Air quality in school - measuring and analyzing CO_2 levels

Students: Marinela Dlaka (7th grade), Marija Cicvarić (7th grade), Iva Kapljić (6th grade)
Mentor: Zrinka Klarin, geography professor
Elementary School Šime Budinić Zadar, Croatia

Summary
An air quality study was conducted at Šime Budinić Primary School in Zadar by monitoring the concentration of carbon dioxide (CO_2) in different school areas (the geography classroom, the school hall, the school kitchen and the school gymnasium). Measurements were taken during summer and winter to analyze differences in carbon dioxide concentration in different seasons and to determine changes in levels during the school day. The results showed that elevated carbon dioxide concentrations were recorded during classes in the classroom, especially in conditions of insufficient airing. Dangerous levels of carbon dioxide were measured in the school kitchen during meal preparation, which indicates a great need for improving the ventilation and airing system. Lower and more stable levels of carbon dioxide were measured in the school gymnasium and school hall because they are larger spaces with better airing. Comparing the data obtained in summer and winter, higher average values of carbon dioxide were observed in all selected areas. Regular airing of school premises, installation of air quality measurement devices and maintenance of green areas around the school are important in maintaining good air quality and creating a healthy school environment. The results of measurements conducted in Vruljica Park showed lower concentrations of carbon dioxide, within acceptable limits for open space. This confirms the importance of green areas for reducing carbon dioxide levels and improving air quality in the city.

Introduction

Carbon dioxide (CO_2) is a colorless and odorless gas that naturally exists in the atmosphere. It is a chemical compound consisting of one carbon atom and two oxygen atoms. It is formed as a result of respiration, the decomposition of organic matter, as a result of human activities, the combustion of fossil fuels (oil, coal, gas) in transport, industry, etc. The values of carbon dioxide in the atmosphere are shown in ppm (parts per million). An important role of carbon dioxide in nature is its participation in photosynthesis, the process by which plants use carbon dioxide, water and sunlight to create oxygen and glucose. The concentration of carbon dioxide in the atmosphere has fluctuated within natural limits for centuries. However, in modern times, the level of carbon dioxide in the atmosphere has reached levels that significantly exceed natural values.

In addition to the outdoor environment, it is important to monitor carbon dioxide in indoor spaces. The level of carbon dioxide in indoor spaces is one of the indicators of air quality. The presence of living beings, human activities, airing, ventilation and plants are the main causes of changes in the concentration of carbon dioxide. Children are particularly vulnerable to air pollution because their organs are still developing and they have lower resistance to harmful substances in the environment. Aside from their homes, schools are the main place where they can be exposed to such pollution. According to the WHO, it is important to regularly measure the air quality in classrooms, especially carbon dioxide levels, in order to react in time if they are elevated[1].

[1] https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

Students at Šime Budinić Elementary School in Zadar wanted to explore the air quality in their schools because during the colder months, they often yawn, feel tired and have headaches in the classrooms.

Research questions, research objectives and hypotheses
The aim of this research is to find out how the concentration of carbon dioxide in different school areas (classroom, school hall, school kitchen and school gymnasium) changes during the school day and during the summer/winter season.

The research aimed to answer the following research questions:

- Is there a significant difference in the concentration of carbon dioxide in different school areas (classroom, school hall, school kitchen and school gymnasium) during the school day?
- Is there a difference in the concentration of carbon dioxide in school areas regarding the summer/winter season?
- How does the frequency of airing and ventilation affect the concentration of carbon dioxide in school areas?

The students' hypotheses are:

- The concentration of carbon dioxide in the air is the highest in the classroom during classes due to poor airing and in the kitchen during meal preparation. The school hall and school gymnasium have lower levels of carbon dioxide in the air due to larger space, better airing and ventilation.
- Carbon dioxide concentration in school areas is higher during winter than during summer due to often closed windows and less fresh air flow.
- Well-aired and ventilated spaces have significantly lower carbon dioxide levels compared to those where airing is irregular or inadequate.

Metode istraživanja
Zadar is located on the eastern coast of the Adriatic Sea, in Northern Dalmatia. It is located in an area with a Mediterranean climate with about 2500 hours of sunshine per year, making it a pleasant place to live. The research in the project was carried out on two locations (Figure 1). The first location is a school building (indoor space) where carbon dioxide measurements were carried out in different areas of the school: the geography classroom, the school hall, the school kitchen and the school hall. The second location is the GLOBE biometric station Vruljica park in Vruljica park (outdoor space).

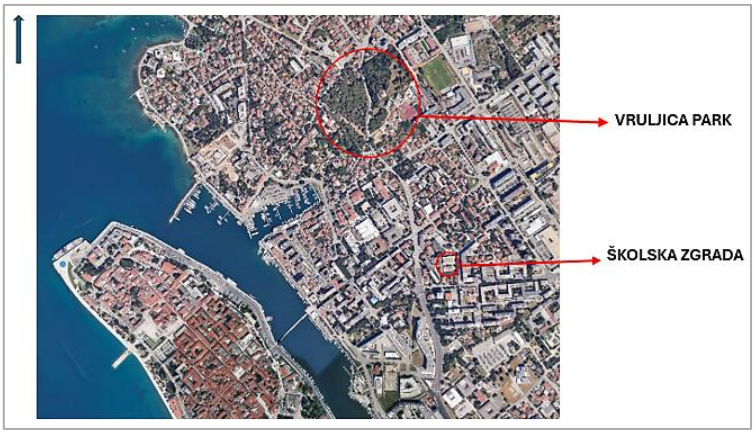

Figure 1 Location of the Šime Budinić school building in Zadar and the Vruljica park

The characteristics of the areas in the school building are listed in Table 1.

