Global Sustainability Challenges
2024; Vol. 2(1): 1-6
https://gsc.unionnikolatesla.edu.rs/index.php/gsc/index
doi:XXXX.2024XXXX.XX
UDC: 502.3:504.5:669.018.674(497.11)
ISSN: 2956-1051 (Online)

Monitoring of air quality and meteorological parameters on the construction site

Lazar Milivojević[1], Sanja Mrazovac Kurilić[2,*], Zvonimir Božilović[1], Suzana Koprivica[1]

[1]Faculty of Construction Management, Union-Nikola Tesla University, Belgrade, Serbia
[2]Faculty of Ecology and Environmental Protection, Union-Nikola Tesla University, Belgrade, Serbia

[*]**Corresponding author:** smrazovac@unionnikolatesla.edu.rs

To cite this article:
Milivojević, L., Kurilić, S.M., Božilović, Z. and Koprivica, S. (Year). Monitoring of air quality and meteorological parameters on the construction site. *Global sustainability challenges, Volume*(Issue), pp. xx-xx. doi:10.11648/xxx.xxxxxxxx.xx.

Received: Mon dd, 2024; **Accepted**: Mon dd, 2024; **Published**: Mon dd, 2024

Abstract: The construction industry is one of the main producers of dust, greenhouse gases and air pollutants. Effective operation and management of construction site operations can significantly reduce the project's carbon footprint and other environmental impacts. Through the cooperation of scientific and research institution and construction company, real-time monitoring of air quality at the construction site was implemented using IoT technologies. An IoT-based system framework that integrates a distributed sensor network to collect real-time data and demonstrate air quality at a construction site was implemented. Different types of sensors were used to collect data related to NO2 and PM2.5, PM10 particles, as well as meteorological parameters – wind speed and direction, humidity, pressure and temperature. The results of real-time measurements provide a picture of the state of air pollution at the construction site and the connection with construction activities that can be managed in order to reduce the concentration of polluting gases and suspended particles. Through on-site monitoring of construction site in Belgrade City, this study found that the dust level of construction activities is relatively high. Comparing the wind direction and PM concentrations, it can be concluded that the construction activity had a significant impact on the air quality around the construction surrounding areas. Regarding the main factors affecting the building construction dust emission, the correlations show that building construction dust emission was not significantly correlated with meteorological factors.

Keywords: construction; PM concentrations; correlation; meteorology

1. Introduction

With the looming consequences of climate changes, sustainability measures, including quantifying the amount of air pollution during various types of activities, have become an important goal in all branches of the economy, including the construction industry. All construction sites generate high levels of pollution over a long period of time. The construction industry is one of the main producers of greenhouse gases (GHG) with a share of about 12% of the total world emissions. According to official figures from the Delhi Pollution Control Committee (DPCC), 30% of air pollution by dust is caused by emissions from construction sites. Various construction activities such as excavation, diesel engine operation, demolition, burning and working with toxic materials contribute to air pollution. The main factor that contributes to air pollution with nitrogen and sulfur oxides during construction projects is the use of heavy equipment, ie. machines (excavators, loaders, bulldozers, etc.) as a result of burning the fuel used by these machines. PM pollution is mainly attributed to excavation work. A significant source of PM 2.5 particles on construction sites are exhaust gases from diesel engines and diesel generator sets, vehicles and heavy equipment. Harmful substances from oils, glues, solvents, paints, treated woods, plastics, cleaning agents and other hazardous chemicals widely used on construction sites also contribute to air pollution.

In the Balkans, Serbia is the leader in the construction industry, which is growing year by year. In August 2022, 2,562 building permits were issued. This construction trend promises a further significant increase in the concentration of greenhouse gases and other pollutants. For these reasons, it is primarily necessary to introduce monitoring of polluting gases and PM particles in real time in order to propose measures to reduce the concentration of polluting gases and PM particles through insight into the amount of pollution present and depending on the atmospheric conditions.

Although emissions of harmful substances in construction industry are becoming more and more significant due to the accelerated trend of construction in Serbia, a real-time emission monitoring tool, which is essential to help construction teams avoid excessive emissions of harmful substances, has not yet been introduced to construction sites in the Republic of Serbia. The great importance of the application of this system and the implementation of this type of research is for the health of the employees at the construction site who often have health problems due to the working conditions, i.e. the poor air quality at the construction sites, which sometimes reaches such a bad quality that it endangers the lives of the workers.

