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EFFECT OF URBAN TRAFFIC ON THE IMMISSION OF CARBON DIOXIDE IN THE UNIVERSITY CAMPUS

WPLYW RUCHU POJAZDÓW W MIEŚCIE NA IMISJĘ DITLENKU WĘGLA NA TERENIE KAMPUSU UCZELNI WYŻSZEJ

Abstract: The condition and quality of atmospheric air plays a very important role in the life of every living organism, including man. Every day we breathe atmospheric air containing CO₂ whose level changes depending both on many external factors and physicochemical processes. The concentration of carbon dioxide in the air changes, among other things, due to the influence of communication routes which may adversely affect the environment. For this reason it is necessary to analyze changes in CO₂ concentrations and try to determine their impact on the functioning of users of the area (so, one can observe and analyze seasonal impact of communication routes on separate sub-areas of research).

Keywords: carbon dioxide, immission, concentration in the atmosphere

Introduction

Atmospheric air quality plays a very important role in the life of every living organism, including man. Especially, city dwellers who are exposed to pollution resulting from increasing number of people inhabiting a limited area, development of industry and energy demand, road and transport system, as well as the presence of natural sources of emissions.

Regular and accurate measurements of CO₂ concentrations in the atmosphere started in the 50s of the twentieth century (periodic measurements have been carried out since 1955 in the observatory at the top of Mauna Loa volcano in Hawaii). Thus, it has been noted that from year to year there is a systematic increase in the concentration of carbon dioxide in the atmosphere (with about 315 parts per million - ppm in 1958 to over 380 ppm in 2006) [1]. Figure 1 shows changes of the global carbon dioxide levels in the last few hundred years [2].

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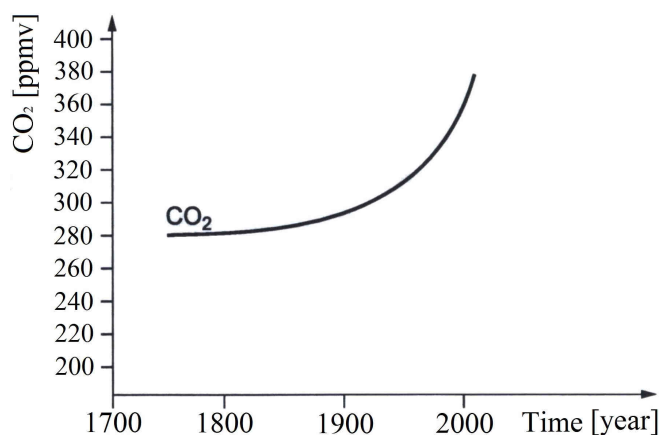


Fig. 1. Changes in the concentration of carbon dioxide [2]

According to Solomon et al [3] climate changes are caused by an increase in the concentration of carbon dioxide and may be irreversible (the authors estimate that after the emissions stop it would take about 1,000 years to return to the previous state), and the levels of average concentrations of CO₂ in the atmosphere would be likely to increase from the current 385 ppm to 450-600 ppm.

Such levels of carbon dioxide may cause acceleration of photosynthesis, and thus have an influence on potential climate changes and a negative impact on humans, animals and vegetation [4-6].

In Poland, systematic measurements of carbon dioxide concentrations have been conducted for about 20 years at Kasprowy Wierch in the Tatra Mountains in the KASLAB laboratory located in the building of the IMGW meteorological observatory. It is the only station in Central and Eastern Europe with such a long record of concentrations of the main greenhouse gases in the atmosphere. The first measurements of CO₂ concentrations in the atmosphere at Kasprowy Wierch started in September 1994. At first (until 1996) the measurements of averaged weekly air samples were performed. Since 1996, the measurements have been carried out by gas chromatography method using an automatic HP 5890 chromatograph equipped with a flame ionization detector and a column packed with Porapak QS [7].

