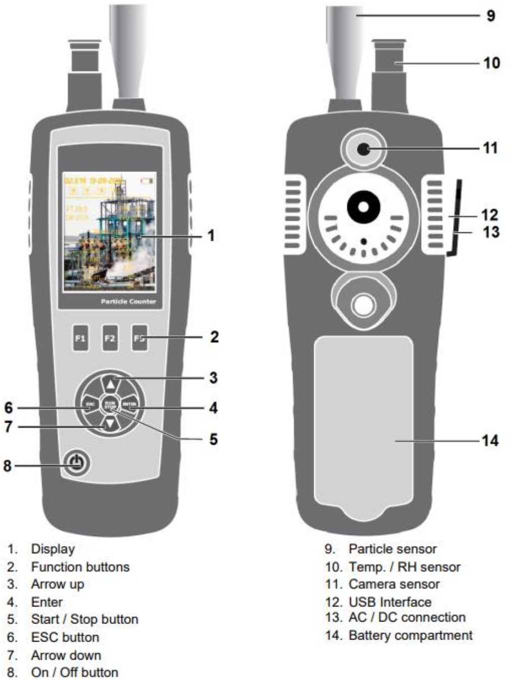

Figure 3 – PCE-PCO 2 measurement device [37]

The measurement device switches on every 30 seconds, performing two measurements within one minute. The subsequent data processing yielded a mean value, providing a clear picture of the recorded data. The analysis started with the device undergoing an automatic rinsing test to avoid bias by adverse effects. Following the test, the equipment automatically activated air suction, lasting five seconds. The device then assessed particulate matter emissions for $PM_{2.5}$ and PM_{10}. *Table 2* suggests other technical parameters of the measurement instrument.

Table 2 – Technical parameters of the measurement instrument [37]

Particle specifications	
Particulate matter channels	$PM_{2.5}$/PM_{10}
Particle concentrations	0 ... 2000 μg/m^3
Resolution	1 μg/m^3
Particle counter specifications	
Particle sizes (in micrometres)	0.3/0.5/1.0/2.5/5.0 and 10 μm
Flow rate	2.83 L/min
Coincidence error	<5% at 2,000,000 particles per cubic foot
Counting efficiency	50% at 0.3 μm
Memory capacity	Stores up to 5000 data sets
Counting modes	Cumulative, differential, concentration

3. RESULTS

The individual measurements aimed at quantifying particulate matter emissions at the bus station, ensuring that our calculations are regular and accurate. The evaluations occurred during the two-hour morning and afternoon rush hours. The data analysis of the full-employed bus station shows that travellers are most vulnerable to emissions at the station between 6:00 and 8:00. To compare the results from both measurements, we set the equal two-hour calculation for the afternoon peak hour, i.e. 14:00–16.00. The evaluations observed the measuring time, i.e. 15 minutes at the busiest platform. Throughout the survey, we monitored the emission standards of each bus found in the car fleet register of the transporter. Most vehicles conformed to the EURO 6 emission standard. As buses with lower emission standards do not provide regular services, we may detect reduced emissions at the bus station in one measured timespan. Since the use of vehicles is in the competence of the transporter, and we must consider these factors, our research ignores the emission standards of the particular bus running to and from the station. Renovating the carrier's car fleet would cut vehicle emissions, tremendously improving the air quality at the bus station and the immediate environment. The following figures suggest our results obtained from morning rush hour measurements at the station.

3.1 Results – morning peak

The following figures depict the movement of particulate matter emissions produced at the bus station. The measurements observe the pre-established methodology. For a clearer picture, we made separate graphs for $PM_{2.5}$ and PM_{10} emissions.

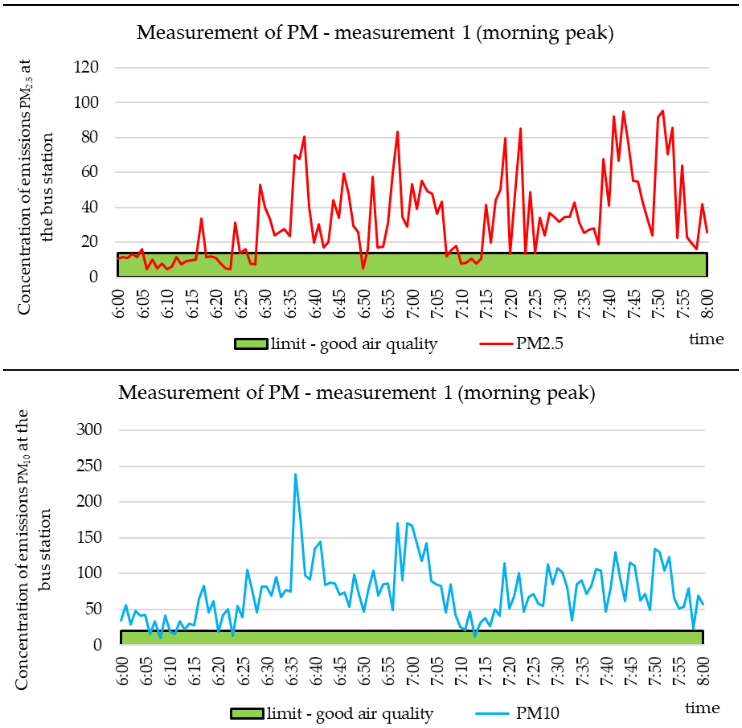

Figure 4 – Production of PM_{10} and $PM_{2.5}$ emissions – 1st measurement, morning [authors]

The following figure illustrates a massive increase in particulate matter in the atmosphere from 6:30, indicating the most dramatic growth from 6:30 to 7:00. After 7:00, the values steadily decreased for approximately 15 minutes to soar again. Platform 11 indicated the highest rates during both measurement periods. The graphical depiction shows 'good' air quality during the first 15 minutes. Emissions and air contamination with particulate matter grow with the number of buses. The station saw the highest particulate matter concentration between 6:30 and 7:00. At this time, emissions topped 200 $\mu m/m^3$ of the PM_{10} values, exceeding the acceptable limit of noxious substances by 900%. The $PM_{2.5}$ emission levels indicated the highest air pollution between 7:30 and 8:00, peaking at 100 $\mu m/m^3$. At this time, exhaust fumes crossed the tolerable limit by 600%, indicating severe harm to human health. The following graph suggests that the concentration of particulate matter soared high above the acceptable ceiling.

