SMOG IN BIALYSTOK IN POLAND. DATA OF PM 2.5 AND PM 10 PARTICULATE MATTER IN OUTDOOR AIR MEASURED IN 2017-2018 BY "THE LABORATORY OF ENERGY-EFFICIENT ARCHITECTURE AND RENEWABLE ENERGIES" AT FACULTY OF ARCHITECTURE OF BIALYSTOK UNIVERSITY OF TECHNOLOGY

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ABSTRACT

The differences between what in the winter 2017 was presented by the government measurement station of air quality, belonging to the Chief Inspectorate of Environmental Protection (CIEP) in Bialystok in Poland, and what the citizens could see and smell, were the reason for installing the monitoring system of PM10 and PM2.5 particulate matter, in the "Laboratory of Energy-efficient Architecture and Renewable Energies" (LEARE) at the Faculty of Architecture of Bialystok University of Technology. The measurements were compared with done by CIEP and the information of "The World Air Quality Index" (WAQI). This project started in 2007. It is proving transparent Air Quality information for more than 70 countries, covering more than 9000 stations in 600 major cities. Since 16 Nov 2017, data was also downloaded from the new European Air Quality Index (EAQI) website, created by the European Environment Agency (EEA). From the beginning of 2018, data from the public-private service AIRLY was added to the study. They installed four online dust meters in Bialystok. The density of the dust measurement network was still insufficient, so the mobile measurements were started. Recently, the use of a drone equipped with a dust meter for tests at various heights has begun.

Measurements deny EAQI presentation of so good air quality in Bialystok. The levels of PM2.5 and PM10 are often much higher than those presented by EAQI and CIEP. Government measuring station, located in the center of Bialystok, poorly reflects air pollution in peripheral districts.

Keywords: *smog, PM2.5 PM10, LEARE, Bialystok, monitoring*

INTRODUCTION

Thirty-three cities from Poland are included in the World Health Organization (WHO) Report 2016 listing fifty cities in the European Union with the most polluted air. In the report of the European Environment Agency (EEA) 2017 mentioning the concentration of PM2.5 in the air in European cities among the ten most polluted as many as seven cities are in Poland. 16 Nov 2017 European Environment Agency

(EEA) and the European Commission introduced a new European Air Quality Index (EAQI) that allows checking the current air quality across Europe's cities and regions. The new EEA online service is based on measurements from more than 2000 air quality-monitoring stations across Europe. The Index consists of an interactive map presenting the local air quality situation at station level, based on five key pollutants that harm people's health and the environment: particulate matter (PM2.5 and PM10), ground-level ozone (O3), nitrogen dioxide (NO2) and sulphur dioxide (SO2). The worst rating for any of the five pollutants measured by the station are showed by a coloured dot on the map, corresponding to the pollution level (turquoise - good, green - fair, yellow - medium, orange - poor, red - very poor).

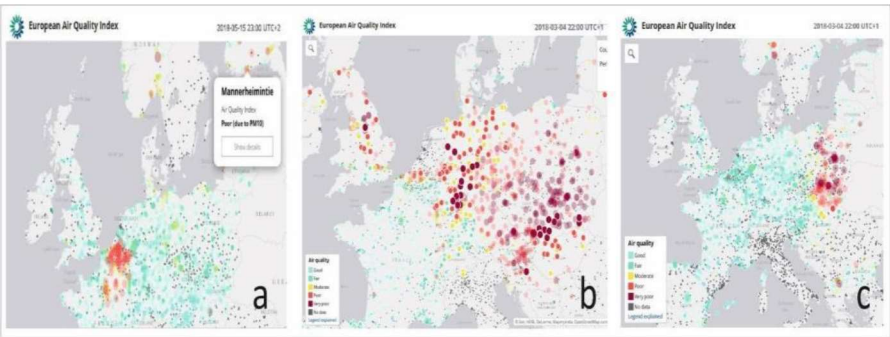

Fig.1 Air quality in Europe according to EAQI: a- rare, b- sometimes, c- often; (gray points mean non-functioning or disconnected measuring stations), a. A. Turecki

BIALYSTOK

The population of the city was 300.000, it`s area ~102 km2. Therefore, the population density is low - less than 3 thousand persons per 1 km2. The city looks green. Especially in terms of greenery. It has many gardens, squares, parks, a very large XVIII c. garden composition, even meadows and forests. Within the city limits, there are as much as 1847 ha , almost 19 km2 of forests, much more in the neighborhood -1175km2. The city is surrounded by them. Currently, after the fall of factories from the 19th and 20th centuries in the city, we have almost no industry that pollutes the environment. In statistics, everything looks "very eco". Some time ago, a slogan promoting the region - the "Green Lungs of Poland" - was created. And so it is, until winter comes. Then it gets a little redder and sometimes brown [Fig.1]. But not as badly as in cities in the south of Poland. Usually, on the governmental air quality maps Bialystok has a green indicator. But even ordinary "observations" reveal a slightly different picture. Especially in peripheral districts of one family houses.