For the first time on a global scale the issue of reducing emissions of greenhouse gases, including carbon dioxide, was raised in 1992 under the United Nations Framework Convention on Climate Change - UNFCCC. One of the most important protocols that refer to the issue of limiting greenhouse gas emissions is the Kyoto Protocol of 1997, which is now better known than the Convention itself. Under provisions of this Protocol countries that have opted for its ratification committed themselves to reduce their emissions by negotiated values of gases such as, inter alia, carbon dioxide, methane and nitrous oxide, *ie* the gases which cause the greenhouse effect.

Currently, in the Polish legislation a superior document related to air protection is the Environmental Protection Law [8] which identifies the principles of protection of the environment and conditions for the use of its resources, taking into account the

requirements of sustainable development, rules for determining the conditions of conservation of the environment, the conditions of introducing substances or energy into the environment, and the cost of using the environment. According to the provisions of the above mentioned Law, the protection of air covers ensuring its best possible quality by maintaining pollutant concentrations below the maximum levels specified by regulations. Air protection consists also in a reduction of the concentrations of substances in the air to acceptable levels at least. The Law does not define carbon dioxide as a substance that adversely affects the quality of atmospheric air. The level of CO₂ in the atmosphere is not defined as acceptable and is therefore not monitored by the State Environmental Monitoring (monitoring of this gas is carried out only for the purpose of emissions trading).

The all Polish environmental law is based on EU environmental legislation, and was implemented before accession in 1999-2001. The main regulation on the air protection is based on CAFÉ Directive [9].

Immission and emission

According to the Polish Environmental Protection Law [8]: “emission are the substances and energy such as heat, noise, vibrations or electromagnetic fields introduced directly or indirectly into the atmosphere, water, soil or earth as a result of human activity”, while “immission is the concentration of pollutants or deposition of pollutants in the environment. The source of immission can be one, but usually many sources of pollution which typically consist of a number of emissions from various sources of pollution”.

The sources of air pollutant emissions are mainly local (central and local) and district heating systems that provide heat for housing, industry and services generating harmful substances in the atmosphere [10-12].

It should be borne in mind that low-emission sources emit pollutants only in the heating season, while district heating systems do this with varying intensity throughout the calendar year. To estimate the amount of fuel used and to determine on this basis the amount of pollutants is possible only for centralized heating systems, while for low-emission sources this is difficult because the size of pollution is determined by weather, local fuel availability and the lack of emission control levels [10].

Another, and sometimes even more important source of air pollution is road transport which often (especially in the centers of large cities) has a more negative impact on the environment than the heating systems themselves [13-15]. This is due to the fact that especially in large urban areas the flow of traffic increases steadily, thus deteriorating air quality (according to the Central Statistical Office CO₂ emissions from transport in Poland increased from 26,403.76 thousand Mg in 2000 to 46,465.74 thousand Mg in 2010 [16]).

The levels of carbon dioxide immissions are closely related to the emission of this pollutant to the atmosphere and occur cyclically (daily, seasonally, annually), while immission fields are not dependent on the location of emitters from district systems.

One of the methods to reduce the level of pollutants in ambient air is to reduce the size of cities through the creation of so-called compact cities in which the negative effects of urbanization on the environment could be prevented or reduced [17]. Unfortunately, this concept is not always feasible due to the nature of the region, its industrialization and historical conditions.

Characteristics of the studied area

Changes in the carbon dioxide immission field were investigated in campus B, *ie* in southern part of the Lodz University of Technology which on the north is adjacent to Skorupki St. through the Bishop Klepacz Park, and on other sides is surrounded by Wolczanska St. (on the east), Wroblewskiego St. (from the south) and al. Politechniki (on the west). Additionally, on the south-west there is the city's power plant EC2.