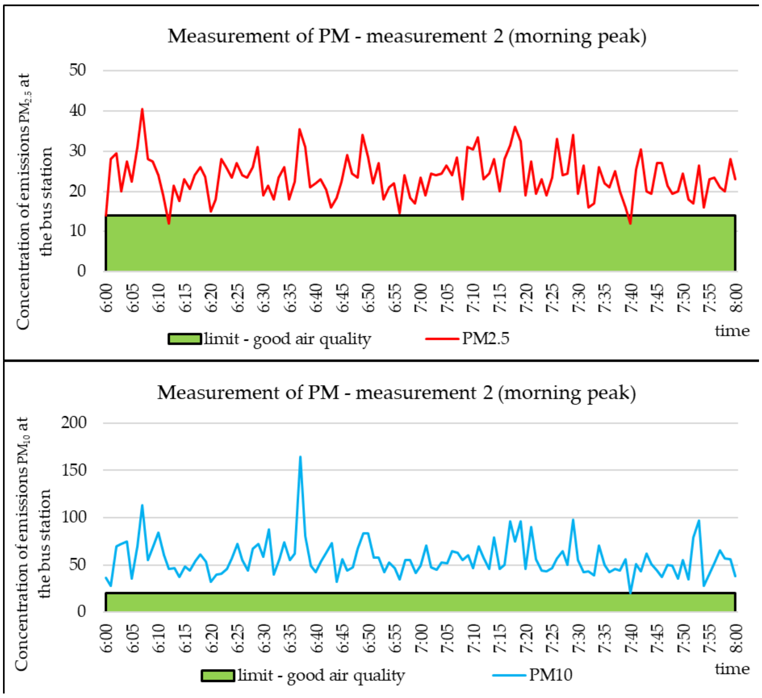

Figure 5 – Production of PM_{10} and $PM_{2.5}$ emissions – 2nd measurement, morning [authors]

Figure 5 illustrates the results of the second measurement, indicating the highest emission rates at platforms 24 and 11 over the monitored period. Those are the busiest platforms, marking the concentration of emissions between 100 and 150 $\mu m/m^3$ for PM_{10} and 30 and 40 $\mu m/m^3$ for $PM_{2.5}$. Throughout the observations, emissions neither reached nor fell below the limit acceptable for human health. Relying on the information on the concentration of particulate matter provided by the Slovak Hydrometeorological Institute, we consider the situation of air quality 'aggravated'.

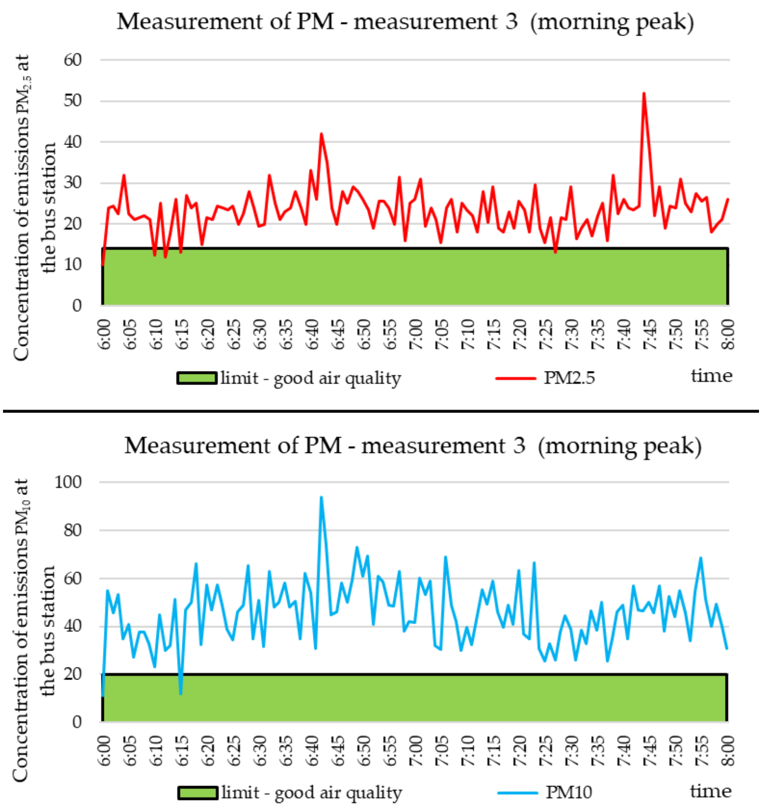

Figure 6 – Production of PM_{10} and $PM_{2.5}$ emissions – 3rd measurement, morning [authors]

The third measurement, as shown in *Figure 6*, is similar to the first two evaluations. The concentration rates of particulate matter mimicked the increased levels of the first two calculations in the first hour of the experiment. At this time, the pollution level ranged between 30 and 40 µm/m^3 for $PM_{2.5}$ and 40 and 70 µm/m^3 for PM_{10}. In the second part of the analysis, the concentration of emissions slightly decreased to soar again at the end of the process. The measurements suggest a consistent air pollution trend, substantially exceeding the limit acceptable for human health. *Figure 7* depicts the results of the fourth measurement, performed at the morning rush hour.

