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FIELD STUDY OF AIR QUALITY IMPROVEMENT BY A "GREEN ROOF" IN KYIV

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Abstract: Currently, a very big problem of cities in Europe and the world is air pollution with combustion products of car fuels, generation of heat and electricity. These impurities affect the microclimate of cities significantly. Pollution not only affects the area outside buildings, but getting into their interior through ventilation systems, which has an adverse effect on the indoor environment of buildings. High concentrations of CO_2, cause a weakening of concentration in working people, which affects the deterioration of safety and work efficiency. For assessing air quality improvement on "green roofs", a field study of CO_2 content has been carried out on the "green roof" of a four-storey building, on a completely identical non-greened building, and on a highway with high-density traffic near them in Kiev. It was found that greening the roof significantly reduces the CO_2 content from 501 ppm on the road and 452 ppm on the roof without protection to 410-415 ppm. It improves the conditions in which people work and rest.
Keywords: air pollution, air quality, green roof, reducing CO_2, sequestration of CO_2

1. INTRODUCTION

The main contributor to the greenhouse effect is CO_2, which is an indicator of the environmental impression of urbocenoses. Despite the sharp fluctuations in the concentration of CO_2 in the Earth's atmosphere over the past geological period, the natural cycle of CO_2 for the last several millennia as a whole has not changed.
Anthropogenic activity violates the equilibrium by releasing CO_2 from natural carbon stores such as fossil fuels and green biomass. Since the beginning of the industrial era in the eighteenth century, the concentration of CO_2 in the atmosphere increased by almost a third. As a result of these actions during the last century, there was a global increase in the average temperature and warming of the climate.
Reduction of CO_2 emissions is the main mechanism for deceleration of climate change. In solving this problem, "green construction" can be considered as promising technologies for reducing ecological footprint due to CO_2 sequestration by additional

biomass (trunk, branches, bark, leaves, roots) and a substrate. One of the effective low carbon technologies are the "green structures" (Alperen Meral et al., 2018), (Chen et al., 2018), (Qin et al., 2018), (Jian-feng et al., 2010), (Kristin et al., 2009), (Kuronuma et al., 2018), (Margareth et al., 2018), (Mayrand and Clergeau, 2018), (Sanderman and Amundson, 2009), (Tuttolomondo et al., 2018), (Yanling et al., 2014). They can improve the quality of air in cities as well as reduce the emission of greenhouse gases. They can improve safety, stabilize the process of drainage of rainwater from the roofs of buildings (Pooriva and Vranayova, 2014), (Ujma and Sowier-Kasprzyk, 2015) and can accumulate rain water in roof ground layers (Itrashvili L. et al., 2017). They fulfill an important role in ensuring the safety and high quality of the structure, which is the roof of the building (Gorny, 2018).

2. METHODOLOGY OF RESEARCH

To determine the effect of sequestration of CO_2 on improving the conditions of people's stay on an intensive "green roof", and in order to estimate the effect of "green roofs" on the level of CO_2 in the air, field studies were conducted on three objects:

I. On the green roof in a four-story building of ZinCo company on M. Lobanovskoho avenue, characterized by a high load of vehicles and frequent traffic jams (Fig. 1 a). Experiments were conducted at expositions with different assortment of plants:

   exposition A - yarrow (*Achillea millefolium*), boxwood (*Buxus sempervirens*), red barberry (*Berberis thunbergii*), salvia (*Salvia officinalis*), mountain pine (*Pinus mugo*), Canada hemlock (*Tsuga canadensis*), bushgrass (*Calamagrostis epigejos*), plains coreopsis (*Coreopsis tinctoria*);

   exposition B (Fig. 2 a) - hostas (*Hosta*), white hydrangea (*Hydrangea alba*), sedge (*Carex*) ;

   exposition C (Fig. 2 b) - *bevelled* lawn (*Lolium perenne*).

II. The neighbouring building, which is completely identical (Fig. 1 b) except no plants on the roof around the measuring point.

