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PM MITIGATION MEASURES UTILIZATION TRENDS ON BUILDING SITES IN NOVI SAD, SERBIA DURING 2019-2022

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Abstract. *The beginning of the new millennium provokes governments and researchers to recognize the importance and the effect that Particulate Matter (PM) has on the whole environment. PM has been marked as one of the key ambient air pollutants, due to its high sorption ability. World Health Organization indicated PM present in ambient air as pollutant with adverse, acute and hazard effect on human health and built environment. The city of Novi Sad, Serbia is rapidly expanding, redefining architectural, urban and environmental matrices. Architectural spatial transformations - construction sites need to be considered as temporal unique pollution hot spots. Trend of active construction sites increasing number in Novi Sad affects the ambient air quality. Goal of the research is to emphasize PM pollution problem on the construction sites in Novi Sad and to illustrate and display the trends in mitigation measures application during 4-year period (2019-2022).*

Key words: *PM, environmental pollution, construction sites, architectural transformations.*

1. INTRODUCTION

The global level of air pollution is considered as the primary environmental challenge of 21st century. World governments, organizations and researchers found that air pollution is mostly caused by human activity, introducing toxic and hazard chemical molecules and suspended particles to the environment. Numerous researches have shown that ambient air pollution can inflict hazard and adverse effects on the environment and human health [1]–[5]. Ambient air pollution has high association with public health, biocenosis status, regional and global climate change [6], [7]. The omnipresent component in ambient air is Particulate

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Matter – PM which is to be considered as basic polluting substance. Fine PM smaller than or equal to 10 μm has been characterized by the World Health Organization to have direct impact on the environment and human health [8].

Heavy industry, a characteristic of developing countries produces significant ambient air pollution problem [9], [10]. Other characteristics of developing countries are weak economy and almost nonexistent resilience of the cities, which makes dealing with pollution problems hard. Developed countries have an economic freedom to dictate necessity for compensation in various areas among which is environmental protection. High PM emission and ambient air pollution are considered as daily routine in developing countries. Increased architectural activity and spatial transformations processes define the urban development, resulting in frequent uncontrolled construction sites. Amplified anthropogenic activities during processes of architectural transformation and city development generates and emits high concentrations of suspended particles in surrounding built and natural environment [11]–[14]. Various researches have confirmed that building through its whole lifecycle emits increased PM concentrations [15]–[17]. Each construction process that follows architectural spatial transformations has different influence on particle emission and is often dependent on meteorological conditions. Distinctive construction activities during the building processes are important sources of PM in the ambient air:

- Site preparation (land clearing and demolition of existing buildings)
- Earth excavation and transport
- Moving equipment and machines
- Transport and storage processes (loading, unloading, transfer and storage)
- Specific activities in accordance with the position being performed
- Final architectural activities

Construction origin of high PM concentrations in the ambient air pressured governments in developed countries to create mitigation measures and models [3], [18]–[22]. The efficiency and utilization of created mitigation measures and models was ensured by introducing legislations and strict inspections.

Meteorological conditions have a great influence on the generation and emission of suspended particles. The used/worked materials are important elements in PM emission and generation processes. In more humid material, the particles are strongly held together (statical tension occurs), which decelerate their emission into the ambient air. The Canadian Environment Agency annual reports estimated that construction processes account around 20% of total suspended particulate emissions [21]. Emitted particulate matter endangers both workers on construction sites and nearby residents [12], [23]. The long-range transport ability (affected by particulate size) allows PM to travel far from the source, creating hazard effect in the long run.

In Serbia, the fundamental architectural research activities and project management disregard the engineering area of environmental protection. As part of the environmental engineering prevention and control of suspended particulates generation, emission and mitigation is neglected and considered unsignificant in areas of architectural spatial transformation. In order to answer all environmental challenges within the architectural activities must imperatively incorporate mitigation measures for negative effects of PM caused by spatial transformations. Architectural build environment, spatial and urban transformation and other building activities demand methodologic planning approach with awareness of the effect it has on the whole surrounding environment both living and built.

Serbia as a candidate for entry in European Union is required to integrate strict environmental protection legislation. Often having cities in top 10 air polluted cities in the world, ambient air pollution is becoming daily routine in Serbia. Necessity to address this question requires understanding of PM life cycle, including source recognition, forming processes, composition, dispersion and atmospheric fate, population exposure and health effects.

After the capital - Belgrade, Novi Sad is the city with highest expansion and development. High architectural activity and numerous spatial transformations are markers of the city expansion and development. Large number of active construction sites and increased pollution are indicators that city is struggling with resilience. As all the architectural processes generate and emits large amounts of polluting substances in surrounding environment, it is vital importance for city and inhabitants that this problem gets resolved.