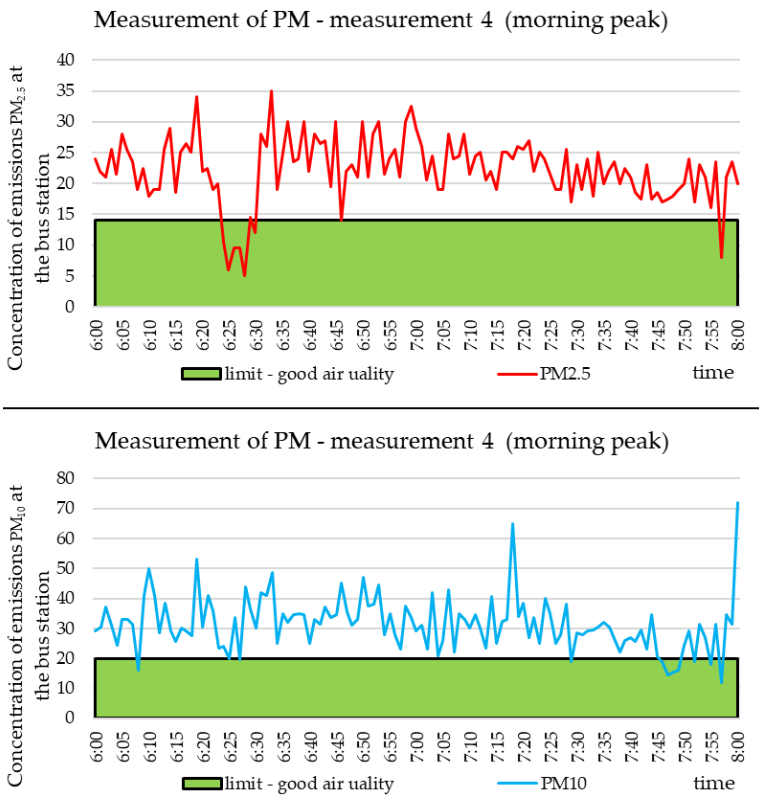

Figure 7 – Production of PM_{10} and $PM_{2.5}$ emissions – 4th measurement, morning [authors]

The final test, *Figure 7*, indicated the lowest pollution level, suggesting the highest concentration at the end of the experiment. The last evaluation mimics the emission trend of the previous measurements conducted at the bus stop, marking the sharpest emission increase at the end of the first tested hour, with the pollution levels from 30 to 40 µm/m^3 for $PM_{2.5}$ and 40 to 52 µm/m^3 for PM_{10}. Then, we witness a steady decline in the concentration, lasting through the end of the analysis. PM_{10} values show the lowest pollution level on this day.

3.2 Results – afternoon peak

The following figures illustrate our results, reflecting the particulate matter emission trend at the bus stop over the monitored period. The measurement time for the afternoon rush hour corresponds to the utilisation rate of outbound buses.

Figure 8 illustrates the emission movement at the bus station. Although the values suggest a lower overall concentration level than in the morning rush hours, the trend is highly inconsistent, indicating frequent slumps and rises. The values of $PM_{2.5}$ do not reflect PM_{10} production all the time, showing an opposite tendency of produced emissions, i.e. $PM_{2.5}$ values were sometimes rising when those of PM_{10} were falling. Platforms 12 and 2 reflected the highest PM_{10} concentration, while bus stop 15 indicated the highest $PM_{2.5}$ values. Our results suggest 'good' air quality at the bus station over the monitored period, as shown in the coloured graph. The green colour illustrates the emission limit acceptable for human health, indicating 'very good' air quality.

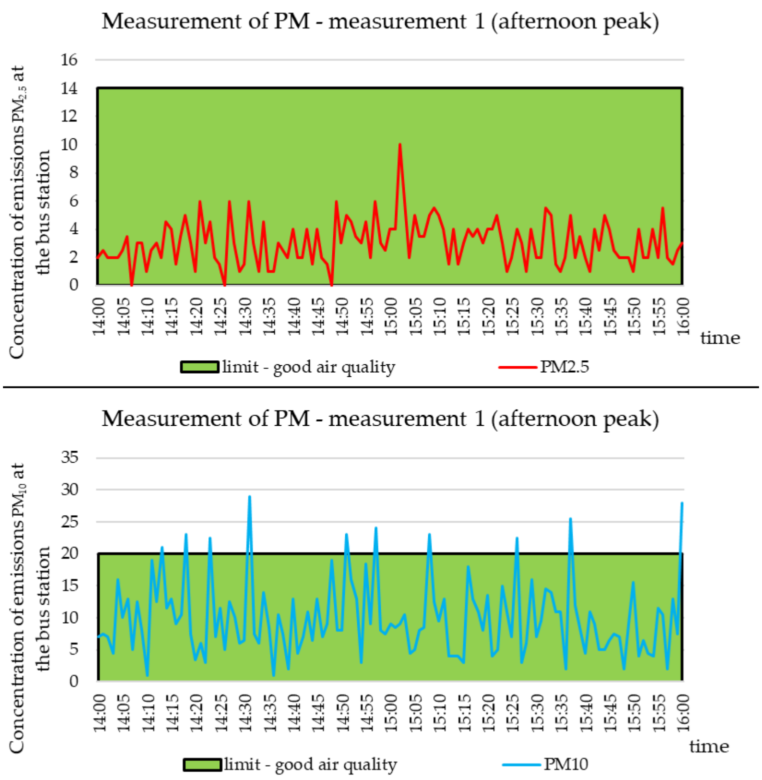

Figure 8 – Production of PM_{10} and $PM_{2.5}$ emissions – 1st measurement, afternoon [authors]