Table 1. Characteristics of the areas in the school building

Rooms in the school building	Sizeof the room	Airing of the room	Ventilation system	Plants
Geography classroom	58 m^2	depending	does not exist	do not exist
School hall	320 m^2	depending	does not exist	exist
School kitchen	25 m^2	depending	exists	do not exist
School gymnasium	630 m^2	constant	does not exist	do not exist

For this study, locations for measuring the concentration of carbon dioxide in the air were determined in each selected area of the school according to pre-agreed criteria. The measurements were carried out at a height of 1.5 meters from the floor, away from windows, doors, air conditioning ventilation and heat sources, in order to avoid various influences on the measured values. All these criteria were applied in all selected rooms of the school.

In the school building, measurements of carbon dioxide concentration in the air were carried out in two seasons: summer (September) and winter (February) for 10 days each during school days. The measurement time is from 8:00 to 14:00 every full hour. The Smart Sensees device intended for indoor spaces was used to measure carbon dioxide concentration on school premises. In order to determine the influence of airing and ventilation on the dynamics of carbon dioxide concentration in indoor spaces, an Intensive Observation Period (IOP) was conducted. The measurement was carried out in the geography classroom in the summer, on September 24 and 25, 2025, in the period from 8:00 to 14:00, every 30 minutes. The first day without airing and ventilation of the classroom, and the second day with airing and ventilation of the classroom. During the specified period, a larger number of measured data was collected in order to obtain a more detailed overview of the dynamics of carbon dioxide concentration data. During the intensive measurement of carbon dioxide concentration, the number of people in the classroom was 25.
Vruljica Park is a city park in Zadar, with an area of about 50,000 m2. The park is divided into a park and a pine forest. The measurement of carbon dioxide concentration in the air was carried out in the part where the Aleppo pine forest prevails at the biometric GLOBE station Vruljica Park. In Vruljica Park, carbon dioxide measurement was carried out in winter, on February 17, 2025. The measurement time was from 8:00 to 14:00, every 30 minutes. In Vruljica Park, the GDX-CO2 Go Direct CO2 Sensor device, intended for measuring carbon dioxide for open spaces, was used.
Two different measuring instruments were used in the study, so certain methodological and research obstacles are possible. The Smart Sensees device is used to measure carbon dioxide in indoor spaces, and the Go Direct CO_2 Sensor in outdoor spaces. Air temperature, humidity and wind speed in indoor and outdoor spaces differ, which affects the change in the value of carbon dioxide in the air and the measurement results. Measuring the concentration of carbon dioxide in Vruljica Park is important because it shows how much carbon dioxide is in the outdoor air, unlike in indoor spaces where there is a large human impact. Parks and other green areas reduce the amount of carbon dioxide because plants use carbon dioxide from the air through photosynthesis. Measurements in Vruljica Park help to understand the contribution of vegetation to improving air quality and the importance of green areas in urban environments.

The collected data are presented in tables and graphs. The data analysis led to conclusions about changes in carbon dioxide concentration and conditions in individual school areas and in Vruljica Park.
The measured carbon dioxide values were classified into 6 categories according to ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) for indoor spaces and 3 categories according to the European standard EN 13779 for outdoor spaces.

Table 2 Categories of indoor carbon dioxide level

CO_2 level (ppm)	Air quality category	Impact on health and well-being
350 - 450 ppm	Very good air quality	Natural level of carbon dioxide in the open air, optimal for breathing.
450 - 800 ppm	Good air quality	Comfortable level, well-ventilated spaces.
800 - 1000 ppm	Acceptable air quality	Feeling of stuffiness in the space, ventilation required.
1000 - 1500 ppm	Poor air quality	Possible drowsiness, decreased concentration, headache.
1500 - 2000 ppm	Very poor air quality	Discomfort, fatigue, headache, urgent ventilation is recommended.
>2000 ppm	Hazardous air quality	Risk of serious problems such as dizziness, nausea, breathing problems.

Table 3 Categories of carbon dioxide levels in outdoor areas

CO_2 level (ppm)	Air quality category	
< 350 ppm	High quality air	Low pollution levels, naturally clean air.
350 ppm - 450 ppm	Moderate air quality	Moderate air pollution. Increased levels of dust, particles or gases.
>450 ppm	Poor air quality	Heavily polluted air, high pollution levels.

During the implementation of the project, several different education and activities were organized with the students in order to better familiarize them with the topic. GLOBE workshops were conducted through the project for gifted students of the Ministry of Science and Education "GLOBE Development Center", from which the instruments used in this research project were financed.