2. MATERIALS AND METHODS

The architectural spatial transformations are constantly changing, progress and improving. Construction sites create specific system with determined expiration date and unseen effect on the total environment. Experiences from developed countries assert that construction processes need to be followed by adequate monitoring and prevention models and methods. Measures can be considered through prediction and detection phase. Prediction determines critical pollution hotspots in the planning sequence, while detection follows the active works and gives real time input. The research is based the detection phase, and implemented through monitoring of construction sites.

The potential of construction sites as the temporal pollution hotspots is designed with environmental software for pollution prediction and modeling ADMS-Urban. The software was applied on the 5 selected construction sites (Figure 1). Optical Particulate Sensor – OPC

Fig. 1 Selected construction sites for application of ADMS-urban

N2 (produced by Alphasense) was used to measure the fine particulates (PM10 and PM2.5) emission on selected sites. Obtained data was compared with EPA's Tier I prediction model [24] and input in ADMS-urban together with meteorological data gained on the official Republic Hydrometeorological Service of Serbia web presentation [25].

The research was realized in the city of Novi Sad, Serbia during 4-year period 2019-2022. Monitoring was performed each year on 100 active construction sites. Periods of monitoring were March to September 2019, April to October 2020, March to October 2021, February to September 2022. During the research period the utilization of PM prevention measures were inspected (Figure 2).

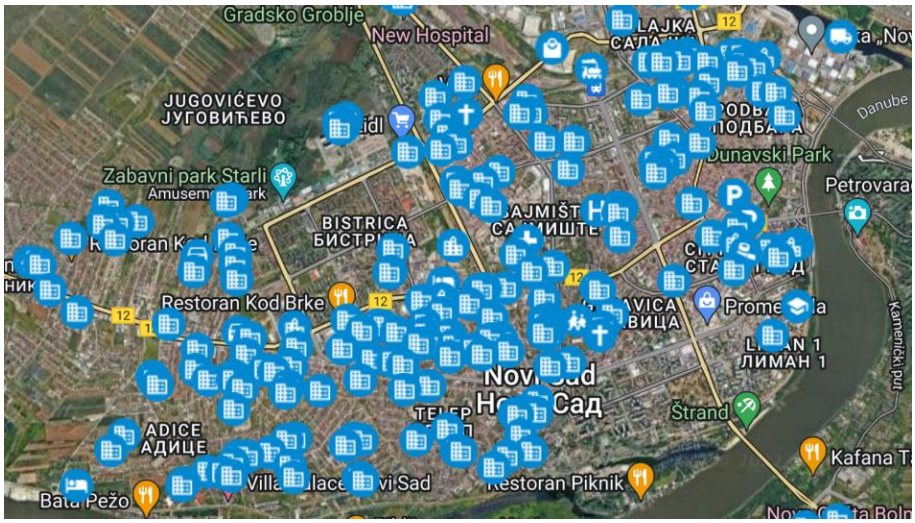

Fig. 2. List of selected active construction sites in Novi Sad during 2019-2022. [26]

The examples from legislations and guidelines of the developed countries were analyzed and observed. The measures were selected and tested to fit the application in Serbia's construction ecosystem. Testing and selection of the measures was performed in the author's PhD thesis research. Selected measures include keeping the existing vegetation, stabilization covers and geotextile, vegetation covering, mulching, adequate material handling, stored and during transport material covering, machine installation of powder materials, protective curtains, wind fences, controlled entrance, washing machine tires before exit (manual or automatic), road paving, road definition and marking, speed limitation, transport road watering, maintenance, water spraying, and use of suppressants.

The research tracked architectural activities on building sites to determine what measures were applied and in what degree. One of the basic measures is to keep existing vegetation in the zones that are not required for works. This measure allows the unnecessary areas not to be exposed to construction site conditions. Other similar methods that can be used on the construction sites include covering exposed ground with covers, geotextile and mulch. Mulch is mostly made of natural materials (shredded wood, hay, stone…) which has low impact on the environment, but it can also be created from plastic materials that require special handling. Adequate material utilization can reduce spilling of materials in the environment and minimize the emission of fine particulates in the ambient air. Powder

materials due to their fraction size are a good source of fine particles in ambient air. Machine installation creates a closed system in which powder materials are not exposed to the environment before the final assembly, consequently reducing the emission in the environment. Barriers such are fences and curtains can provide primary blockades for fine particles spreading. Defined entrance to the building site and road management allows a more efficient control of the architectural activities. These measures also minimize traction and PM generation on the building sites. Water use on constructions sites is the most direct way to stop fine particle emission. It binds particles and creates particle clusters that can hardly become airborne. In addition to this cheap measure – water, a more efficient but also more expensive method is the use of the suppressants. Suppressants, depending on their chemical composition could have adverse effect on the environment.