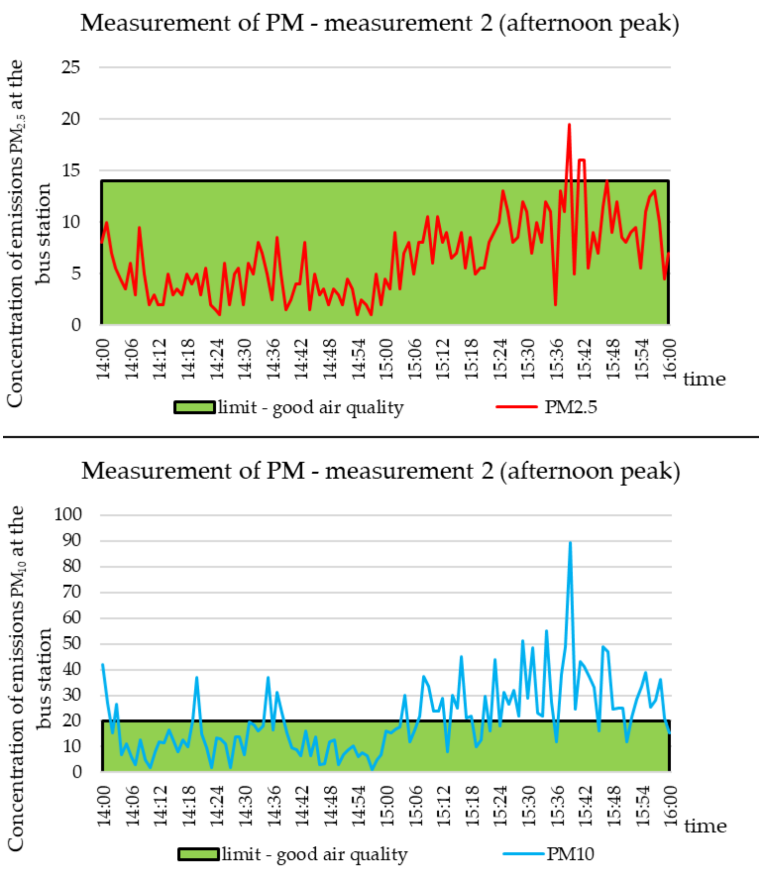

Figure 9 – Production of PM_{10} and $PM_{2.5}$ emissions – 2nd measurement, afternoon [authors]

Figure 9 reflects the emission trend, showing apparent inconsistencies between afternoon and morning measurements. The values of particulate matter emissions are not growing until the second hour, indicating a sharp increase and steady decline in the first sixty minutes. The third measurement (*Figure 10*) suggests a steady growth and a gradual decrease at the end. Platform 15 reflected the highest values, indicating between 50 and 100 μm/m^3 for PM_{10} and 25 and 35 μm/m^3 for $PM_{2.5}$. Although the acquired data show an increased concentration of particulate matter at the bus station, the harm to human health is the same as in the morning peak.

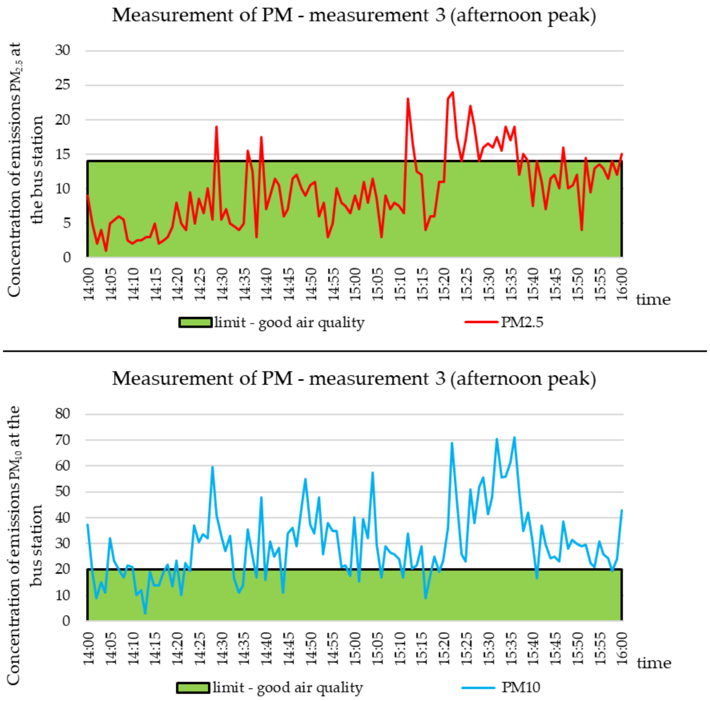

Figure 10 – Production of PM_{10} and $PM_{2.5}$ emissions – 3rd measurement, afternoon [authors]

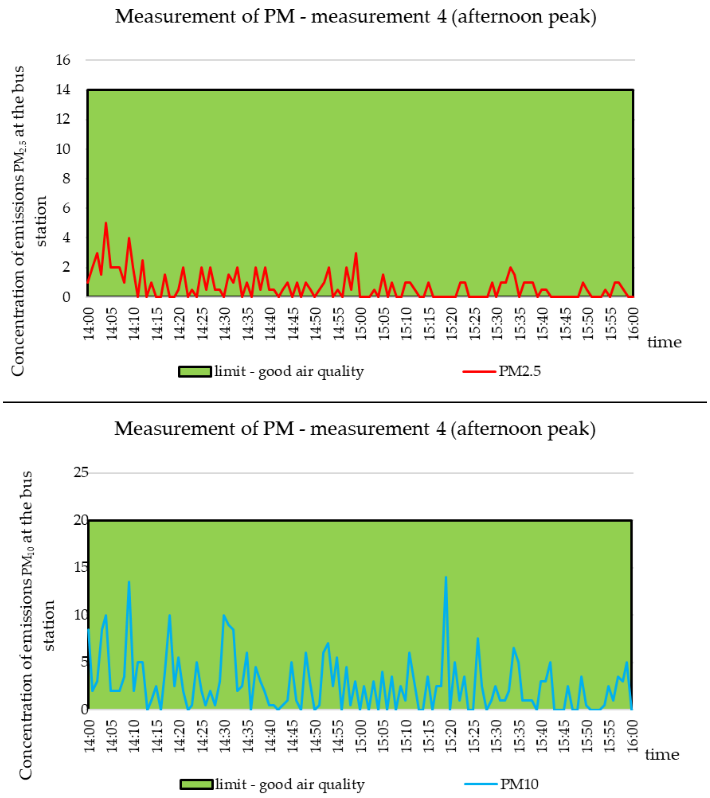

Figure 11 – Production of PM_{10} and $PM_{2.5}$ emissions – 4th measurement, afternoon [authors]

The values from the third measurement, as seen in *Figure 10*, imply a growing trend in particulate matter concentration. Platforms 14 and 15 marked the highest values, peaking at 25 μm/m^3 for $PM_{2.5}$ and 70.25 μm/m^3 for PM_{10}. These places were also the busiest. The graphical depiction suggests enormous disparities between the $PM_{2.5}$ and PM_{10} emissions.

Figure 11 depicts the movement of particulate matter emissions during the fourth measurement, indicating similarities between individual trends. The emissions are the lowest of all afternoon tests, with the highest rates at platforms 15, 12 and 14, suggesting eco-friendly values and 'very good' air quality.

