ANN MODEL OF AIR QUALITY ON THE CONSTRUCTION SITE

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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.

Key words: construction; PM concentrations; correlation; meteorology

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 (Moraes et al , 2016; 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 (Luo, 2017; Guo, 2010) 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. 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.

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 (Figure 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 works, are placed on the north and northwest side from monitoring device on the constructin site. The 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.

Figure 1

Location of the construction site on the map of Belgrade

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 , 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.

RESULTS AND DISCUSSION

The measurement results are shown in Figures 3-8 and Table 1. The results are given as Full Day results (FD), where the graphs show the measurement results during the total time, 24 hours a day, for all 15 days, as well as Working hours results (WH) that show the separated working hours from 7 a.m. to 5 p.m. on weekdays (Monday to Saturday).

Table 1 Basic statistical analysis of measured parameters

	PM2.5 (µg/m³)	PM10 (µg/m3)	NO2 (µg/m³)	p (kapa)	T (°C)	hum (%)	v (m/s)
FD av	15.301	16.811	94.243	1004.78	25.192	51.030	0.354
FD SD	9.5752	11.155	131.989	2.618	6.401	18.534	0.698
FD min	1	1	0	999	12.4	18.1	0
FD max	133	143	510	1010	46.2	98.3	17.8
WH av	14.660	16.0597	167.741	1004.977	28.600	20.2	0.467
WH SD	9.147	10.577	144.859	2.835	5.556	13.749	0.574
WH min	1	2	0	999	15.2	91.1	0
WH max	71	82	510	1010	41.1	40.696	3.2

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

Apart from the basic statistical analysis, Table 1, a correlation analysis was done between PM concentration and meteorological data. Table 2 shows that the concentrations of PM10 and PM2.5 were not significantly correlated with any meteorological factor.

Table 2 Values of the linear correlation coefficient among the measured parameters

	PM2.5	p	hum	T	v
PM10	0.987	-0.092	0.299	0.201	0.003
PM2.5	1	-0.103	0.297	0.236	0.008
p		1	0.053	-0.416	-0.989
hum			1	-0.660	-0.030
T				1	0.326

ANN

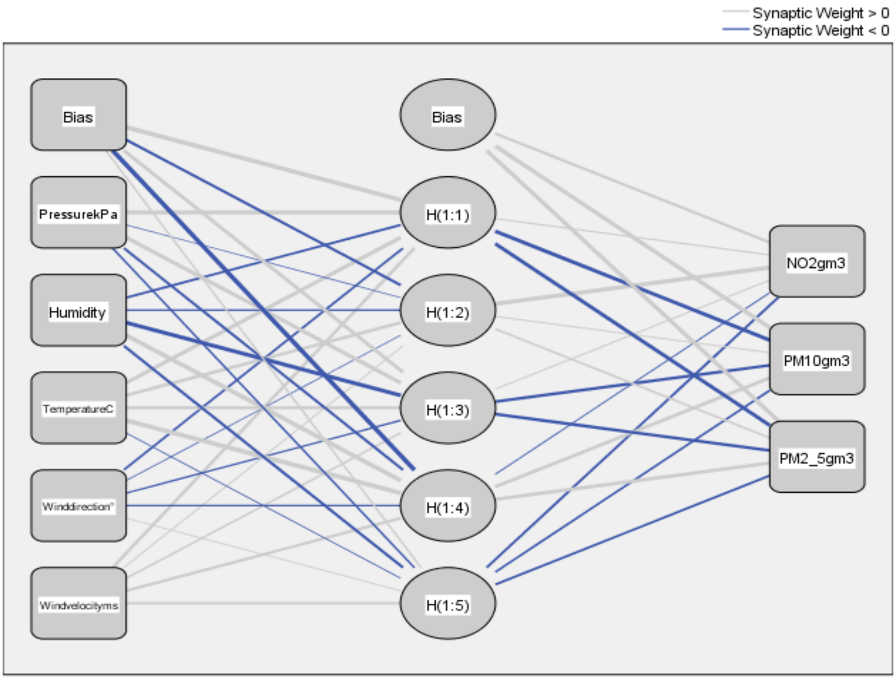
Case Processing Summary

		N	Percent
Sample	Training	1040	69.7%
	Testing	452	30.3%
Valid		1492	100.0%
Excluded		0	
Total		1492	