The area covers about 16 hectares of which large part is occupied by the 19th century palaces and revitalized industrial buildings of the former LODEX factory. The complex comprises 19 buildings belonging to the Lodz University of Technology. Significant parts of campus B are rigid pavements, such as access roads and parking lots. The area is characterized by the diversity of buildings. There are both densely built-up and green areas. The most densely built-up area is occupied by the building of "Three Departments" along with the buildings of the Center for Laser Diagnostics and Therapy, Faculty of Process and Environmental Engineering (FPEE) and the Institute of Turbomachinery. The lowest building density has the area of FPEE Dean's Office (Fig. 2).

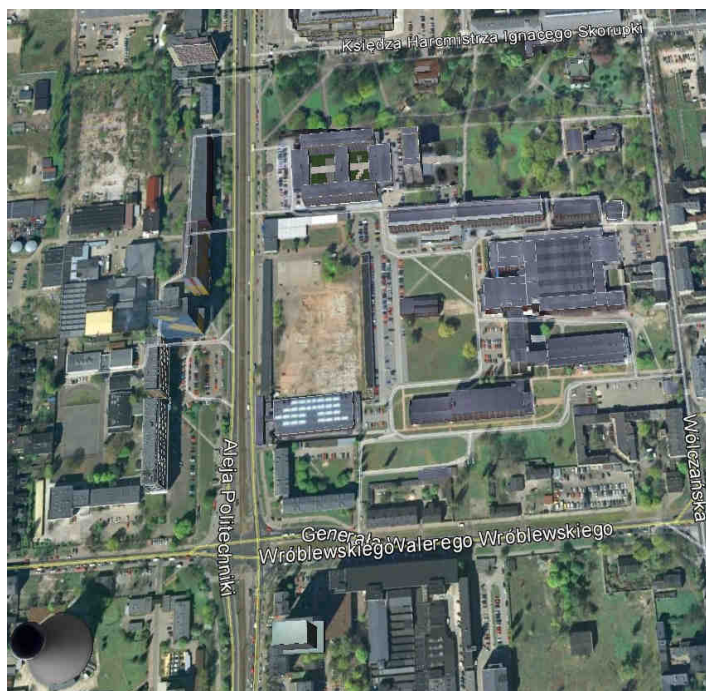


Fig. 2. View of campus B [18]

Measuring points were located in the corners of the existing buildings. Due to the type of building, on the west side there were much less measuring points than on the east side (Fig. 3). Measurements were taken in March and April in 2012 and 2014. Each time in March, the measurements were made in 83 points, while in April in 86 points extending

the research area with 2 points localized along al. Politechniki and 1 point at Wroblewskiego St.