4. EVALUATION

The acquired data allow us to explore the ecological impacts of emissions produced by bus transport, suggesting their mean values from individual assessments. This method provides for average emissions generated during each measurement. The following graph (*Figure 12*) proposes the results of our calculations.

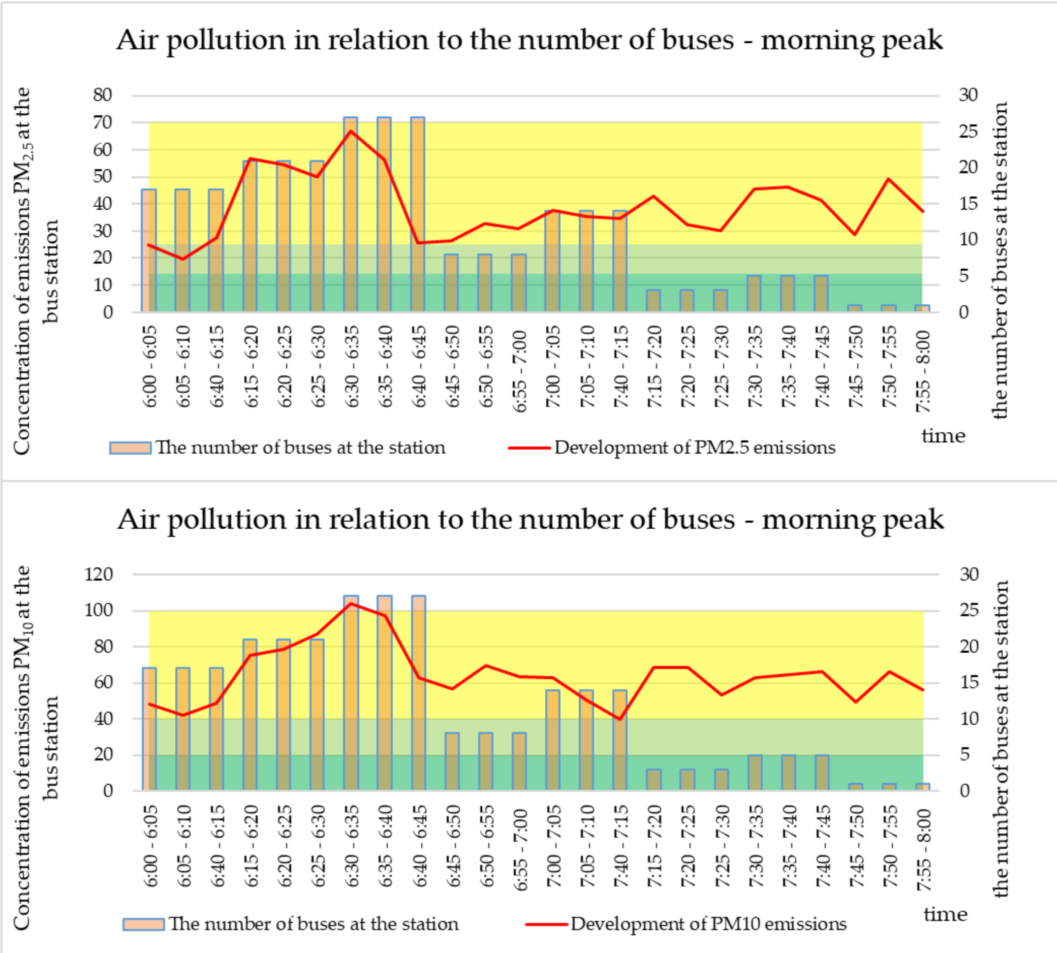

Figure 12 – Air pollution in relation to the number of buses at the bus station in morning peak [authors]

The graph depicts the average emission figures at the bus station during morning measurements. The red curve illustrates emission production (represents the mean value), reflecting previous repeated tests. The diagram informs on the number of buses (bar chart) present at the bus station, allowing us to assess the impact of the traffic on the emissions produced at the station. As the transporter adhered to the schedule, the number of buses did not change during the measurements, ensuring an equal amount of incoming and outgoing vehicles throughout the survey. Our results confirmed the profound impact of the traffic on air quality, revealing that air contamination grew substantially with the number of employed buses. This widespread phenomenon occurred during all measurements, suggesting increased particulate matter concentrations in the atmosphere when the bus station became busier. The following graph (*Figure 13*) depicts the trend in exceeding the concentration level over the monitored period.

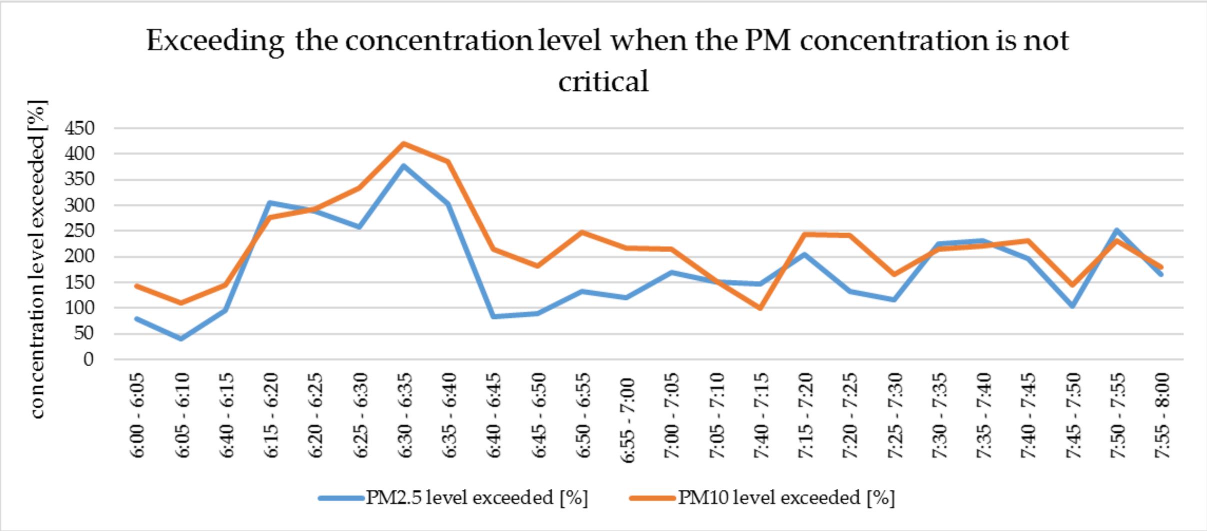

Figure 13 – Exceeding the PM concentration level when the pollution is not critical – afternoon measurement [authors]