There are several reasons - historical, technical, economic, social and wrong location of government measurement station.

- During the Second World War 80% of the city center was destroyed. New buildings are connected to the heating network of the city.

Thermal power plants, located in the periphery, have high chimneys, so “high emission” of exhaust fumes due to the effective filtration required by law is limited and usually blown out into suburban areas.

- Districts around the city center that survived WWII were inhabited usually by poor residents. Their homes were made in a very economical way with low insulation and tightness of the: walls, roofs and windows. Currently, many of them are almost one hundred years old and have not been renovated. The traditional heat sources of these houses are ovens and furnaces that use solid fuels. Their characteristic feature is a bad combustion process and heavy smoking during the ignition.
- The economic situation of some owners is bad, many of them are elderly. They cannot afford to improve technical condition of their houses, good quality fuel, sometimes any, so they burn waste. We define this as "energy poverty". Only municipal help can solve this problem.
- Poorly conceived economy and avarice forcing to not wasting anything that burnt can heat the house, as well as saving on the costs of waste disposal by burning. One can see the smoke in districts inhabited by wealthy owners [Fig.2].

Fig.2 Morning heating in one family houses district - S-E part of Bialystok,

Source: A. Turecki

- The main municipal air quality measurement station is located in the middle of downtown Bialystok [1] where buildings are connected to the heating network. What's worse, it was placed in the middle of large complex of 11-story buildings [Fig.3]. They form a high ring that stops the flow of air from neighboring areas and major urban roads,

so the air quality in this place is usually better than in other parts of the city.

That was the reason for installing the monitoring system of PM10 and PM2.5 particulate matter, in the "Laboratory of Energy-efficient Architecture and Renewable Energies" at the Faculty of Architecture of Bialystok University of Technology [2].

Fig.3 A – Hypsometry of Bialystok: 1- LEARE, 2- CIEP main station of air quality measurement, 3 – districts not connected to city heating net. B – photo of central district where main measurement station is located: 2- main station, Source: A. Turecki

MONITORING SYSTEM

The basis of the system are two SDS011 dust meters analyzing the scattering of laser light on dust particles (Mie Theory). They are managed by a PIC microcontroller, with an Ethernet interface for transmission over the Internet. Current data is visible on two displays. SDS011 enables measurement of particles in the range of 0-999 µg/m3. The meter has a built-in fan that forces the flow of sampled air through the laser sensor chamber. The system enables continuous readings and recording of data that it sends to the server. This allows you to generate charts and transmit current and historical data. At outdoor air humidity above 65% dust meter readings are overstated by fog droplets. Preheating the tested air can eliminate that problem, but LEARE monitoring hasn`t such equipment yet.

The study of parallel measurements of dust meters with and without air preheating was presented by J. Bartyzel "*at average air humidity of 65%, the differences of readings between the dustmeters with and without preheating differ by 10-15%"*[3]. Such differences can be considered as acceptable at the values several times higher than recommended in the EU.

The meter analyzes the outside air stream in the ventilation unit with the intake at height 4m above the ground. Ventilation works in 24/7 mode. Measurements were taken and recorded every 30 seconds, what allows testing the short-term changes of dust.

However this meter isn`t “golden standard”, but in periods of good, average and poor air quality, without winds, it repeatedly shows similar values of PM2.5 and PM10 as the CIEP main measurement station. Due to the insufficient number of measurement stations, low-cost meters may be useful in assessing the distribution of air pollution in cities. Measurements of air dustiness around the burning waste warehouse in Warsaw were possible thanks to the dense network of such meters [4]. In December 2016, the National Advisory Council for Environmental Policy and Technology provided US-EPA recommendations for how to maximize the benefits of citizen science and ... integrate it into the full range of EPA’s work [5].