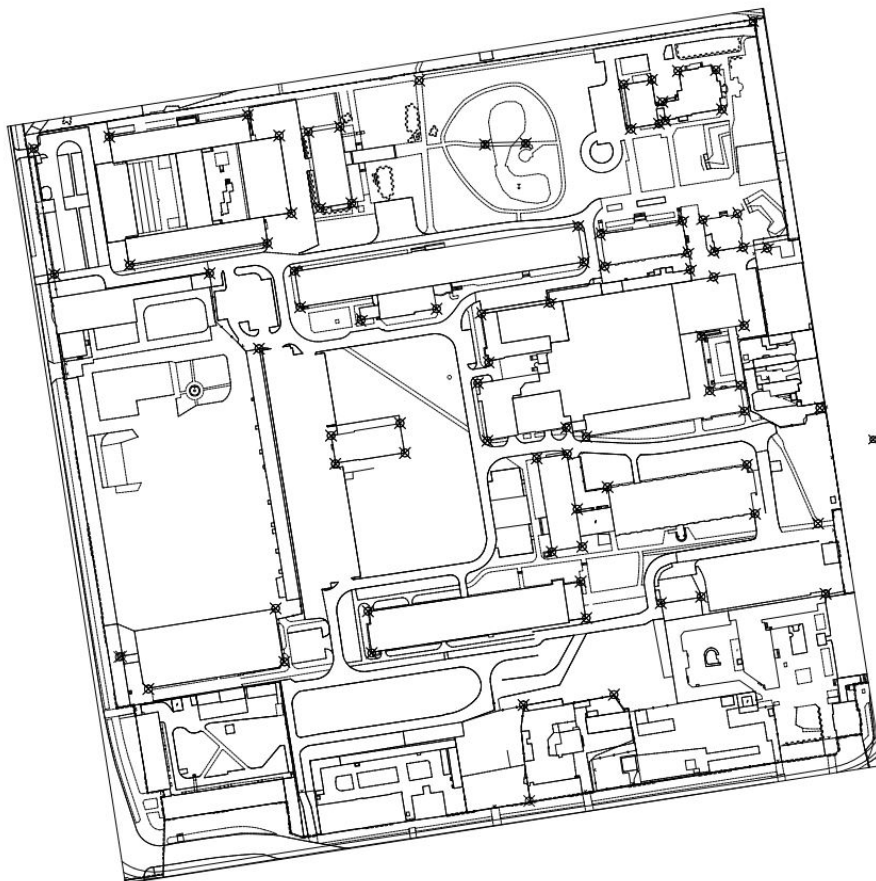


Fig. 3. Measuring points \times on the area of campus B

The measurement methodology

In the measurements a VEGA-GC microchromatograph (Pollution S.p.A., Italy) was used (Fig. 4). With this device analysis can be made in field conditions. The device is equipped with 2 batteries, a tank with carrier gas (helium), a pump for samples and a computer module. In the device two columns operating in parallel can be installed (Table 1 gives basic information on the possibilities of measurements using different columns installed in the VEGA GC microchromatograph). A thermal conductivity detector (TCD) enables the analysis of samples at a minimum concentration of 500 ppb (0.005 ppm) over a period of 6 to 300 seconds depending on the type of gas tested [19].

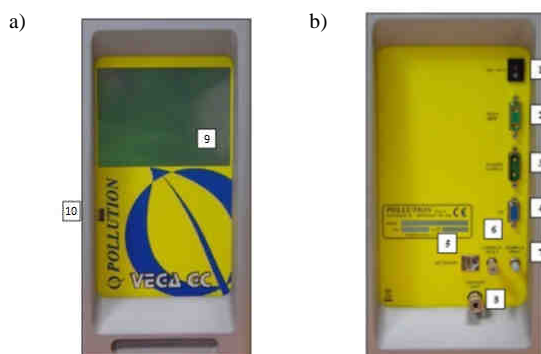


Fig. 4. The image of VEGA-GC microchromatograph (a and b) [19]: 1 - on/off switch; 2 - port of multipoint connector of the VEGA MPS sampler (additional equipment); 3 - port of the external power connector 110-220 V AC - 12/24 V DC; 4 - RS-232 or RS-485 connector (possibility of connecting external monitor screen); 5 - LAN Ethernet port (possibility of connecting the device to local network or Internet); 6 - sample inlet; 7 - sample outlet; 8 - carrier gas connector (possibility of connecting external cylinder with carrier gas); 9 - LCD touch screen 6.5"; 10 - USB port (possibility of exporting data to external storage, connecting external keyboard/mouse and external printer)

Table 1

Columns of VEGA-GC microchromatograph [19]

Name of column	Description	Exemplary gases
CP Sil 5CB	capillary column packing: pure (100%) methyl group on a silicone scaffold; application: hydrocarbons containing carbon particles from C3 to C8 (C10), aromatic hydrocarbons of high boiling point	benzene; toluene; xylene; pentane; propane; ethylbenzene; decane; heptane; hexane; ethanol; acetone; chlorofluorocarbons (CFCs); formaldehyde; methanol
PPQ	packed column, application: hydrocarbons containing carbon particles from C1 to C4	N ₂ ; N ₂ O; H ₂ O; CO ₂ ; CH ₄ ; acetylene; ethane; chloroethane; ethanol; ethylene; propane
Molsieve 5A (M5ABF)	packed column, application: carbon monoxide, methane	CO; H ₂ ; CH ₄ ; N ₂ ; O ₂ ; He; Ar; Ne
CP Wax 52 (52CB)	capillary column packing: polyethylene glycol application: polar substances of high boiling temperature	acetone; acetaldehyde; acetic acid; methanol; ethanol; propanol; butanol; methylbutane; hexanol; C1-C4 glycols