Data visualization and data analysis
Figures 2 to 10 graphically show the measured carbon dioxide values in four school areas (geography classroom, school hall, school kitchen and school gym) in which student measurements were taken. The measurements were taken on ten school days during September 2024 and February 2025. In September, measurements were taken from 9 to 13 and from 16 to 20 September 2024. In February, measurements were taken from 3 to 7 and from 10 to 14 February 2025. The measurement time is from 8:00 to 14:00, every full hour. 70 measurements were taken in each school area. The measured carbon dioxide values are shown in line diagrams and tables. The graphs show seven different colored lines (blue, orange, dark green, light blue, purple, light green, and dark blue) showing measured values from 8:00 a.m. to 2:00 p.m. measured every full hour. The tables show data on measured carbon dioxide values that affect air quality. Different colors show air quality categories: green - very good air quality, yellow - good air quality, orange - acceptable air quality, red - poor air quality, blue - very poor air quality, and purple - hazardous air quality.

Figures 2 and 3 graphically show the measured carbon dioxide values in the geography classroom. The volume of the classroom is 630 m3, and there are windows along the entire length of the eastern side. There is no ventilation system or potted plants in the classroom, and airing depends on the students and the teacher. During the colder part of the year, the classroom is heated by a central heating system. Every 45 minutes, students rotate according to the school schedule. Figure 2 shows the measured carbon dioxide values in September 2024, and Figure 3 in February 2025. Table 4 shows a comparison of the obtained summer/winter data and the average value per hour in the geography classroom.

The graph in Figure 2 shows the data for September 2024. The measured carbon dioxide values in the geography classroom show the lowest value of 463 ppm, and the highest measured value is 1890 ppm. Very good air quality was not measured, good air quality was measured 25 times, acceptable air quality was measured 20 times, poor air quality was measured 19 times, very poor air quality was measured 6 times, and hazardous levels were not recorded.

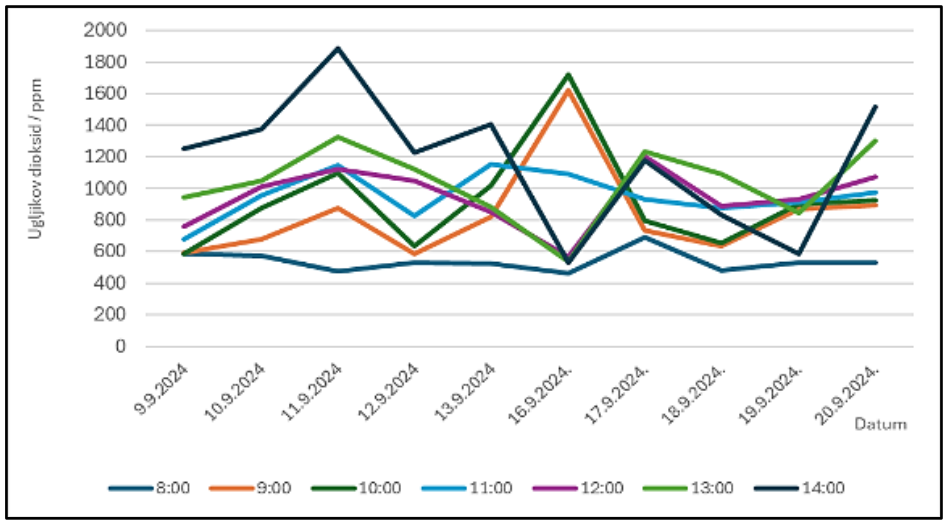

Figure 2 Graphical representation of carbon dioxide values in a geography classroom, September 2024

The graph in Figure 3 shows the data for February 2025. The measured carbon dioxide values in the geography classroom show a minimum value of 492 ppm, and a maximum value of 2502 ppm. Very good air quality was not measured, good air quality was measured 17 times, acceptable air quality was measured 5 times, poor air quality was measured 28 times, very poor air quality was measured 18 times, and hazardous levels were recorded 2 times.