The morning peak recorded the highest pollution at 6.15, with 66,8 μm/m^3 for $PM_{2.5}$ and 104 μm/m^3 for PM_{10}, several times exceeding the critical limit. It is almost 360% for $PM_{2.5}$ (blue curve) and nearly 420% for PM_{10} (orange curve). The overall air quality ranked 'worse' and may undermine travellers' health from the long-time perspective.

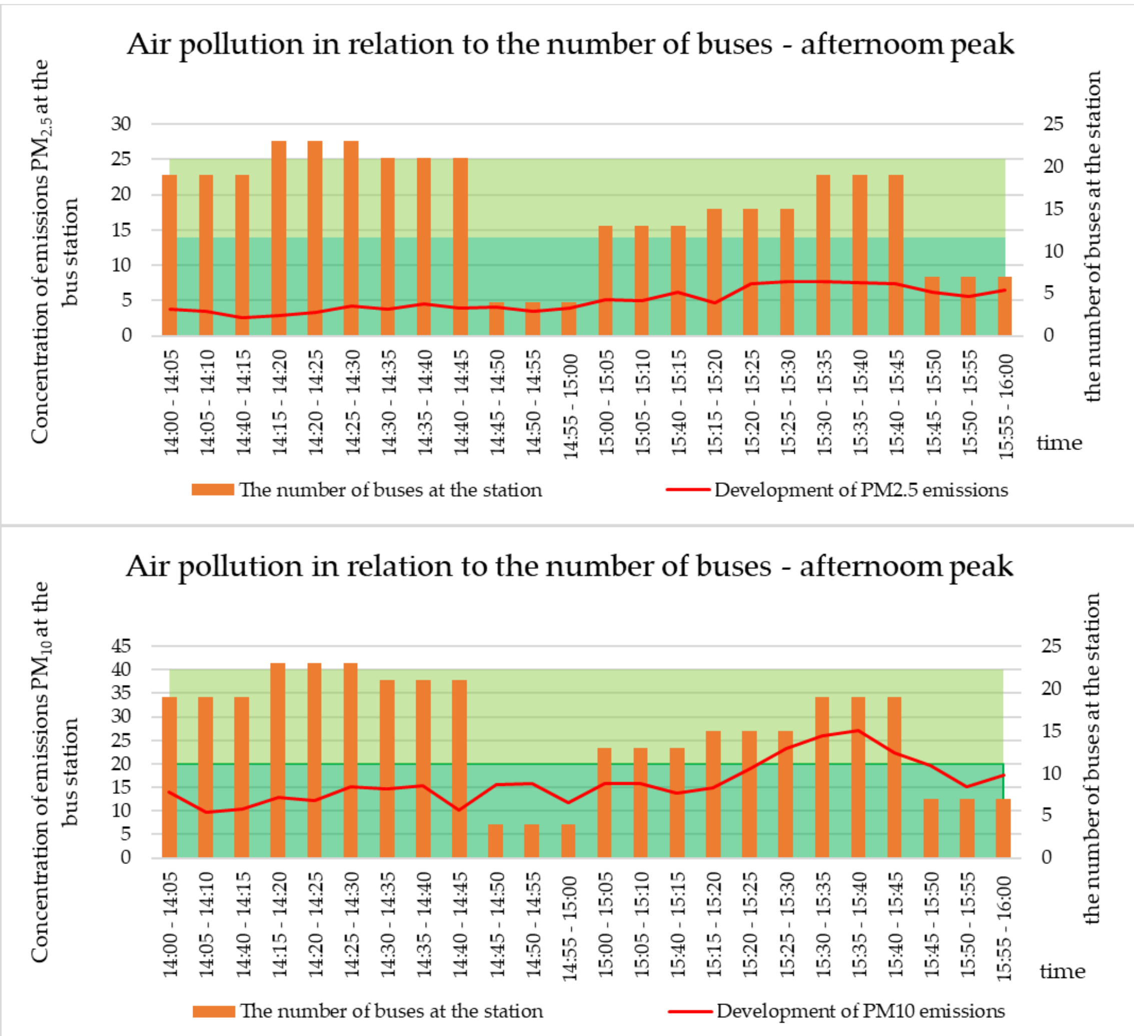

Figure 14 – Air pollution in relation to the number of buses at the bus station in afternoon peak [authors]

Figure 14 illustrates the particulate matter pollution movement at the bus stop during the afternoon peak, indicating slight air contamination. The lower number of incoming and outgoing vehicles and less traffic on adjacent roads significantly reduce pollution. Like during the morning measurements, the air quality worsens upon dispatching more buses to the field. The following graph depicts the phenomenon, illustrating the proportional tolerable limit of PM concentration safe for human health.