Particulate matter (PM) is one of the most common air pollutants globally as well as nitrogen oxides (NOx), photochemical oxidants including ozone (O3), carbon monoxide (CO), lead (Pb), and sulfur dioxides (SO2) (EPA, 2021).

In the last few years, research has been done on the effects on dust concentration at construction sites, with a focus on PM10 and PM2.5 (De Moraes et al., 2011; Hassan et al., 2016; Yan et al., 2019). It was found that there are a number of factors that influence the concentration of PM particles at the construction site. Certainly, the surroundings of the construction site itself represent a source of certain emissions that are transported and registered on the construction site itself, independently of the activities on the construction site. These are so-called background emissions. When it comes to meteorological factors, several studies have been done on the connection between meteorological parameters and the concentration of polluting substances (including PM particles), and there are conflicting views on that topic. Some authors (Araújo et al., 2014) believe that meteorology has an extremely important influence on the concentration of PM particles at the construction site, although due to the lack of concentration data, they failed to develop a model for the dependence of PM particle concentrations on meteorological parameters. According to some other authors (Zhang et al., 2009), dust emissions from construction sites have significant seasonal changes, which was also confirmed by other researchers in their research (Zhao et al., 2010). This again indicates a strong relationship between the concentration of PM particles and meteorological parameters. In some research (Guo, 2010; Luo, 2017) that also studied the relationship between construction works and meteorological parameters, it was concluded that PM particles are highly positively correlated with wind speed and relative air humidity, and weakly with temperature. In addition to excavation work, internal works on buildings also have a certain contribution to emissions. Kinsey et al. (2004) found that vehicles leaving a construction site can carry a large amount of dust and sediment to nearby roads, leading to the rise of secondary dust. Azarmi et al. (2014) carried out a detailed monitoring of certain phases of work on the construction site, such as mixing concrete, drilling and cutting. PM10, PM2.5 and PM0.1 Concentrations of PM particles during drilling and cutting activities were up to 14 times higher than background concentrations. De Moraes et al., 2016 focused on monitoring the concentration of particulate matter (PM10) generated from concrete and masonry in construction activities. These and similar studies have shown that certain phases and activities during work on construction sites are an important factor that affects the concentration of PM particles (Fan et al., 2011).

The goal of this research is a deeper and more detailed analysis of the relationship between the concentrations of PM particles on the construction site that are emitted due to excavation work and meteorological parameters. The data analysis was done to check the possibility of applying artificial intelligence to predictions of the concentration of PM particles depending on the weather conditions.

2. Materials and Methods

The experiment, which consisted of measuring the concentrations of suspended particles PM2.5 and PM10, then NO2, as well as meteorological parameters (pressure, temperature, humidity, speed and wind direction) was carried out at one construction site in Belgrade (Fig. 1) during 15 days in July 2022, from the first to the fifteenth of July. The excavation zone is located west and southwest of the location of the measuring station, while additional sources of emissions on the construction site, such as carpentry and reinforcement work, are placed on the north and northwest side from monitoring device on the construction site. Figure 2 shows the distances of individual emission sources from the measuring station. Emissions from other sources come from the south and east direction and can be treated as background emissions. During the whole fifteen days, two electric powered machines were working in the excavation area. All days except Sunday, work was done from 13:00 to 17:00. The waste was taken away by truck every day.

The devices that were used were sensor type and the results were recorded every 5 minutes.

RS-MG111-WIFI-1 is an air environment multi-element transmitter. It is used to detect NO2, PM2.5 and PM10. The transmitter adopts the original imported sensor and control chip, which has the characteristics of high precision, high resolution and good stability. Using WIFI network transmission, it is directly connected to the on-site WIFI network, and the connection is convenient. With the free monitoring platform software or the free IoT cloud platform,

Figure 1. Location of the construction site on the map of Belgrade

it directly formed Online Integrated air environment monitoring system, widely used in building HVAC, building energy saving, smart home, schools, hospitals, airport stations and other places.

Another device is CC-M12 weather station: an anemometer (WD, WS), temperature, pressure and humidity with RH&T and 4G communication.