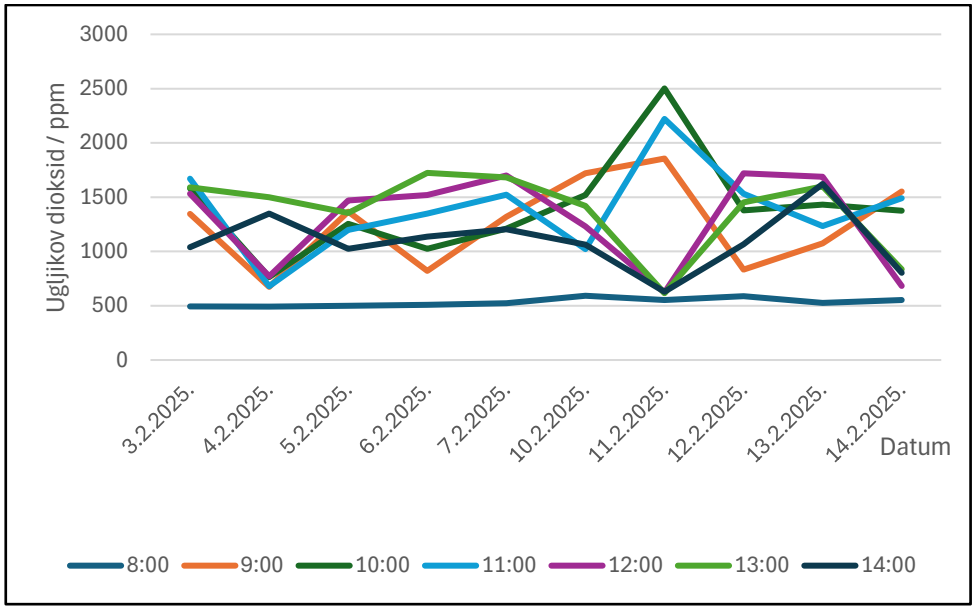

Figure 3 Graphical representation of carbon dioxide values in a geography classroom, February 2025

Table 4 Comparison of summer/winter data and mean hourly carbon dioxide levels in the geography classroom.

Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima
8:00	8:00	9:00	9:00	10:00	10:00	11:00	11:00	12:00	12:00	13:00	13:00	14:00	14:00
587	493	590	1345	583	1582	678	1670	756	1532	945	1590	1250	1040
574	492	680	674	873	764	956	680	1010	770	1046	1500	1378	1350
476	501	875	1366	1100	1255	1145	1200	1122	1470	1328	1354	1890	1025
530	510	589	820	635	1025	826	1350	1046	1520	1123	1724	1225	1137
523	522	823	1320	1018	1210	1152	1524	850	1701	879	1682	1409	1205
463	592	1623	1720	1721	1520	1089	1023	567	1230	538	1420	528	1063
690	552	731	1856	798	2502	930	2221	1200	622	1231	615	1180	629
479	589	638	832	656	1378	874	1531	891	1720	1092	1452	830	1066
528	527	871	1076	902	1432	912	1235	931	1689	844	1599	583	1622
531	553	895	1552	928	1374	974	1489	1074	682	1299	836	1520	802
538	**533**	**831**	**1256**	**921**	**1404**	**954**	**1392**	**945**	**1293**	**1032**	**1377**	**1179**	**1093**

Color legend: 350 - 450 ppm, very good air quality - green color, 450 - 800 ppm, good air quality - yellow color, 800 - 1000 ppm, acceptable air quality - orange color, 1000 - 1500 ppm, poor air quality - red color, 1500 - 2000 ppm, very poor air quality - blue color, 2000+ ppm, hazardous quality - purple color.

By comparing the collected data, the concentration of carbon dioxide during the day in the geography classroom varies significantly, and these differences depend on the time of day and the season summer/winter. At 8:00, carbon dioxide levels are relatively low and the same in both periods. From the obtained data, it can be concluded that the geography classroom is aired in the morning hours, before the students enter the room. From 9:00 to 13:00, there is a significant increase in the concentration of carbon dioxide, and the differences between summer and winter become increasingly pronounced. In winter, the values reach a critical level of more than 2000 ppm, which indicates dangerous air quality. This shows that in the winter months, a larger number of students, with frequently closed windows and poorer air circulation, negatively affect the air quality in the classroom. At 14:00, a decrease in carbon dioxide levels is observed, however, winter values are in some

cases very high, while summer values are somewhat lower. This indicates that in winter, the space between shifts is aired less.

Figures 4 and 5 graphically show the measured carbon dioxide values in the school hall. The volume of the school hall is 2204 m3, and most of the space is open to the height of the second floor. The space has large entrance doors and corridors with windows. Potted plants are placed in several places. In the winter, the school hall is heated by central heating, with the system temperature set to lower values. There is no built-in ventilation system in the hall, and airing depends on the school's technical staff and teachers. Figure 4 shows the measured values in September 2024, and Figure 5 shows the measured values in February 2025. Table 5 shows a comparison of the obtained data summer/winter and the average value per hour in the school hall.

The graph in Figure 4 shows data for September 2024. The measured carbon dioxide values in the school hall show a minimum value of 429 ppm, and a maximum value of 692 ppm. Very good air quality was measured 1 time, good air quality was measured 69 times, acceptable air quality was not measured, poor air quality was not measured, very poor air quality was not measured, and hazardous levels were not measured.