Technical data of the device [19]:

1. Power supply: adapter 110-220 V AC - 12/24 V DC; 2 nickel-metal-hydrogen batteries (NiMh).
2. Carrier gas: possibility of using helium, hydrogen, nitrogen or argon from an external source - gas cylinder. Required flow rate - 10 cm³/min; possibility of using helium, hydrogen, nitrogen or argon from an external source - gas cylinder. Required flow rate - 10 cm³/min.
3. Dimensions: 17 × 38 × 41 cm (width × height × depth).

4. Weight: 9 kilos without batteries; 13 kilos with two installed batteries.
5. User interface: color touch screen LCD with a diagonal of 6.5".
6. Working conditions: operating humidity 0-95%; working temperature: 0-50°C.
7. Characteristics of samples: sample temperature 0-120°C; sample pressure 50-200 kPa.
8. Working time: 60-300 s (depending on the number of analyzed substances).
9. Detector: thermo-conductive TCD.
10. Calibration: every 6 months.
11. Minimum concentration: 500 ppb (parts per billion) (1 billion - 10^9) solvent molecules.
12. Operation system: WINDOWS XP EMBEDDED.

Measurements of carbon dioxide concentrations were made in the PPQ packed column installed in the VEGA-GC microchromatograph. Each measurement was performed at a 90 s interval.

To evaluate a specific type of pollutant and its amount the chromatograph was calibrated on the basis of test gas. Figure 5 shows a calibration curve.

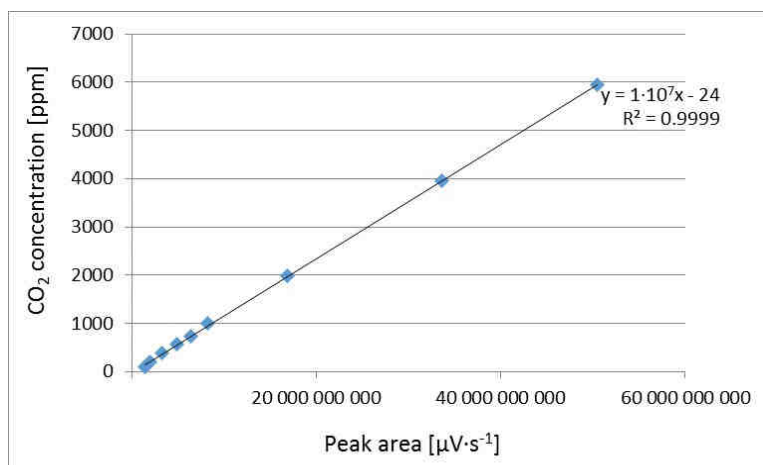


Fig. 5. Plot of the calibration curve for carbon dioxide [20]

A method developed by Cichowicz for carbon dioxide measurement with the use of VEGA-GC microchromatograph was applied in the study. In the first step, two batteries were charged and then mounted and a portable bottle with carrier gas (helium) was installed. Next, the operating system (computer) was started and connected to MC2 and MC-Plan program in order to tune the device. The next step was launching the program with a defined methodology of carbon dioxide measurement. After heating the device, the process of automatic measurement was started and the researchers went to the first measuring point. During the measurements the measuring device was set in the direction free from buildings (in the vicinity of the pavement). Due to 83 and 86 measuring points, an external device equipped with a GPS receiver was used and at the start of sample supply to the device on the memory card the date, time and GPS coordinates were saved. Then, on a geodesic map the surface of the built-up area, *ie* the sum of surfaces of ground floors of all buildings in the area calculated in the outer wall contours (with clearances and arcades) was

determined. The number of storeys in the buildings in the analyzed areas was specified and an average storey height of the buildings was assumed. Thanks to this, multiplying the built-up area by the number of storeys and their average height we obtained cubic capacity of the building. When dividing the surface of the area by the sum of cubic capacities of the built-up area we obtain an estimated building density of the area. This quantity is related to the arithmetic mean of carbon dioxide concentration recorded in the measuring points located in the area.

