Analyzing and visualisation of indoor airpollution

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Abstract: *The exposure on high concentrations of PM particles causes various serious diseases such as cardiovascular, respiratory related diseases and cancer as discovered in more scientific studies. According to experts, there is no immediate victory for pollution, but action must be taken, as this problem cannot wait for future times and generations. In this paper, we will analyze air pollution with PM10 and PM2.5 in indoor urban areas (apartments, workplaces, etc.). This will help the competent authorities to model an urban development plan, traffic density and air quality measures for the population that spends most of the day in an indoor environment. Another benefit would be to obtain information from the results of the online indoor monitoring - to decide whether purifiers should be purchased to reduce air pollution in permissible limits. Visual modeling with GIS (interpolation) gives a dynamic visual representation of the indoor space, clearly showing which parts of the place are polluted and accordingly take action.*
KEYWORDS*: INDOOR AIR POLLUTION, PM PARTICLES, GIS INTERPOLATION*

1. Introduction

The Republic of North Macedonia faces a significant public health problem caused by ambient air quality. Each year, concentrations of pollution exceed the limit values that affect human health. The problem is evident throughout the country, and to a greater extent is present in urban settlements. The most problematic pollutants are suspended particles that can have a serious impact on health.

The impact of external pollution is also reflected on indoor pollution, as the need for daily fresh air ventilation requires doors and windows to open in order to allow fresh and "clean" air to enter into the apartments. If the outside air has high concentrations of PM particles, then accordingly the indoor air is also polluted. This makes our living conditions worse and potential increase of health problems. It is important to know the exposure from indoor sources of pollution, as we spend most of our time indoors. For this purpose, it is crucial to identify the source of pollution and then to determine their impact on pollution from that exposure. And to understand where the pollution comes from, it is necessary to measure the PM concentration levels.

The Ministry of Environment and Physical Planning of the Republic of N. Macedonia manages the State Ambient Air Quality Monitoring System, consisted of a number of automatic air quality monitoring stations (occasionally out of use), as well as two mobile monitoring stations. The data from all monitoring stations are collected into a database where they are verified, validated, processed, analyzed, presented and reported on daily basis.

Indoor air pollution monitoring can be measured via mobile intelligent pollution monitoring devices or personal pollution meters (carried with them). The results of the measurements used in this paper are obtained using a PM particle pollution instrument for PM10, PM4, PM2.5, PM1, TSP particle size, and model Aerocet 831 (Met One Instruments).

Many pollution studies focus on measuring concentrations of pollutants in residential buildings, offices, shops, malls, and restaurants where people spend most of their daily time in order to compare different indoor environments and identify sources of pollution [1]. Furthermore, several studies have shown that indoor air quality depends on the location of buildings, ventilation characteristics and sources of air pollution in the area, and it has been shown that indoor air pollution levels can often exceed the level of outdoor pollution [2]. The study [3] that analyzed indoor air quality at two different locations - two apartments and two offices. Quality has been assessed during two experimental campaigns. Both offices reported higher particulate values that could be linked to indoor smoking, as well as poor room cleaning and other human activities. Next related paper [4] examined dust in the house (sampling) and soil around the building. The objective was to identify sources (by chemical analysis of the particles) and quantitative levels of toxicants. Another paper [5] addresses the health risks for infants from dust pollution in homes, which may be much greater than for the adults. Studies on asthma have shown that air pollution can lead to increased asthma prevalence [6]. The aim of this study is to examine the association between air pollution (fine particulate matter (PM2.5), sulfur dioxide (SO2) and ozone (O3)) and human health. The study case [7] makes an analysis of health risk in an office building in Taipei. At any sampling point, it is easy to ascertain whether the measured value exceeds the regulatory standards and subsequently to calculate its health hazards. However, at non sampled points, the possible concentrations and corresponding health effects caused by indoor air pollutants can only be interpolated by using spatial statistical methods such as Kriging.

The paper is organized accordingly as follows. In section II we present Data collection and Analysis, while in Section III we present the Results and Discussions. Section IV presents the GIS visualization and interpolation of the data. Section V concludes the paper and presents possible solutions for future work.