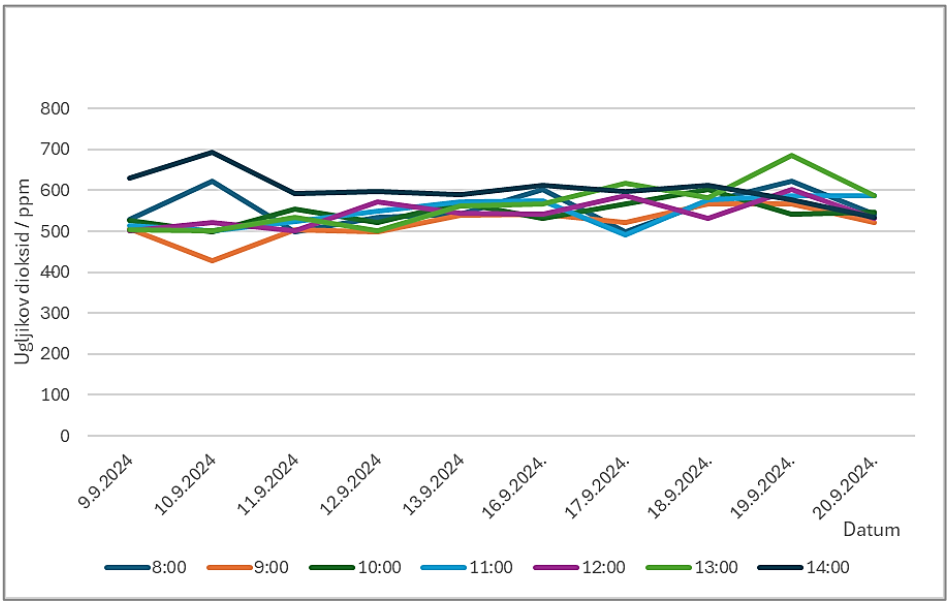

Figure 4 Graphical representation of carbon dioxide values in the school hall, September 2024

The graph in Figure 5 shows the data for February 2025. The measured carbon dioxide values in the school hall show a minimum value of 503 ppm, and a maximum value of 871 ppm. Very good air quality was not measured, good air quality was measured 68 times, acceptable air quality was measured 2 times, poor air quality was not measured, very poor air quality was not measured, and hazardous levels were not measured.

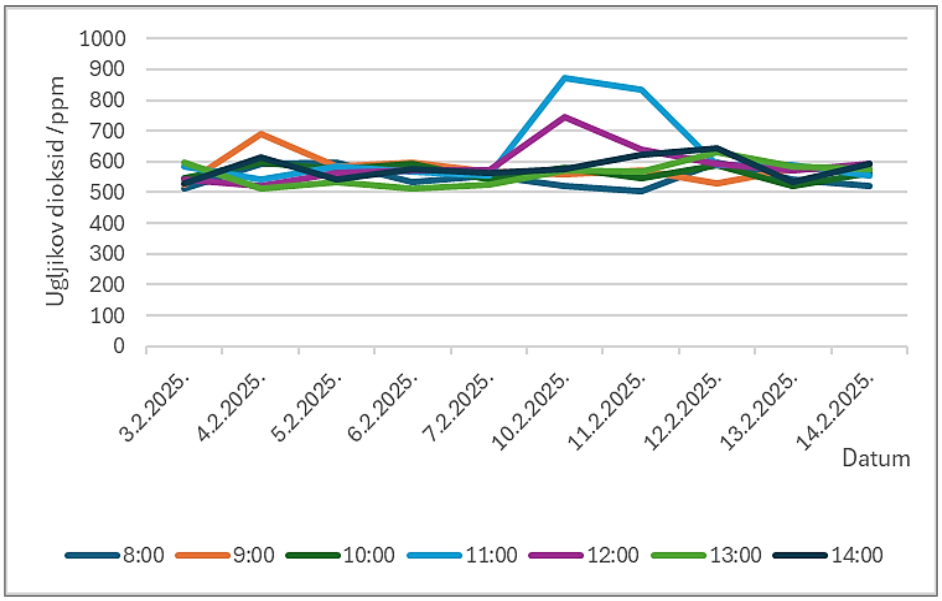

Figure 5 Graphical representation of carbon dioxide valuesin the school hall, February 2025

Table 5 Comparison of obtained summer/winter data and mean hourly carbon dioxide levels in the school hall.

Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima
8:00	8:00	9:00	9:00	10:00	10:00	11:00	11:00	12:00	12:00	13:00	13:00	14:00	14:00
529	513	506	526	526	546	513	583	502	542	504	599	629	529
621	591	429	689	499	599	502	542	521	521	501	512	692	612
498	598	504	584	555	575	524	584	502	562	533	533	591	541
533	533	498	598	522	592	548	568	572	572	501	511	598	578
542	553	538	567	569	542	571	556	544	571	561	527	589	563
603	522	541	558	532	579	574	871	541	744	566	571	612	575
499	503	521	571	568	548	491	832	587	641	618	567	598	622
572	599	566	531	601	588	578	587	532	591	581	632	612	642
622	542	566	576	542	521	586	588	601	572	685	584	578	532
542	522	521	576	547	562	588	556	532	591	587	575	533	592
556	**547**	**519**	**577**	**546**	**565**	**547**	**626**	**543**	**590**	**563**	**561**	**603**	**578**

Color legend: 350 - 450 ppm, very good air quality - green color, 450 - 800 ppm, good air quality - yellow color, 800 - 1000 ppm, acceptable air quality - orange color, 1000 - 1500 ppm, poor air quality - red color, 1500 - 2000 ppm, very poor air quality - blue color, 2000+ ppm, hazardous quality - purple color.