The devices are portable (with the possibility of installation outdoors and indoors). Such a system allows the manager of the construction site and the company to have a detailed insight into the quality of the environment in real time. In doing so, sources of harmful gas emissions are identified from three main activities in construction: earthworks, transport and interior works. Different types of sensors were used to collect data related to NO2, PM2.5, PM10 particles, as well as meteorological parameters – wind speed and direction, humidity, pressure and temperature. Web and mobile application provide data visualization (map, list, chart), notifications/alarms when values are outside the defined range, algorithms for data processing, export to csv file.

SPSS 23.0 statistical software was used for data analysis in this study.

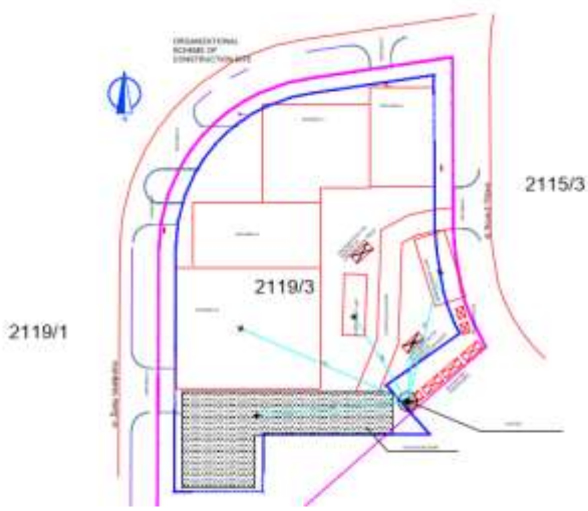

Figure 2. Sketch of the construction site with the marked positions of the measuring device, the excavation zone, as well as other potential sources of emissions

3. Results and Discussion

The measurement results are shown in Figures 3-8. The results are given as Working hours results (WH) that show the separated working hours from 7 a.m. to 5 p.m. on weekdays (Monday to Saturday).

By monitoring the concentration of polluting substances, 3 sets of data were obtained, including PM2.5, PM10 and NO2.

As shown in Figures 3-5, these 3 sets of data are plotted in a line graph.

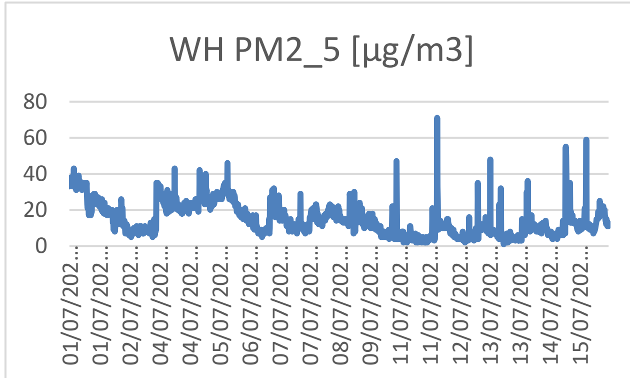

Figure 3. Time dependence of the concentration of PM2.5 particles in the air at the construction site during the excavation works in a period of 15 days (data during working hours)

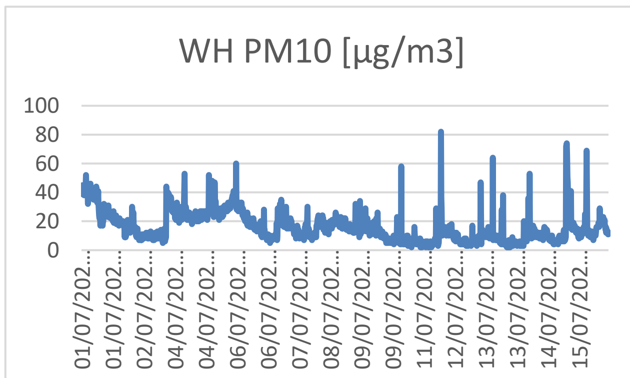

Figure 4. Time dependence of the concentration of PM10 particles in the air at the construction site during the excavation works in a period of 15 days (data during working hours)