To determine the meteorological conditions during the measurements, data from the weather station located in the Wladyslaw Reymont airport in Lodz were used [21]. The weather station is about 5 km from campus B in a bee line.

Table 2 summarizes the basic values of meteorological data, which were recorded at the Lodz-Lublinek station for days and hours during which the measurements were made.

Table 2

Weather data [21]

Date of measurement/ Parameter	20.03.12	02.04.12	23.04.12	25.04.12	20.03.14	03.04.14	24.04.14	28.04.14
Temperature [°C]	9-13	7	9-13	15	11-15	8-19	8-19	13-16
Cloudiness	light overcast	partly overcast	partly overcast	cloudless	light overcast	cloudless	cloudless	partly overcast
Wind flow velocity [km/h]	22-31	26-30	9-15	13-19	17-33	6-13	17-21	6-17
Wind direction	W	W	SW	SW	W	W	W	SW
Pressure [hPa]	1031.2	1005.1	1008.1	1005.8	1018.5	1005.1	1019.8	1009.1
Relative humidity [%]	53-70	49-53	51-81	44-82	55-72	40-57	46-64	72-94

Fields of carbon dioxide immission

As a criterion for the analysis of air quality in campus B the impact of two arterial roads, *ie* al. Politechniki (Figs. 6 and 7) and Wolczanska St. (Figs. 8 and 9), was assumed. Results of the measurements were classified according to distance from the roads. Four sections were established: 0-50, 50-100, 100-150 and 150-200. In the particular sub-areas arithmetic means of carbon dioxide concentrations were determined. On this basis the impact of communications routes on air quality in the tested area could be observed. Due to the specific nature of campus B, on the side of Al. Politechniki much fewer measuring points were located than on the side of Wolczanska St. For these reasons, while analyzing the impact of the roads on the tested area a different number of measuring points was taken to determine the average concentration of carbon dioxide.

In March 2012 and 2014 the average carbon dioxide concentration in the sub-area which was closest to Al. Politechniki was 373 ppm each time, while in April 2012 and 2014 it was 706 ppm and 369 ppm, respectively. It was observed that in both years in March these values were decreasing with increasing distance from Al. Politechniki. On the other hand, basing on the measurements taken in March 2012 and 2014, on the side of Wolczanska St. an increase of carbon dioxide concentration with distance from the road

could be observed. This may be caused by an increase in housing density and traffic on the roads inside campus B as well as by use of students' parking lots in close proximity to the tested area.

The situation was quite different in April 2012, when the average concentration of carbon dioxide increased with distance from Al. Politechniki, and decreased with distance from Wolczanska St. However, in April 2014, the average concentration of carbon dioxide varied within the same range irrespective of the distance from Al. Politechniki, and decreased with increasing distance from Wolczanska St.