By comparing the collected data, the concentration of carbon dioxide during the day in the school hall is stable. During all observed hours, the values generally remain within the range of good to acceptable air quality. At 8:00, carbon dioxide concentrations are similar in both summer and winter. Summer values range between 498 and 621 ppm, while in winter they are almost the same or only slightly higher. In the morning, the school hall is well ventilated and students enter the school. From 9:00 to 12:00, carbon dioxide levels increase slightly, but are still at the level of good air quality. A slightly greater increase is recorded in winter, at 11:00, where some values reach 871 ppm. This is due to the larger number of students in the school hall during the colder part of the year when it rains and air circulation is weaker due to closed windows and doors. In the afternoon, from 13:00 to 14:00, the level of carbon dioxide increases slightly, especially in winter, but the values remain within the good air quality. The reason for this is the change of students from the first and second shifts.

Figures 6 and 7 graphically show the measured carbon dioxide values in the school kitchen. The volume of the school kitchen is 48 m3. The school kitchen was created by converting a former hallway. It is equipped with a ventilation system, while airing depends on the school's technical staff. A large gas stove and two ovens are used in the kitchen for preparing meals. Figure 6 shows the measured carbon dioxide values in September 2024, and Figure 7 in February 2025. Table 6 shows a comparison of the obtained data summer/winter and the average value per hour in the school kitchen.

The graph in Figure 6 shows the data for September 2024. The measured carbon dioxide values in the school kitchen show the lowest value of 499 ppm, and the highest measured value is 2521 ppm. Very good air quality was not measured, good air quality was measured 20 times, acceptable air quality was measured 12 times, poor air quality was measured 11 times, very poor air quality was measured 13 times and hazardous levels were measured 14 times.

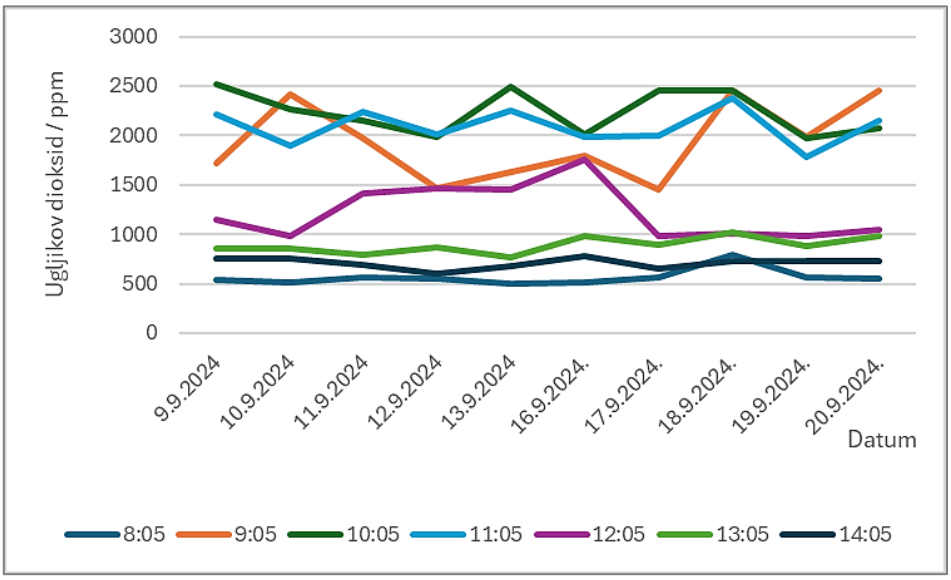

Figure 6 Graphical representation of carbon dioxide values in the school kitchen, September 2024

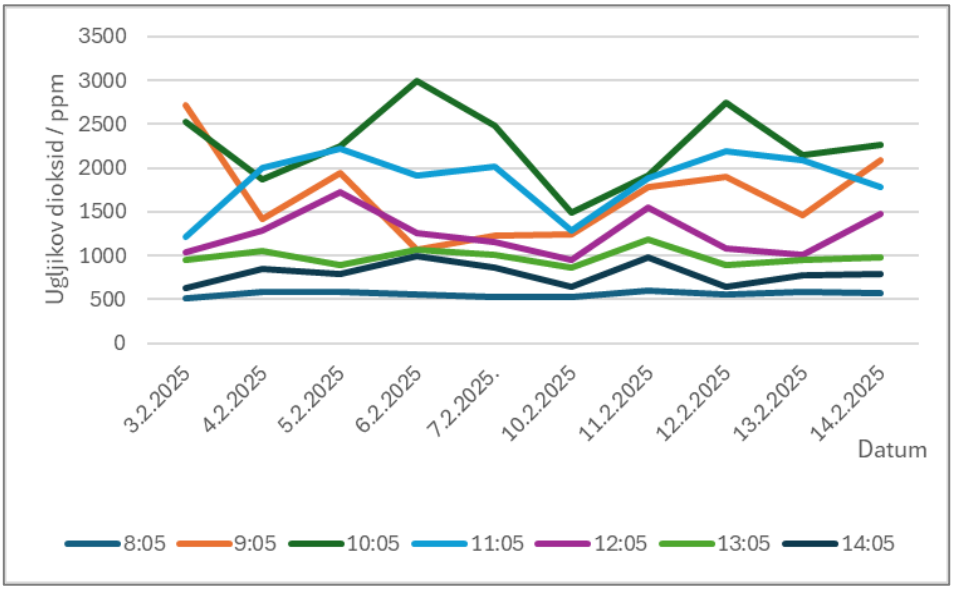

Figure 7 Graphical representation of carbon dioxide values in the school kitchen, February 2025

Table 6 Comparison of summer/winter data and mean hourly carbon dioxide levels in the school kitchen.

Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima
8:00	8:00	9:00	9:00	10:00	10:00	11:00	11:00	12:00	12:00	13:00	13:00	14:00	14:00
542	516	1721	2721	2521	2531	2210	1210	1142	1042	854	954	752	635
508	588	2413	1413	2265	1865	1899	1999	986	1286	856	1056	754	854
563	583	1978	1948	2147	2247	2245	2214	1420	1720	789	889	687	787
547	556	1465	1065	1985	2985	1998	1912	1462	1250	863	1063	598	998
499	523	1635	1223	2487	2480	2256	2020	1447	1147	765	1002	678	862
509	529	1789	1235	2008	1487	1985	1286	1752	947	978	865	785	648
568	599	1457	1788	2456	2009	2004	1885	987	1552	896	1178	654	985
788	558	1458	1897	1451	2745	1879	2184	1002	1087	1015	886	724	644
563	578	1985	1454	1968	2151	1785	2084	978	1002	875	955	732	774
548	563	2452	2085	2078	2258	2145	1785	1050	1478	987	975	724	789
563	569	1835	1682	2136	2265	2042	1857	1222	1251	887	982	708	797

Color legend: 350 - 450 ppm, very good air quality - green color, 450 - 800 ppm, good air quality - yellow color, 800 - 1000 ppm, acceptable air quality - orange color, 1000 - 1500 ppm, poor air quality - red color, 1500 - 2000 ppm, very poor air quality - blue color, 2000+ ppm, hazardous quality - purple color.

By comparing the collected data, the concentration of carbon dioxide during the day in the school kitchen varies significantly, and these differences depend on the time of day and the season summer/winter. In the period from 8:00 to 9:00, carbon dioxide values are generally lower and similar between summer and winter. During this part of the day, the room is freshly aired and meal preparation is just beginning. The values are below 800 ppm, which indicates good air quality. However, as the day progresses, the concentration of carbon dioxide increases, with the highest values measured between 10:00 and 12:00. Extreme values were recorded during these hours, especially during the winter period. At 10:00 in winter, a value of as much as 2985 ppm was recorded, which indicates a dangerous level. In summer, the values are also high at this time, but slightly lower compared to winter. During the summer months, there is a greater possibility of airing the room due to more favorable weather conditions and open windows. In the afternoon, from 1:00 PM to 2:00 PM, carbon dioxide levels drop but are still slightly higher in winter. During this period, the cooking process in the kitchen is completed.

Figures 8 and 9 graphically show the measured carbon dioxide values in the school gym. The volume of the school gym is 3304 m3. The windows are placed against the ceiling on the north and south sides along the entire length of the wall. Airing is enabled throughout the year because the windows are always open, except during heavy rain or strong winds. There is no ventilation system installed in the gym. Figure 8 shows the measured carbon dioxide values in September 2024, and Figure 9 in February 2025. Table 7 shows a comparison of the obtained data summer/winter and the average value per hour in the school gym.

The graph in Figure 8 shows the data for September 2024. The measured carbon dioxide values in the school gym show the lowest value of 406 ppm, and the highest measured value is 648 ppm. Very good air quality was measured 1 time, good air quality was measured 69 times, acceptable air quality was not measured, poor air quality was not measured, very poor air quality was not measured and hazardous levels were not measured.

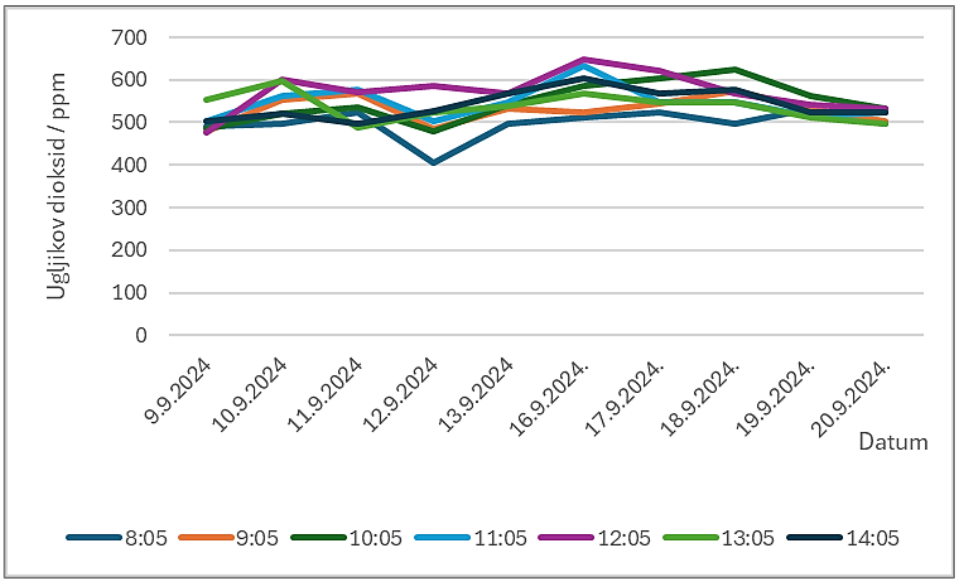

Figure 8 Graphical representation of carbon dioxide values in a school gymnasium, September 2024

The graph in Figure 9 shows data for February 2025. The measured carbon dioxide values in the school gym show a minimum value of 451 ppm and a maximum value of 698 ppm. Very good air quality was not measured, good air quality was measured 70 times, acceptable air quality was not measured, poor air quality was not measured, very poor air quality was not measured and hazardous levels were not measured.