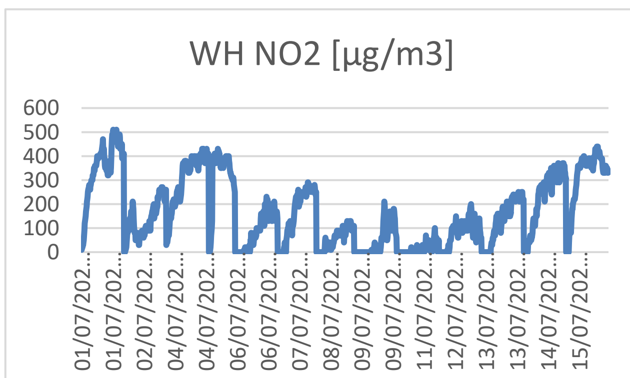

Figure 5. Time dependence of the concentration of NO2 particles in the air at the construction site during the excavation works in a period of 15 days (data during working hours)

From the results shown, it can be seen that PM2.5

concentrations during working hours they ranged from 1 to 71 µg/m3. The average value of PM2.5 concentration during working hours was 14.66 µg/m3. Average daily concentrations of PM2.5 were respectively per day, for all 15 days: 26.46, 14.69, 21.06, 26.87, 27.09, 15.76, 15.16, 16.55, 11.66, 7.26, 5.75, 9.38, 8.36, 10.20, 15.26 µg/m3.

PM10 concentrations during working hours ranged from 2 to 82 µg/m3. The average value of the concentration during working hours was 16.06 µg/m^3. Average daily concentrations of PM10 were between respectively per day, for all 15 days: 29.18, 16.22, 23.05, 30.21, 30.15, 16.97, 16.04, 17.50, 12.69, 7.98, 6.48, 10.55, 9.11, 11.08, 16.94 µg/m3.

It can be noted that the highest values of PM10 and PM2.5 particle concentrations were during the night hours, which can be attributed to stabilization of the atmosphere according to Yao et al. (2015).

According to WHO limits, PM$_{2.5}$ should not exceed 5 µg/m^3 annual mean, or 15 µg/m^3 24-hour mean; and that PM$_{10}$ should not exceed 15 µg/m^3 annual mean, or 45 µg/m^3 24-hour mean. Analyzing the average 24-hour values for PM2.5 and PM10, it can be concluded that PM2.5 represents a far greater health hazard due to far higher values compared to the prescribed daily limits. It can be observed that more than 50% of days, including non-working days, PM2.5 exceed the permissible 24-hour value according to WHO standards, which is not the case with PM10.

NO2 concentrations ranged from 0 to 510 µg/m3 during working hours. The average value during working hours was 94.243 µg/m3. A significant increase in NO2 concentration can be observed at the construction site during working hours. About 70% is a higher average daily value during 10 working hours compared to all 24 hours.

The impact on the concentration of NO2 can be explained by the transport of waste that was taken to the construction waste disposal site by truck every day, but also by the impact of traffic from nearby roads.

By monitoring meteorological data, 4 sets of meteorological data were obtained, including wind speed, temperature, humidity and atmospheric pressure.

As shown in Figures 6-8, 4 sets of data are plotted in a line graph.

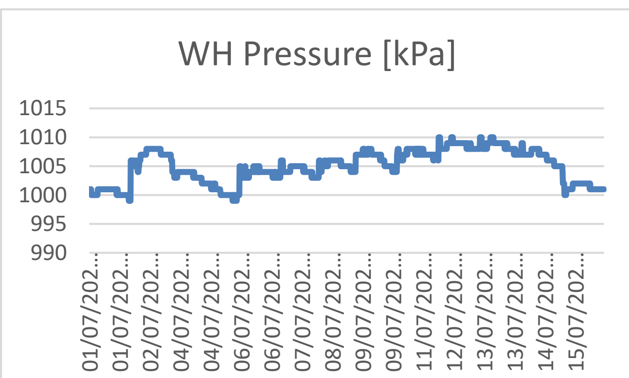

Figure 6. Time dependence of air pressure at the construction site during excavation works in a period of 15 days (data during working hours)

The pressure ranged from 999 to 1010 kPa during working hours. The average value during working hours was 1004.78 kPa. (Fig. 6)

Humidity during working hours ranged from 40.696 to 91.1%. The average value during working hours was 20.2%. The temperature during working hours ranged from 15.2 to 41.1°C. The average value during working hours was 28.6°C. (Fig. 7).