The place where the laboratory was built has high variability directions of wind at low speeds, with an annually average lower then 3.5 m/s. In addition to measurements of air pollution, other data provided by weather station Davis, located on the roof of the laboratory, were used. It can monitor and record many parameters: external temperature, humidity, wind speed and direction, solar radiation, UV index, atmospheric pressure, precipitation. Five of them were used: external temperature, humidity, wind speed, wind direction and solar radiation.

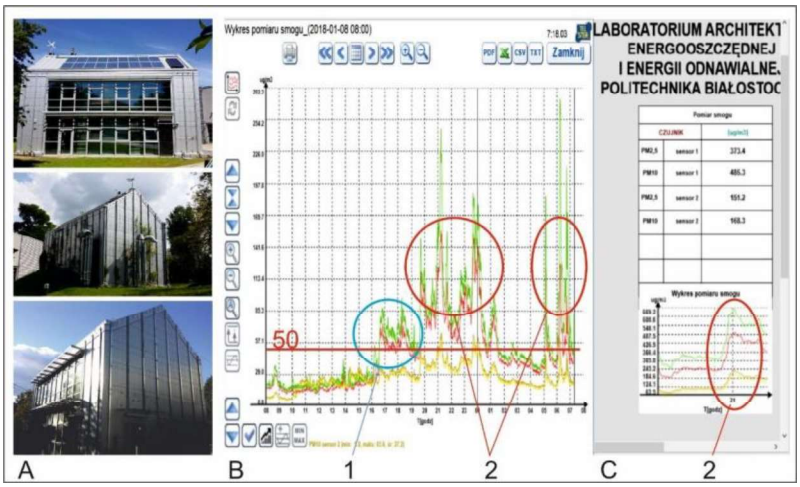

Fig.4 Laboratory of Energy-efficient Architecture and Renewable Energies at the Faculty of Architecture of Bialystok University of Technology: A- photos; B- chart of daily PM2.5 and PM10 values: 1- probably cooking, 2- heating: morning and evening; C- interface of the dust monitoring system: 2- evening heating
Source: A.Turecki

MEASUREMENTS

The laboratory building is located on the border of two different types of districts. The city center connected to the heating network of Bialystok on the east side. From the west and south, the laboratory building parcel is adjacent to the district of old, two-story buildings, usually heated by burning poor quality fuel. They are both residential and commercial, so the behavior of their users and the duration of their operation vary. In residential buildings that are permanently inhabited, the use of cooking stoves and hearths is used for heating and preparing

meals. Small houses have single central oven, integrating heating and cooking. Heating usually takes place twice a day - in the morning and more intensively in the evening. Cooking three times - also in the afternoon. Commercial buildings, used during the day, are intensively heated once in the morning - at night they cool down.

The effect of heating these buildings on air dust around the laboratory building was tested. The dependence was visible during the windless days or when the winds were blowing from their side. Then the dust levels of PM2.5 and PM10 were significantly increased. At that time photographs were taken to see the smoke from the chimneys. Long exposure times - from 10-30s allowed showing it also at night. The weather station Davis indicated outdoor air humidity above 65%.

When the wind blew from the side of neighboring buildings the system recorded "thermal activity" of their inhabitants. It showed not only heating in the early morning and evening hours, but also short-term lower increases during the day - probably associated with cooking.

At the end of 2017, only two CIEP stations and the LEARE measurement point were operating in Bialystok. Only three measuring points is less than one on 33km2 area, and all located in the city center. To test air pollution in the rest of the city, a portable dust meter was additionally used [Fig.5].