III. A point on M. Lobanovskoho Avenue near the buildings.

Age of plant material was one month.

a  b 

Fig. 1. General view of buildings:
a - ZinCo four-storey green roof building on M. Lobanovskoho Avenue;
b - identical building on M. Lobanovskoho avenue without green roof

Measuring devices are shown in table 1. At the point I, on exposures A (Fig. 3 a), B (Fig. 3 b), and C (Fig. 3 c), CO_2 measurement was carried out at the centre of the exposure itself and at a distance of 0.50 m from the exposure. The experiment was conducted from 12:00 to 13:00 on 4 July 2018. On that day there was a cloudy weather and gusty wind with short-term gusts at the roof level up to 10,5 m/s.

Fig. 2. General view of exposures: a - exposure B; b - exposure C

Table 1
Characteristics of measuring devices

Size	Measuring device	Range	Error
Illumination, lux	Lux meter Mastech M56610	0…50000 lux	± 5 %
Wind speed, m/s	Data logger Testo 445; sensor Testo 0635 1049 "hot ball"	0…10 m/s	± 5 % ± 0,03 m/s
CO_2 concentration, ppm	Gas analyser GM8802	0…2000	± (50 ppm + 3 %)
Temperature, °C		0…50 °C	± 0,3 °C
Relative humidity,%		10…90 %	Absolute ± 5%

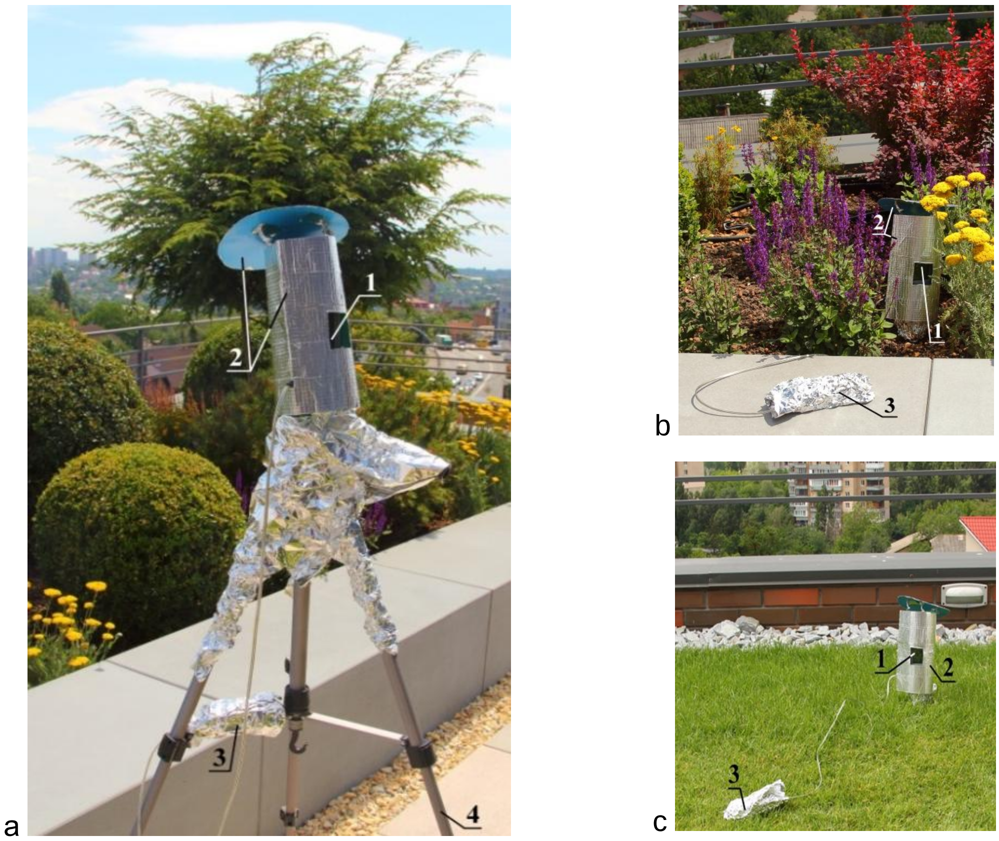

Fig. 3. Measuring the CO_2 level: a - exposure a (walk); b - exposure b; c - exposure c:
1 - gas analyser GM8802; 2 - protective thermal reflecting cylinder;
3 - battery for power supply; 4 - tripod

The brightness during the clear weather on the roof was 99.3 thousand lux. In cloudy time, the illumination was 38.5 … 39.9 thousand lux. The air temperature on the roofs varied from 27.7 °C to 29.1 °C, and in the street it was 30.2 … 30.4 °C.