2. Data collection and Analysis

All measurements were made during the winter, when outdoor air pollution is at its highest. Multiple series of measurements have been made at different times and different environments where PM particles (PM10, PM4, PM2.5, PM1 and TPM) might be present using a calibrated instrument. Moreover, the concentrations of the same pollutants (PM10, PM2.5) from the operating measuring stations in the City of Skopje (State Automated Air Quality Monitoring System - MOEPP, Center and Karposh measuring stations) were used for comparison with the external pollution.

The selected facilities for analysis were: a residential apartment in the center of Skopje, a microbiological laboratory in the Faculty of Medicine and a classroom for lab exercises full with students. Time series of measurements were made in different PM particle pollution environments. Different scenarios have been created in order to get the level of pollution without using a purifier and then using a purifier.

The limit values of the pollution parameters according to European standards (which are also implemented in our country) are as follows (the color scheme corresponds to the concentration levels on Table 1).

	PM_{10}	$PM_{2.5}$
Very high	180-	110-
High	90-180	55-110
Medium	50-90	30-55
Low	25-50	15-30
Very low	0-25	0-15

***Table 1**. Concentration limit values (in µg / m3)*

A value comparison of all campaigns in a residential apartment is shown on Fig. 1. Pollution values are obviously lower when using a purifier (fourth-14/15 and fifth campaign-26/27).

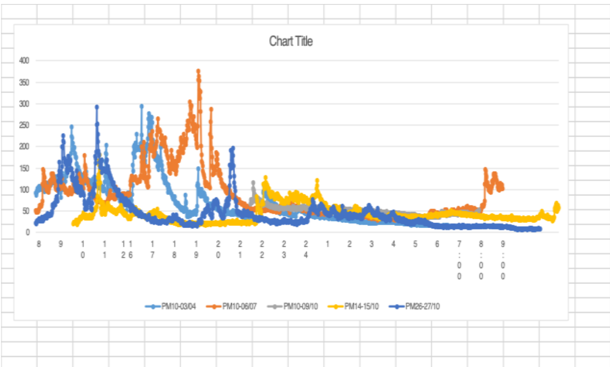

Fig 1. Comparison of all PM10 measurement campaigns

Fig. 2 presents the situation with PM10 pollution levels at the outdoor station 24h on average. It shows at what time of the campaign the external pollution exceeds the permissible limits of 50 µg/m3). Almost for the whole period of 04-22/12 the values are above the permitted limits and from 22-28/12 they are within the permissible limits.

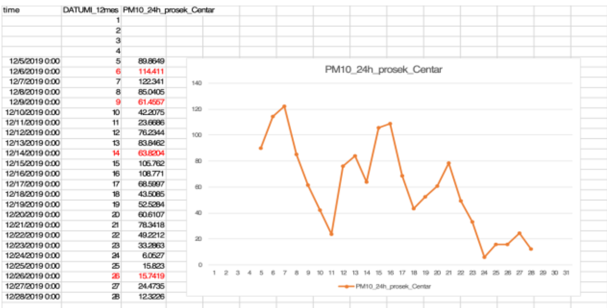

***Fig 2.** Average 24h PM10 measurement values for 12-2019 (outdoor pollution)*

3. Results and Discussion

From the results above, it can be concluded that the connection of indoor air pollution and outdoor air pollution is evident. Due to the need of indoor ventilation on a daily basis, pollution cannot be reduced (especially when outside concentrations are high). However, when the outside concentrations are low, it is crucial to open doors and windows for extensive indoor ventilation. For this purpose, the monitoring of outdoor air pollution is required, and the use of an air purifier is required in our apartments.

If ventilation is used to purify rooms or air conditioning inverters for heating, regular cleaning or replacement of filters is necessary (as recommended by the manufacturer). This is especially relevant in office spaces.

When all the measurements are completed, the following conclusions can be drawn with the respect to measurements of PM10 parameters in all campaigns. The average values are given in Table 2.

Measurement location - PM10	c-1	c-2	c-3	c-4	Total (Average µg / m3)
Residential apartment	116.47	120.3	36.38	93.82	91.75
Microbiology -ical laboratory	63.49	66.92	109.9	46.07	71.39
Student Lab	110.70	73.76	55.19	74.64	78.57

***Table2:** - Average PM10 values for all measurements*

Table 2 shows that, in average, pollution levels are highest in the residential apartment (due to kitchen use), but decreases significantly when the purifier is activated (campaign 3) and when activities are reduced.

The measurements of PM2.5 parameters in all campaigns with its average values are given in Table 3.