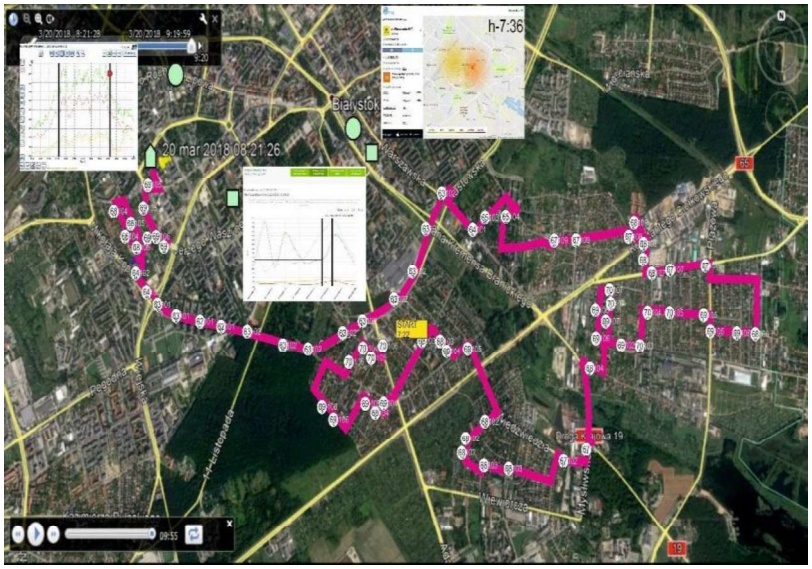

Fig.5 Graph of mobile measurement in S-E part of Bialystok. The value of PM2,5= ~62-70µg/m3, PM10= ~101-106µg/m3; (20.03.2018, h. 7:22-8:21; dust meter SDS011 [without air preheating], mounted on the car, speed 30-40km/h, recorded every 30s; GPS positioning; GoogleEarth map; charts from CIEP, AIRLY and LEARE), Source: A. Turecki

At the end of April 2018 LEARE began the study of the vertical smog distribution using a drone to lift the dustmeter into the air at a height of 100m. The photos taken in winter 2017, from a height of about 30m showed a smog layer

approximately 50m [Fig.6]. These measurements will be continued in the next winter.

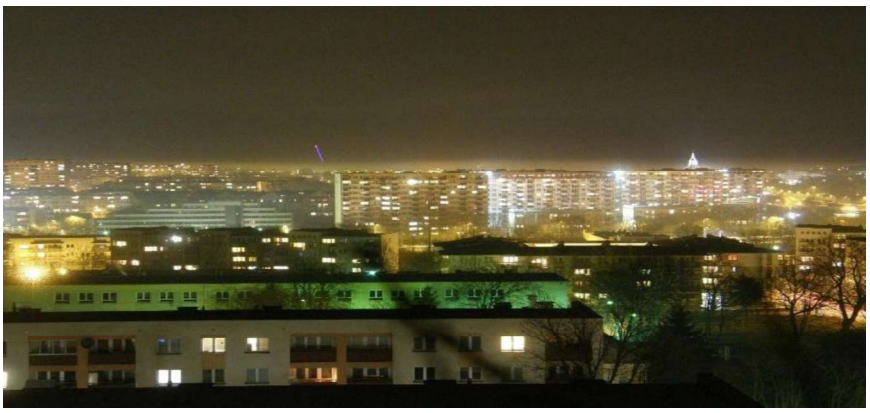

Fig.6 Smog visible on the long exposure photo (15s), N-E part of Bialystok, (31.03.2017 h.22:05
Source: A. Turecki

CONCLUSION

The LEARE monitoring system operate steadily for many months. During the periods of good, average and poor air quality, without winds, despite the use of low-cost meter it repeatedly shows similar values of PM2.5 and PM10 as the CIEP main measurement station. Local maximum concentrations of PM2,5 and PM10 often far exceeded the maximum values shown by the city station. The 30 second measurement period allows to show even short-term high particles concentrations, invisible in one and eight hours averages.

LEARE location on the border of district of old, two-story buildings, heated individually allows to study the impact of such districts on the level of air pollution. They determine the formation of smog in Bialystok - the city center is heated by a central network powered by municipal heat plants which have good filtration and thanks to their high chimneys, emissions are transferred to rural areas. In single family homes districts, there are characteristic hours of dust growth: 6-8, 13-15, 17-19 and 21-23. They are poorly presented in data measured by station located in the city centre.

Not only “energy poverty” and poor technical condition of old houses is the cause of smog formation in Bialystok - one can see the smoke in districts inhabited by wealthy owners.

Due to the insufficient number of measurement stations, low-cost meters may be useful in assessing the distribution of air pollution in cities. Such data, although not fully precise, allow to create maps of smog distributions in the city, helpful in future activities improving air quality, directing resources where they will be most effective

In cities with central districts connected to heating net and neighbourhoods of homes heated individually with bed solid fuel, measurements should be made by a many stations - central and peripheral in accordance with local wind directions.

Measurements carried out behind the ventilation unit with recuperation show improvement in air purity due to the efficient operation of its filters. This improves the health conditions in the buildings and reduces the risk of many diseases.

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