3. RESULTS

Results of measurements of CO_2 concentration, ppm, temperature, °C, relative humidity, %, and air velocity, m/s, are given in Table 2. The reference values (MPC CO_2, 2018) are given in Table 3.

Table 2
Results of measurements

Experimental point	**Tempe-rature, °C**	**Relative humidity, %**	**Wind speed, m / s**	**CO_2 con-centration, ppm**
On the walk between Exposures A and B	25,3	40,3 %	1,15…4,5 average 2,08	415
Inside the exposition A	28,3	39,4	—	320
On the walk near the exposition C	25,5	39,0	—	410
Inside the exposition C	27,7	39,4	—	329
No plants	28,9	33,9	2,12…10,5 average 5,17	452
On the avenue near the buildings	30,3	32,6	0,68…2,85 average 1,65	501

Table 3
Reference values of CO_2 concentration (MPC CO2, 2018) in the air of the working zone,

Type of reference value	**CO_2 concentration, ppm**
Normal level in the outside air	350…450
Acceptable level	≤ 600
Complaints on bad weather	600…1000
The maximum level in ASHRAE and OSHA standards	1000
Man feels a general weakness	1000…2500
Possible unwanted health effects	2500…5000
The maximum concentration for eight hours of a working day	5000

4. DISCUSSION

Thus, the greening of a roof contributes to a significant reduction in CO_2, which improves the conditions for people to rest on it. This is especially important for districts with insufficient landscaping and tight traffic. A huge influence on the process of photosynthesis gives the carbon dioxide content in the air. Increasing concentration helps to increase the productivity of photosynthesis. A slight decrease in concentration dramatically reduces the productivity of the process of photosynthesis. In these areas, as a rule, there is an increased concentration of CO_2 in the streets, in apartments and in working areas. On the "green roof" walks, the CO_2 concentration (410 ... 415 ppm) corresponds to the normal level (Table 3) in the outside air. On a non-green roof, the CO_2 concentration (452 ppm) slightly exceeds the upper limit of concentration in the outside air (Table 3). In the avenue, this concentration (501 ppm) significantly exceeds this limit and approaches the upper limit of an acceptable level (Table 3).

It should be noted that during the experiments there were only periodical "traffic light jams" and wind. During rush hours there is a complete traffic jam when vehicles stop and periodically ride at speed up to 5 km/h. At this time, the concentration of CO_2 in the avenue should be significantly higher, especially in windless weather. The significantly lower concentration of CO_2 at the exposure indicates an intensive absorption by plants. It should be noted that in the shade-tolerant plants, the peak of the activity of photosynthesis is observed in the penumbra. In light-loving plants, the intensity of photosynthesis is high only in full sunlight.

In Tkachenko and Mileikovskyi, 2018, there are researches of application of "green structures" for automatic sun protection in the summer around glazing. In Tkachenko, 2018, there is a research of the cooling effect of the “green roofs”, which shows the possibility of passive cooling of rooms. If we use glazing for ventilation (periodical opening or by special ventilation slots), the structures can additionally cool due to "cooling effect" and reduce necessity in external air because of CO_2 sequestration and O_2 release. The same effect can be achieved using the “green structures” for air intake.

5. CONCLUSION

Field studies of CO_2 concentration on "green" and non-greened roofs have shown that "green roofs" significantly affect the level of CO_2. On the "green roof" walks, the CO_2 concentration (410 … 415 ppm) corresponds to the normal level in the outside air. On a non-greened roof, the CO_2 concentration (452 ppm) slightly exceeds the upper limit of concentration in the outside air. At the avenue near the buildings, this concentration (501 ppm) significantly exceeds this limit and approaches the upper limit of an acceptable level. During the experiments, there were only "traffic light jams" and wind. In peak hours there is a full traffic jam, and the concentration of CO_2 should be significantly higher, especially in windless weather. Therefore, the "green roofs" can solve the problem of high CO_2 concentration in densely populated poorly greened micro-districts with traffic jams or industrial districts. The "green structures" can be used for reducing the necessity of external air for ventilation.

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