Measurement location - PM2.5	c-1	c-2	c-3	c-4	Total (Average µg / m3)
Residential apartment	49.0	65.3	21.0	20.9	39.09
Microbiological laboratory	31.0	45.2	68.4	23.0	41.94
Student Lab	47.8	50.7	23.5	47.7	42.45

***Table3:** - Average PM2.5 values for all measurements*

Table 3 shows that the average air pollution is above the permissible limit of 25 µg / m3. The most contaminated is the student lab, but the levels are significantly reduced when the air purifier is switched on (used in campaigns 3 and 4 in the apartment) as well as when activities are reduced.

4. GIS Visualization and Interpolation

Geographic Information Systems (GIS) or so-called Spatial Information Systems is an advanced tool for obtaining spatial relationships and for facilitating the proper understanding and resolution of related complex problems.

The apartment is on the fifth floor of a building, covers an area of 80 m2 and is occupied by 4 people. It is located in the center of Skopje and 50 meters away from a frequent road. Measurements were taken in several places: in the kitchen, in the living room and near the balcony, while the daily activities such as cooking or opening the balcony door were performed. Measurement were made for PM10 and PM2.5 particles every minute, in order to visualize the pollution at different locations in the apartment.

To visualize the indoor pollution in the apartment, the GIS tool of the ArcMap software ver. 10.4. is used. The living room and the layout of the measuring points are given on Fig. 32.

Fig3: *Arrangement of measuring points in the apartment*

Campaign 1 and 2 were conducted at measuring point 2, campaign 4 was performed at measuring point 3, while campaign 3 was at same measuring point. Equation [1] is applied to all of these points.

HQ = Ci/RfC…………………..……………………..[1]

Where:

C denotes the exposure concentration (µg /m3),

RfC denotes reference concentration (µg / m3).

If Equation 1 is applied to all of these places relative to the average value of the respective campaign, the following quality indices are obtained. For measuring point 1:

HQ1 = C1/RfC=36.38/50=0.7276……………………..[1]

For measuring point 2:

HQ2 = C2/RfC=120.35/50=2.4

For measuring point 3:

HQ3 = C3/RfC=93.82/50=1.8764

In order to get an idea of the pollution levels in the whole apartment and not to make additional measurements in the space, one of the interpolations available with the ArcMap tool can be done.

IDW (inverse distance weighting) is a deterministic interpolation that determines the cell values in combination with a set of surrounding points. The IDW process uses an interpolation method that evaluates the cell values with the average values of the environmental data point samples.

On the other hand, Kriging interpolation interpolates a raster surface from points that use Kriging. Execution speed depends on the number of dots stored in an access database and the size of the search window.

After applying the interpolation, the following pollution visualization is obtained from the average data measured.

The Fig.4 shows that the areas of the apartment that are most exposed to external pollution and pollution from kitchen activities are the most critical places in the apartment.

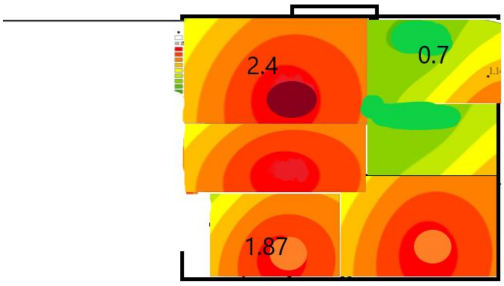

Fig4: *Arrangement of measuring points in the apartment*

Interpolation from ArcMap measurement data is given on Fig.4. Figure 4 shows different parts of the apartment and the level of pollution concentration implemented in three points with randomly assigned coordinates over the period of measurement. IDW interpolation is applied.

Also time visualization from the measured data is done. This is presented on Fig.5.

Fig5*: Time visualization of GIS data*

5. CONCLUSION

One of the benefits of the paper is the air pollution information in urban indoor areas (apartments, workplaces, etc.). This will allow the competent authorities to remodel urban development, to manage traffic density, which are connected to air quality in order to improve the quality of life of the population that gravitates to these urban environments. Another contribution would be to obtain information from the results of the online indoor monitoring and to determine the need to use air purifiers in order to reduce air pollution in certain rooms within permissible limits.

Visual modeling with GIS (interpolation) in the paper gives us a dynamic visual representation of the indoor situation, where we easily conclude which parts of the apartment are polluted and take appropriate action.

5. ACKNOWLEDGMENTS

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