3. RESULTS AND DISCUSSION

With the application of environmental modeling software ADMS-Urban dissemination of PM generated and emitted from construction sites has been modeled. Dispersion of suspended particulates from 5 selected sites on the 100 m height has been shown on the architectural matrix of Novi Sad (Figure 3). Observing the modeled dispersion allows understanding of the

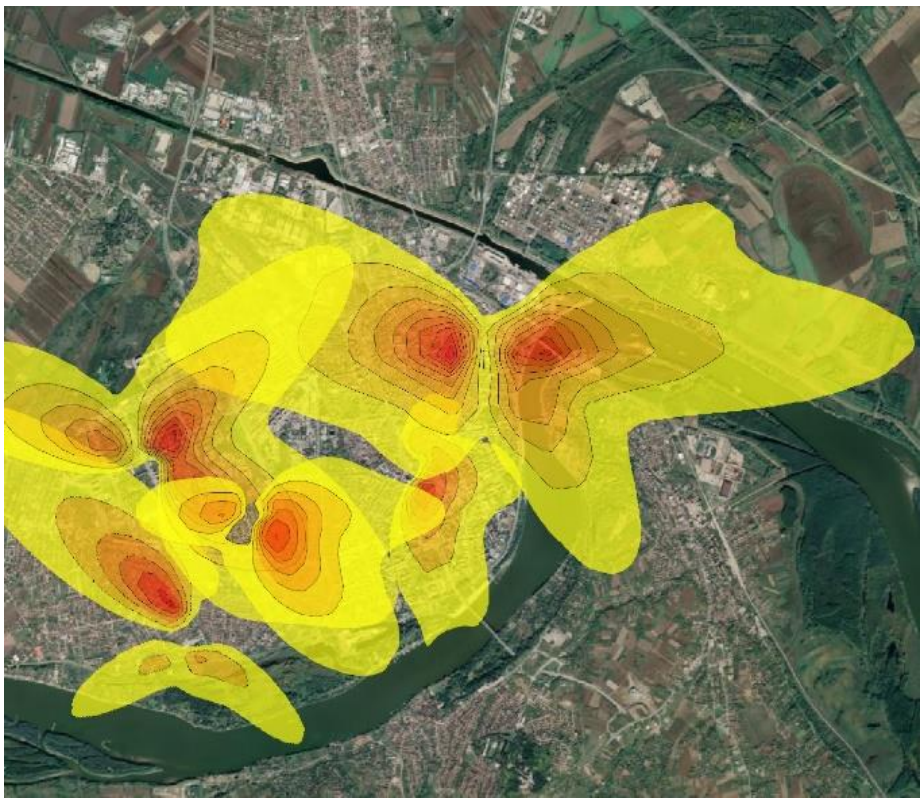

Fig. 3 Modeled dissemination of PM emitted on construction sites (PM concentrations: red to yellow – high to low)

real potential of PM from construction sites to pollute the ambient air. The model indicates that only one construction site is enough to cover a huge part of the urban city matrix. On the Novi Sad urban matrix example, it is *de facto* depicted that minimal number of active construction sites is required to cover the city with the suspended particle pollution veil.

The research results (Table 1) display low level of utilization for most of the selected PM prevention measures. The existing legislations were not designed for application of mitigation measures, but some of the demands are in compliance with environmental protection standards. It is best noticeable in the utilization of measures: setting up wind fences, controlled entrance, road definition and marking, and speed limitation. These measures are fully applied. Legislations prescribe that all building sites are required to have defined and organized roads and an entry point, maximum speed limit of 20 km/h, with closed fences installed around the site. High percentage of machine installation of powder materials can be seen in economical and practical reasons as it is more efficient, easier and cheaper measure. Road paving achieves high percentage for its practical reasons as it allows highly effective movement of machines and workers on the construction site.

Medium to low usage can be observed in termso adequate material handling, covering of the stored material and material during transport, setting up the protective curtains, road watering and water spraying.. The main reasons for the poor quality of material handling, storing and transportation are the insufficient number of qualified workers together with an increasing number of construction sites. The explanation for water spraying can be found in the low experience of the leading engineers and sparing water. Monitoring the cases where the existing vegetation was kept, different areas were covered including mulching, where maintenance, use of suppressants and washing of the tires was present indicated numbers that can be defined as statistical error. The reasons for these results are found in the lack of legislation and care for the environment, high prices and absence of education.