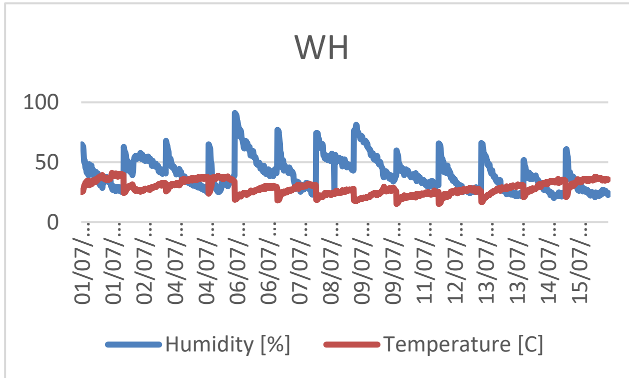

Figure 7. Time dependence of temperature and humidity at the construction site during excavation works in a period of 15 days (data during working hours)

The wind speed ranged from 0 to 3.2 m/s during working hours. The average value for all 15 days during working hours was 0.467 m/s. (Fig. 8).

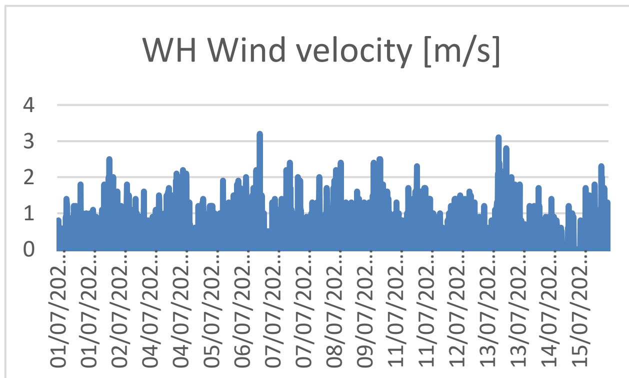

Figure 8. Time dependence of wind speed at the construction site during excavation works in a period of 15 days (data during working hours)

4. Conclusion

The data of meteorological and construction intensity were collected to determine the main factors affecting the construction dust emission, which can provide a basis for reducing the impact of dust generated by construction activities on the surrounding area. The main conclusions of the article are as follows:

Through on-site monitoring of construction site in Belgrade City, this study found that the dust emission level of construction activities is relatively high. The average PM10 concentration was 16.42 µg/m3 and the PM2.5 concentration was 8.37 µg/m3. Analyzing the average 24-

hour values for PM2.5 and PM10, it can be concluded that PM2.5 represents a far greater health hazard due to far higher values compared to the prescribed daily limits. In addition, compared with the upwind direction concentration, the construction site makes downwind direction PM10 and PM2.5 concentration increased by around 70% and 35%, respectively, which indicates that the construction activity had a significant impact on the air quality around the construction surrounding areas.

Regarding the main factors affecting the building construction dust emission, the results show that building construction dust emission was not significantly correlated with any single meteorological factor when it did not change too much.

A further subject of research will be the application of machine learning in the development of a predictive model that would aim at smart management of the construction site while taking into account the quality of the working and living environment.

Acknowledgments

Authors wish to thank University Union-Nikola Tesla, Belgrade, Serbia, for the support. This research was funded by Union-Nikola Tesla University, grant number 231/1.

Conflicts of Interest

Authors declare that there is no conflict of interest.

References

Araújo, I., Costa, D., & Moraes, R. (2014). Identification and Characterization of Particulate Matter Concentrations at Construction Jobsites. *Sustainability (Switzerland), 6*, 7666–7688. https://doi.org/10.3390/su6117666

Azarmi, F., Kumar, P., & Mulheron, M. (2014). The exposure to coarse, fine and ultrafine particle emissions from concrete mixing, drilling and cutting activities. *Journal of Hazardous Materials*, *279*, 268–279. https://doi.org/10.1016/j.jhazmat.2014.07.003

De Moraes, R. J. B., Costa, D. B., & Araújo, I. P. S. (2016). Particulate Matter Concentration from Construction Sites: Concrete and Masonry Works. *Journal of Environmental Engineering*, *142*(11). https://doi.org/10.1061/(ASCE)EE.1943-7870.0001136

De Moraes, R. J. B., Costa, D. B., Priscylla, I., & Araújo, S. (2011). *Particulate Matter Concentration from Construction Sites: Concrete and Masonry works*. ASCE: Reston.