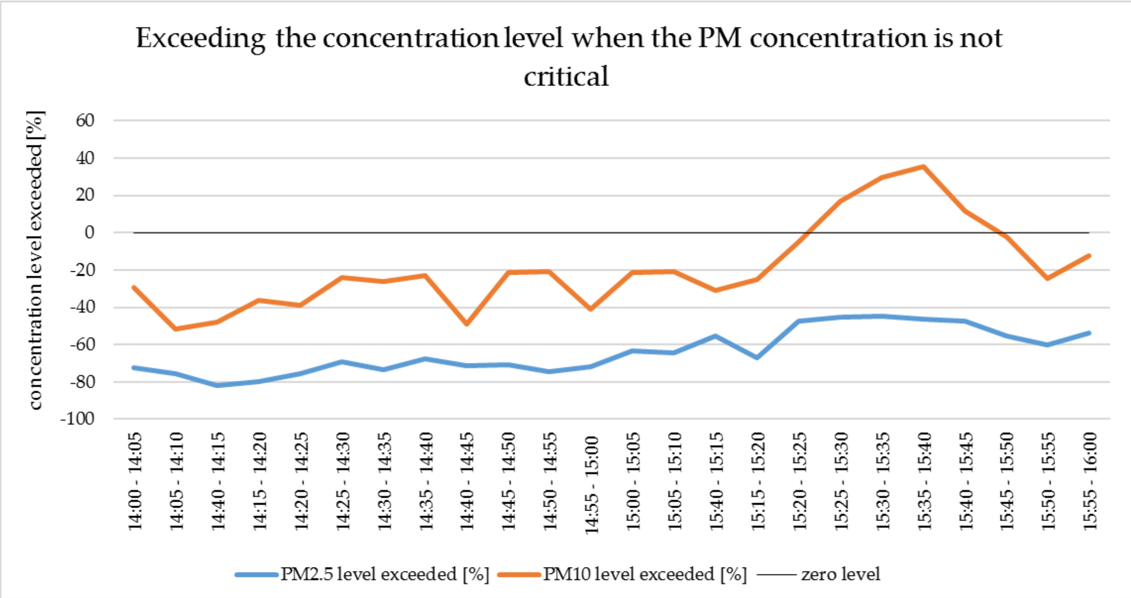

Figure 15 – Exceeding the PM concentration level when the pollution is not critical – morning measurement [authors]

Figure 15 suggests the proportional value of exceeding the air quality limit safe for human health. The curve predominantly continues below zero (minus levels), not exceeding the pollution limit prescribed by the Slovak Hydrometeorological Institute. The trend broke the sub-zero continuity between 15.25 and 15.50 when more buses come and leave, exceeding the tolerable pollution limit roughly by 30 %. Upon comparing both measurement periods, the afternoon peak witnessed a tremendous air quality improvement, given the less intense urban traffic on the busy neighbouring road network. The air quality then ranks ‘very good’.

5. DISCUSSION

The acquired data allowed us to assess the air quality at the bus station, suggesting changeable values. The adjacent busy road communications severely poison the surrounding atmosphere, especially noticeable during morning rush hours. Studies [38, 39] which dealt with the same issue confirm our results. Particulate matter emission values at the bus station reflected data acquired from practical measurements, indicating massive air contamination in densely crowded places. A bus station is an ideal place to conduct our experiments on the air quality assessment. Travellers are the most vulnerable to air pollution in the closed premises of the station, where the contaminated air cannot spread into the atmosphere. The particulate matter produced by vehicles accumulates in confined places and cannot easily dissolve into the air. Yajun Wu et al. explored emissions generated in underground carparks, revealing a strong correlation between the number of vehicles and air pollution values [40]. Their study emphasises low public awareness of air contamination.

Bus drivers often leave the engine running when passengers get on, causing a significant increase in exhaust fumes at the station. This phenomenon of ‘negative externality’ indirectly harms everybody around the bus station premises. Idle buses with engines turned on produce massive exhaust emissions, while turning off the engine would significantly decrease the air contamination at the bus station premises. A team of experts [41] explored the environmental advantages of electrified transport. As suggested, the Euro 6 emission standard for vehicles regulates exhaust emission limits for most buses incoming and outgoing from the bus station. Since Euro 6 ES became effective on 1 October 2013, it does not apply to all buses, excluding vehicles older than ten years.

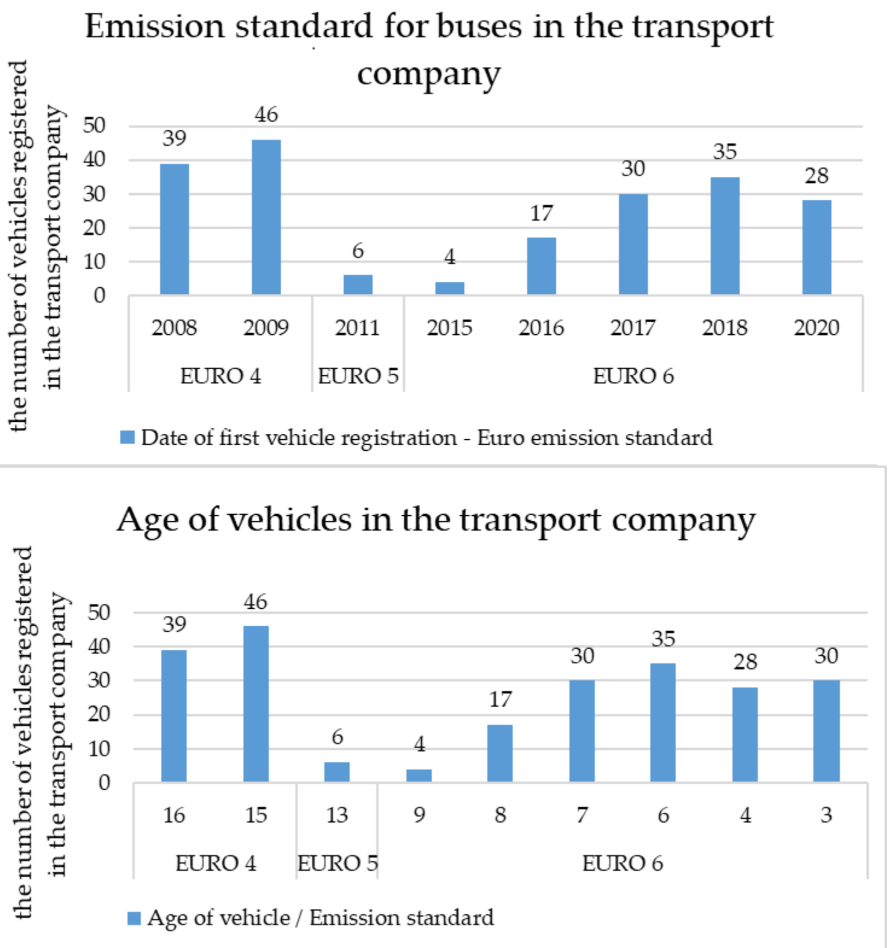

Figure 16 – Analysis of vehicle age and Euro emission standard – vehicles arriving at the bus station [authors]