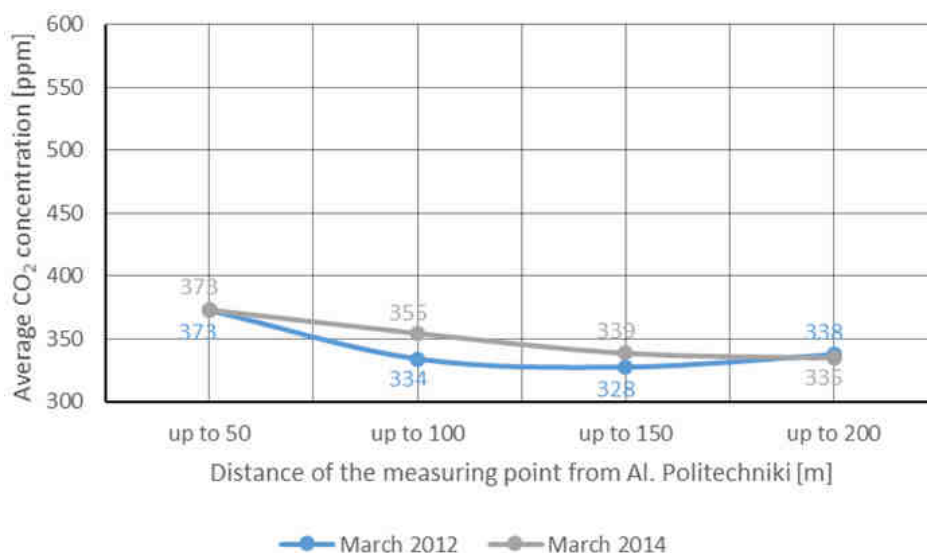


Fig. 6. Impact on campus B, Al. Politechniki, March 2012 and 2014

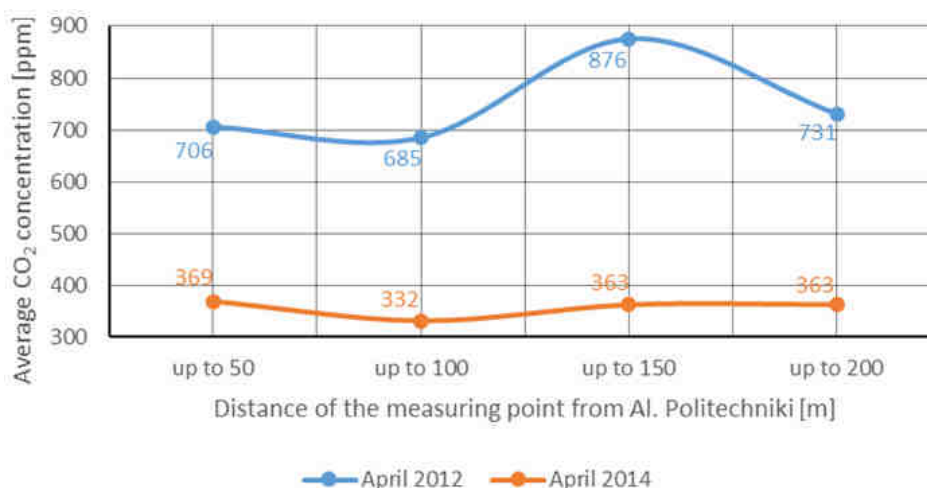


Fig. 7. Impact on campus B, Al. Politechniki, April 2012 and 2014

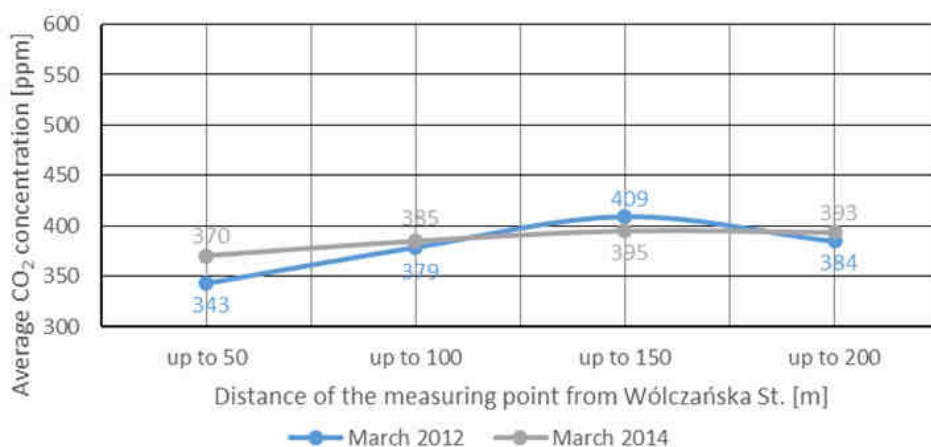


Fig. 8. Impact on campus B, Wolczanska St., March 2012 and 2014

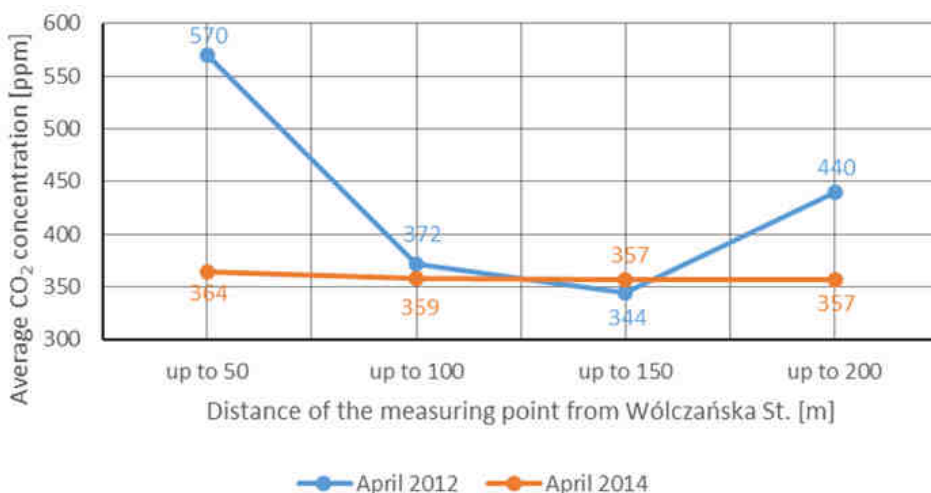


Fig. 9. Impact on campus B, Wolczanska St., April 2012 and 2014

Conclusions

Every analysis of changes in the field of pollutant immission in a given area can be useful for monitoring the atmosphere and should be periodically or continuously carried out and continually improved. After access to the European Union, Poland introduces more and more effectively new methods to improve the monitoring system. Systematic attempts are made to reduce pollution from large industrial plants using, for instance, the best available techniques. However, as regards gases emitted from district heating systems they are purified to the level specified in permits for emissions and their potential exceedance causes serious financial consequences.