EPA. (2021, June 9). *Criteria Air Pollutants*. Https://Www.Epa.Gov/Criteria-Air-Pollutants#sel.

Fan, S. B., Li, G., & Tian, G. (2011). Fugitive dust emission characteristics from construction site by field measure. *Environmental Science & Technology*, *34*(S2), 209–211.

Guo, M. (2010). Construction Fugitive Dust Quantification Modeling Based on BP Neural Network. *Lanzhou University: Gansu, China*.

Hassan, H. A., Kumar, P., & Kakosimos, K. E. (2016). Flux estimation of fugitive particulate matter emissions from loose Calcisols at construction sites. *Atmospheric Environment*, *141*, 96–105. https://doi.org/https://doi.org/10.1016/j.atmosenv.2016.06.054

Kinsey, J. S., Linna, K. J., Squier, W. C., Muleski, G. E., & Cowherd, C. (2004). Characterization of the Fugitive Particulate Emissions from Construction Mud/Dirt Carryout. *Journal of the Air & Waste Management Association*, *54*(11), 1394–1404. https://doi.org/10.1080/10473289.2004.10471007

Luo, Y. (2017). *Study on Dust Emission Characteristics of Typical Construction Site in Chong Qing*. Southwest University.

Yan, H., Ding, G., Li, H., Wang, Y., Zhang, L., Shen, Q., & Feng, K. (2019). Field Evaluation of the Dust Impacts from Construction Sites on Surrounding Areas: A City Case Study in China. *Sustainability*, *11*(7), 1906. https://doi.org/10.3390/su11071906

Yao, L., Lu, N., Yue, X., Du, J., & Yang, C. (2015). Comparison of Hourly PM2.5 Observations Between Urban and Suburban Areas in Beijing, China. *International Journal of Environmental Research and Public Health*, *12*(10), 12264–12276. https://doi.org/10.3390/ijerph121012264

Zhang, W. T., Wang, X. S., Liu, Z. R., Zhang, Y., Shao, M., Cheng, Q., Wu, D. G., & Tian, W. (2009). Construction Fugitive PM 10 Emission and Its Influences on Air Quality in Guiyang. *Acta Sci. Nat. Univ. Pekin*, *46*, 258–264.

Zhao, Y., Yu, L., Zhang, C. H., Wang, Q., Jing, T., & Chen, Z. (2010). Spatial dispersion laws of particulate matter from construction work site of municipal engineering. *Ecology and Environmental Sciences*, *19*(11), 2625–2628.

Procena zagađenja i zdravstvenog rizika od prisustva teških metala u PM10 na teritoriji centralne Srbije

Lazar Milivojević[1], Sanja Mrazovac Kurilić[2, *], Zvonimir Božilović[1], Suzana Koprivica[1]

[1]Fakultet za graditeljski menadžment, Univerzitet Union-Nikola Tesla, Beograd, Srbija
[2]Fakultet za ekologiju i zaštitu životne sredine, Univerzitet Union-Nikola Tesla, Beograd, Srbija

*Autor za korespondenciju: smrazovac@unionnikolatesla.edu.rs

Abstrakt: Cilj rada je ispitivanje koncentracija i prostorna distribucija teških metala (As, Cd, Pb i Ni) u PM10 u centralnoj Srbiji. Procenjeni su rizici po zdravlje ljudi usled prosustva teških metala. Rezultati su pokazali da vazduh u centralnoj Srbiji ne sadrži značajne koncentracije teških metala osim u rudarskom području (Bor). Procena kontaminacije je pokazala da As, Cd, Ni i Pb u vazduhu potiču iz antropogenih izvora. Procena nekancerogenog zdravstvenog rizika je pokazala da je ingestija bila primarni put izlaganja svim metalima u vazduhu i da su Pb i As najviše doprinosili nekancerogenim rizicima. HI vrednosti su izračunate za decu (HI=6,3E-07), što ukazuje da će deca verovatno imati veće zdravstvene rizike u poređenju sa odraslima (Hi=7,1E-08). Nekancerogeni rizici koji donose svi proučavani elementi teških metala i kancerogeni rizici koje donose As, Cd i Ni za decu i odrasle bili su u prihvatljivom opsegu.

Ključne reči: vazduh, teški metali, procena kontaminacije, procena zdravstvenog rizika, PM10