Network Information

Input Layer	Covariates	1	Pressure [kPa]
		2	Humidity [%]
		3	Temperature [C]
		4	Wind direction [°]
		5	Wind velocity [m/s]
	Number of Units[a]		5
	Rescaling Method for Covariates		Standardized
Hidden Layer(s)	Number of Hidden Layers		1
	Number of Units in Hidden Layer 1[a]		5
	Activation Function		Hyperbolic tangent
Output Layer	Dependent Variables	1	NO2 [?g/m3]
		2	PM10 [?g/m3]
		3	PM2_5 [?g/m3]
	Number of Units		3
	Rescaling Method for Scale Dependents		Standardized
	Activation Function		Identity
	Error Function		Sum of Squares

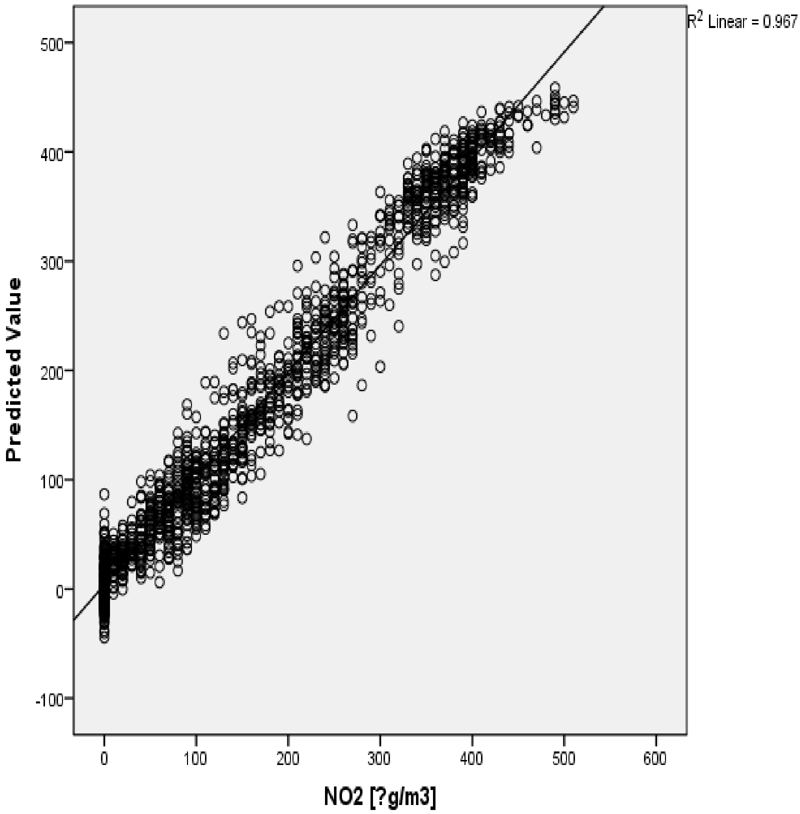
a. Excluding the bias unit

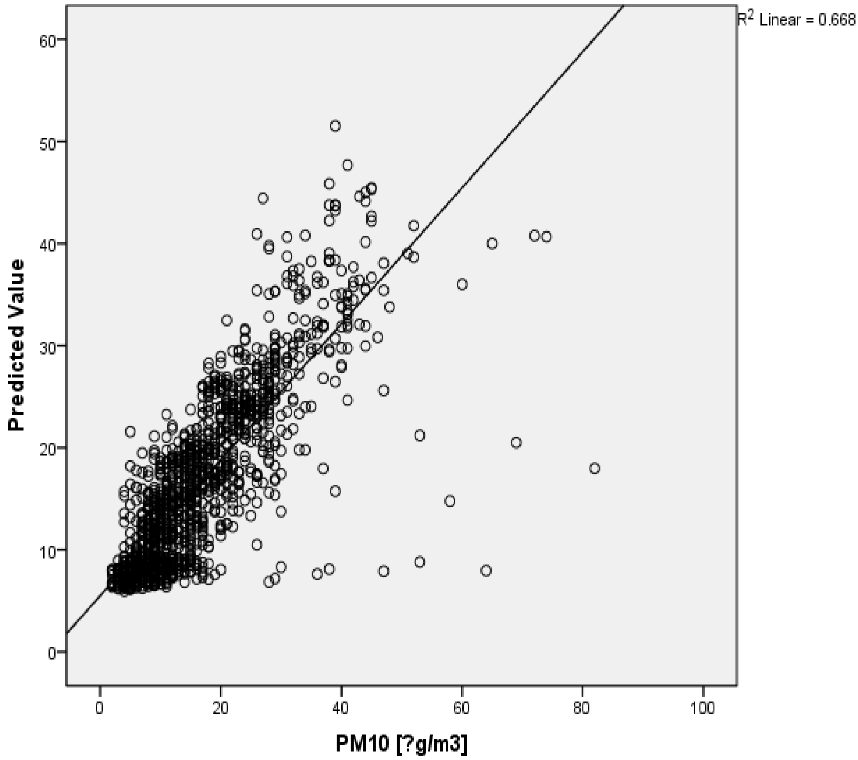


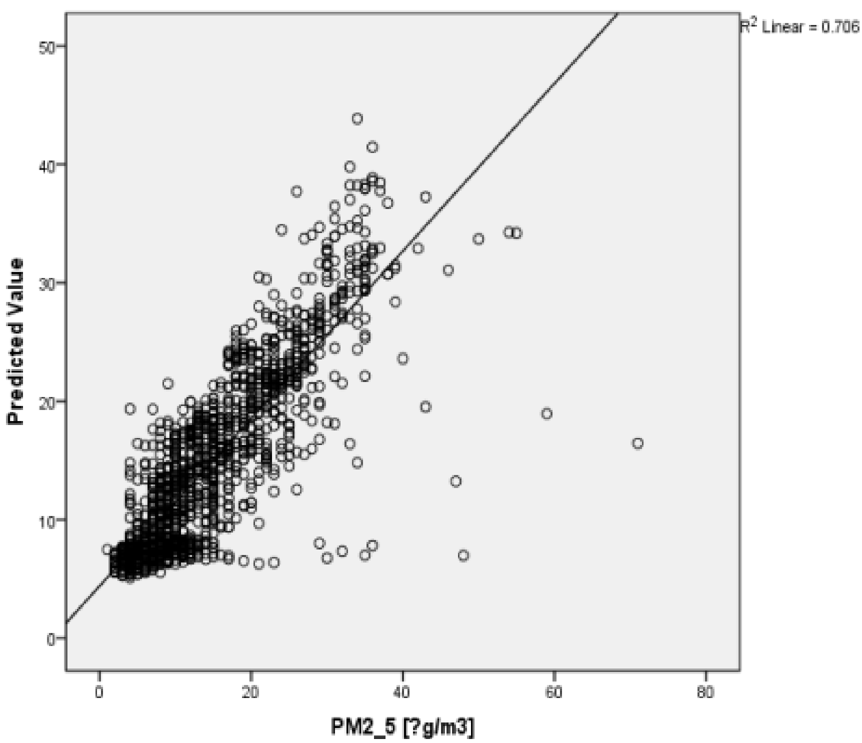
Model Summary

Training	Sum of Squares Error		351.995
	Average Overall Relative Error		.226
	Relative Error for Scale Dependents	NO2 [?g/m3]	.033
		PM10 [?g/m3]	.342
		PM2_5 [?g/m3]	.303
	Stopping Rule Used		1 consecutive step(s) with no decrease in error
	Training Time		00:00:00.318
Testing	Sum of Squares Error		106.071
	Average Overall Relative Error		.186
	Relative Error for Scale Dependents	NO2 [?g/m3]	.034
		PM10 [?g/m3]	.302
		PM2_5 [?g/m3]	.268

a. Error computations are based on the testing sample.


R2 Linear = 0.967
500
400
300
200
100
0
-100
Predicted Value
0
100
200
300
400
500
600
NO2 [?g/m3]


R² Linear = 0.668
60
50
40
30
20
10
0
Predicted Value
0
20
40
60
80
100
PM10 [?g/m3]


R² Linear = 0.706
50
40
30
20
10
0
Predicted Value
0
20
40
60
80
PM2_5 [?g/m3]

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.

Considering the very low correlation between the concentration of PM particles and meteorological parameters, the possibility of applying ANN for the purpose of creating a prediction model is excluded. 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.

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