Table 1 Utilization of measures on construction sites 2019-2022.

Monitored measures	2019.	2020	2021	2022
Keeping the existing vegetation	1%	5%	5%	4%
Stabilization covers and geotextile	0%	0%	0 %	0 %
Vegetation covering	3%	5%	4 %	3%
Mulching	0%	5%	3%	3%
Adequate material handling	20%	22%	20 %	25 %
Stored material covering	23%	30%	30 %	35 %
Material transport covering	33%	33%	35 %	38 %
Machine installation of powder materials	89%	92%	92 %	93 %
Protective curtains	25%	38%	40 %	47 %
Wind fences	100%	100%	100 %	100 %
Controlled entrance	100%	100%	100 %	100 %
Washing machine tires before exit (manual or automatic)	0%	0%	2 %	3 %
Road paving	73%	75%	75 %	81 %
Road definition and marking	100%	100%	100 %	100 %
Speed limitation	100%	100%	100 %	100 %
Transport road watering	30%	25%	30 %	30 %
Maintenance	9%	11%	10 %	11 %
Water spraying	25%	28%	30 %	32 %
Use of suppressants	0%	0%	0 %	0 %

The 4-year investigation results manifest as the trend of stagnation, whereas mention only fully applied measures are one defined by legislation. Some measures (material handling, installation, covering and transport together with the protective curtain and road paving) show an increasing trend, where economic benefit factors can be considered as reasons. There is also ian ncreasing trend of water spraying, which can be justified by the temperature rise and less rainfall.

4. Conclusion Remarks

The application of the ADMS-Urban software with original experimental obtained data provided the PM dissemination model which exposed the minimal number of construction sites required to transport the particle matter over a city like Novi Sad. The designed model allows the definition of the construction sites as the temporal architectural spatial pollution hotspots.

The inspection of applied architectural activities explained and presented in the research results has indicated that there are two main factors for application of selected measures. PM prevention and mitigation measures are applied based on economic and legislations factors. The results distinctively depict that the legislation defined measures (with high financial penalties) were fully applied. Law defined measures are dependent and highly correlated with the economic factor. Economic beneficial factors provide the necessary push for the utilization of measures. Mechanization and material availability, efficiency, workers education and qualification level, time consumption and other are part of the basic elements on the building site that affect the economic dynamics.

Suspended particle mitigation and prevention utilization architectural trend for the city of Novi Sad in the research and investigation four years period (2019-2022) for the most measures is stagnation. Slightly increase is perceived for material handling, installation, covering and transport together with the protective curtain and road paving. Economic benefits in domain of architectural spatial transformations dominantly control and dictate trends in PM mitigation measures utilization. Other factor that affects the application of the PM mitigation and prevention measures on the construction sites in city of Novi Sad can be concluded as good practice of the contractor companies and as a part of the management experience of leading engineers.

This investigating of architectural PM mitigation and prevention measures utilization trends on construction sites in Novi Sad is the consecutive part of the first ever research in Serbia started in the PhD thesis study of the author. The ambient air pollution and the search for solutions is one enormous battlefield between architectural spatial transformations, artistic impression, profits, benefits, environment, governments, corporations and health. Adopting policies and methods in correspondence to existing architectural trends will provide cities with the possibility to be sustainable and resilient.

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TREND PRIMENE PM MITIGACIONIH MERA NA GRADILIŠTIMA U NOVOM SADU, SRBIJA TOKOM 2019-2022

Početak novog milenijuma naveo je vlade i istraživače da prepoznaju važnost i efekat koji suspendovane čestice (eng. Particulate Matter - PM) imaju na celokupono okruženje. Suspendovane čestice su označene kao jedan od ključnih zagađujućih supstanci ambijentalnog vazduha usled sopcionih sposobnosti. Svetska zdravstvena organizacija je indikovala da PM čestice prisutne u ambijentalnom vazduhu mogu imati štetan, akutan i hazardan efekat na ljudsko zdravlje i izgrađeno okruženje. Grad Novi Sad se ubrzano razvija, redefinišući arhitektonske, urbane i matrice životne sredine. Arhitektonske prostorne transformacije – gradilišta moraju se posmatrati kao specifične vremenski ograničene tačke zagađenja vazduha. Trend povećanja broja gradilišta u Novom Sadu utiče na kvalitet ambijentalnog ambijentalnog vazduha. Cilj istraživanje je da naglasi problem emisije suspendovanih čestica sa gradilišta u Novom Sadu i da prikaže trend primene mitigacionih mera tokom četvorogodišnjeg perioda (2019-2022).

Ključne reči: *Suspendovane čestice, gradilišta, arhitektonske prostorne tranformacije, trend*