The use of gas microchromatography enables precise and accurate measurements of carbon dioxide concentrations. Based on the tests carried out in this study it can be assumed that in the analyzed area there are only local variations in CO₂ concentrations which can adversely affect the functioning of the users of the area. Additionally, a seasonal impact of communications routes on separate sub-areas was observed.

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WPŁYW RUCHU POJAZDÓW W MIEŚCIE NA IMISJĘ DITLENKU WĘGLA NA TERENIE KAMPUSU UCZELNI WYŻSZEJ

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Abstrakt: Stan i jakość powietrza atmosferycznego odgrywają bardzo ważną rolę w życiu każdego organizmu żywego, w tym i człowieka. Na co dzień oddychamy powietrzem atmosferycznym, w którym występuje CO₂, a jego poziom zmienia się w zależności zarówno od wielu czynników zewnętrznych, jak i procesów fizykochemicznych. Stężenia ditlenku węgla w powietrzu ulegają zmianie między innymi ze względu na wpływ arterii komunikacyjnych, które mogą negatywnie oddziaływać na otoczenie. Z tego powodu należy przeprowadzać analizy zmian stężeń CO₂ i próbować określać ich wpływ na funkcjonowanie użytkowników danego terenu (dzięki temu można zaobserwować i przeanalizować sezonowy wpływ szlaków komunikacyjnych na wydzielone podobszary badań).

Słowa kluczowe: ditlenek węgla, imisja, stężenia w atmosferze