Figure 14 suggests the age and Euro emission standard performance for vehicles operating at bus stations. Although the carrier continuously renovates and upgrades the car fleet, the company keeps records of vehicles highly exceeding prescribed emission levels. Despite the growing pressure to renew car fleets and thus reduce exhaust emissions, all public transport vehicles run on diesel fuel. Diesel-engine buses may cause severe air pollution compared to alternative fuel vehicles [42]. Accelerating and decelerating buses produce increased $PM_{2.5}$ and PM_{10} concentrations at the bus station, where a smooth ride for a longer time would significantly reduce exhaust emissions. The study [43] shows that heavy-traffic localities suffered from increased particulate matter concentrations during rush hours, including exhaust fumes from running engines and massive crowds at the bus station and platforms. These aspects significantly influence PM levels. Our research suggests that the particulate matter concentrated at the bus station clashes with the evaluation of the Slovak Hydrometeorological Institute, indicating poorer air quality than the Institute suggests, namely during the morning peak time. Increased air contamination persists throughout the morning rush hours, severely damaging human health [44]. Prolonged exposure to PM_{10} and $PM_{2.5}$ causes cardiovascular and respiratory diseases, leading to premature death [45].

Some cities have equipped bus stations with systems for continuous air quality monitoring [46]. The data informs travellers and other people about the air quality at the station via digital symbols [47]. Permanent air quality monitoring allows for imposing remedial measures to improve the situation. Moore et al. used an anemometer to prove that traffic flow strongly correlates with the particulate matter concentrated inside bus shelters, revealing that particulate matter concentrations are contingent on wind direction towards the shelter [48]. Despite all the findings, the vehicle plays a key role in regard to the process of creating and spreading exhaust gas emissions related to the determination of air quality. Kendra et al., in their research, monitored the environmental burden of distinct modes of transport. The results show that the structure of the vehicle fleet has the greatest effect on the selected ecological impacts of individual transport modes in terms of age and type of traction used for its propulsion [49].

6. CONCLUSION

Our research revealed that vehicles rank among the worst air polluters. Although all combustion engines produce massive emissions, diesel-powered buses generate the highest concentrations of particulate matter and toxic substances that harm human health. Permanent air contamination over the recommended limit causes long-term impairment to the human organism. Our study aimed at exploring $PM_{2.5}$ and PM_{10} particulate matter concentrations emitted into the atmosphere at the bus station in Žilina. We used an air sampler to collect and examine the data, analysing particulate matter concentration in the air. The research revealed massive amounts of particulate matter released into the atmosphere during morning rush hours, indicating 66 µm/m^3 for $PM_{2.5}$ and 104.5 µm/m^3 for PM_{10}. The measured values substantially surpassed the acceptable limit of 14 µm/m^3 for $PM_{2.5}$ and 20 µm/m^3 for PM_{10}, exceeding the tolerable level by 360% for $PM_{2.5}$ and 420% for PM_{10}. Our analysis revealed that the PM released from buses predominantly concentrated in roofed bus station premises, severely undermining the health of travellers and staff.

Following these results, it is evident that further measures and research are needed to alleviate air pollution at bus stations, especially during the morning traffic peaks. In the future, research should focus on evaluating the efficiency of various approaches for reducing emissions from buses with compression ignition engine. Investigating the impact of introducing alternative propulsion systems, such as electric or hybrid buses, could bring valuable knowledge in terms of the options to improve air quality. It could also be beneficial to analyse the long-term impact of mitigating PM concentration on the health of passengers and bus station staff. Based on these findings, it could be possible to design specific proposals for improving transport infrastructure and its organisation at bus stations, thereby reducing PM exposure.

Upon achieving the research outcomes, it is possible to present a comprehensive overview of the development of air quality at the bus station under investigation. The results may contribute towards improving air quality and thus the overall health of the inhabitants of urban areas. Further research in this topic is essential for achieving sustainable development and providing healthier environment for all the parties involved.

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Branislav Šarkan, Michal Loman, Ondrej Stopka, Jacek Caban, Arkadiusz Małek

Kvantifikácia objemu pevných častíc na autobusových staniciach

Abstrakt

Prehustená mestská doprava výrazne prispieva k znečisteniu ovzdušia v mestách. Počas čakania na autobusových zastávkach môžu byť cestujúci vystavení zvýšenej kontaminácii spôsobenej vozidlami vrátane pevných častíc (PM). Moderné usporiadanie, poloha a dizajn autobusovej zastávky ignoruje kvalitu ovzdušia a umožňuje nadmerné vystavenie znečisteniu. Pevné častice vážne poškodzujú životné prostredie, ohrozujú ľudské zdravie a vážne poškodzujú všetky živé organizmy. Cieľom výskumu je monitorovať emisie častíc na autobusovej stanici v meste Žilina (Slovensko) a zhromažďovať údaje o emisiách výfukových plynov vypúšťaných z autobusov v priestoroch stanice. Keďže vozidlá s pohybom alebo motorom v chode neustále produkujú emisie do ovzdušia, meriame kvalitu ovzdušia počas špičiek na autobusovej stanici. Výsledky naznačujú priamu súvislosť medzi prechádzajúcimi vozidlami a produkovanými emisiami častíc, keď odhaľujú niekoľkonásobne vyššie úrovne emisií. Počas rannej špičky bola prekročená koncetrácia pevných častíc o 360 % pre $PM_{2,5}$ a 420 % pre PM_{10}. Výskum ukázal, že PM uvoľňované priamo z autobusov majú tendenciu sa hromadiť v krytých priestoroch autobusovej stanice, čo vážne poškodzuje zdravie cestujúcich a personálu. Naša štúdia varuje pred možnými rizikami zhoršenia ľudského zdravia, keďže čakajúci cestujúci vdychujú nevedomky kontaminované častice. Naše výsledky naznačujú najväčších producentov emisií a navrhujú nápravné opatrenia.

Kľúčové slová
kvalita vzduchu; emisie; častice; vozidlo; autobus; stanica.