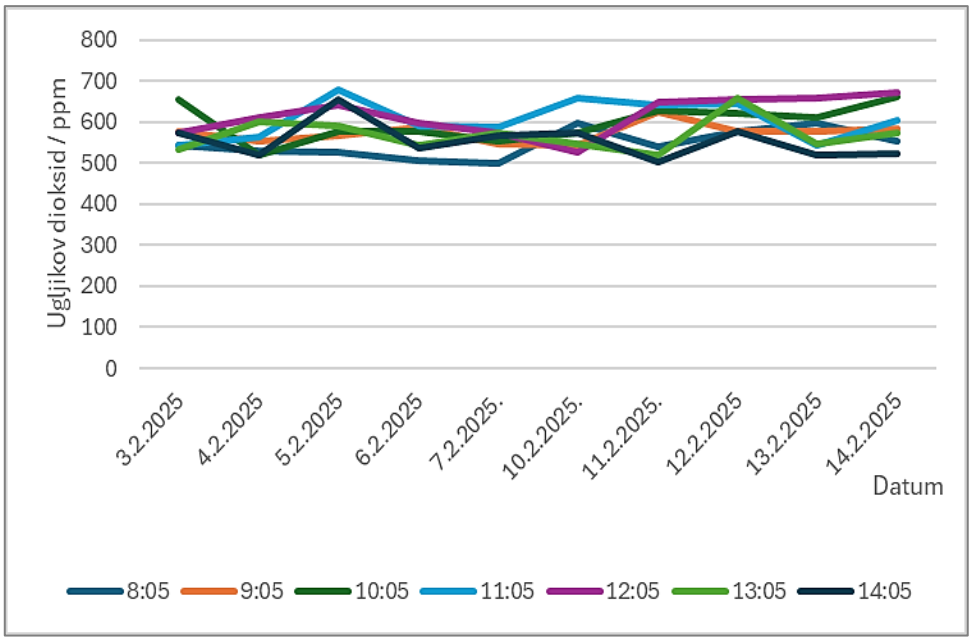

Figure 9 Graphical representation of carbon dioxide values in a school gymnasium, February 2025

Table 6 Comparison of summer/winter data and mean hourly carbon dioxide levels in the school gymnasium

Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima	Ljeto	Zima
8:00	8:00	9:00	9:00	10:00	10:00	11:00	11:00	12:00	12:00	13:00	13:00	14:00	14:00
492	542	478	578	485	655	502	542	475	575	552	532	503	573

498	528	552	552	521	521	563	563	602	612	599	599	521	521
525	525	567	567	536	576	578	678	572	642	489	589	496	656
406	506	486	586	478	578	502	592	587	597	523	543	526	536
498	498	532	548	542	553	547	587	567	572	538	574	568	568
511	598	523	542	586	572	632	657	648	527	568	548	603	575
523	541	544	623	604	626	548	642	622	648	548	518	568	503
498	578	574	578	625	622	547	645	568	654	547	658	578	578
532	598	532	578	562	612	514	542	542	658	512	547	523	518
496	552	504	582	532	662	524	604	533	672	496	572	524	523
497	546	529	573	547	597	545	605	571	615	537	568	541	555

Color legend: 350 - 450 ppm, very good air quality - green color, 450 - 800 ppm, good air quality - yellow color, 800 - 1000 ppm, acceptable air quality - orange color, 1000 - 1500 ppm, poor air quality - red color, 1500 - 2000 ppm, very poor air quality - blue color, 2000+ ppm, hazardous quality - purple color.

Comparing the air quality data in the school gym for September 2024 and February 2025, the measured carbon dioxide values are stable throughout the school day, in both seasons. At 8:00 a.m., carbon dioxide levels are relatively low in both periods. Summer values range between 406 and 532 ppm, while winter values are slightly higher, but within the limits of good air quality. This indicates a fresh and well-ventilated space before the start of classes. Between 9:00 a.m. and 2:00 p.m., carbon dioxide values in both periods remain within the limits of good air quality, with slightly higher winter values. The general slight increase in carbon dioxide concentrations in February is due to weather conditions and reduced ventilation.

The Intensive Observation Period (IOP) of carbon dioxide concentration in the geography classroom was conducted in September (summer) over 2 days. The measurement time was 23 and 24 September 2024 from 8:00 to 14:00, every half hour. The first day was without ventilation and airing, and the second day was with constant airing (all windows and doors of the classroom open) and ventilation of the classroom. During the intensive measurement, the number of people in the classroom was 25. Figure 10 shows the measured carbon dioxide values during the intensive measurement period.

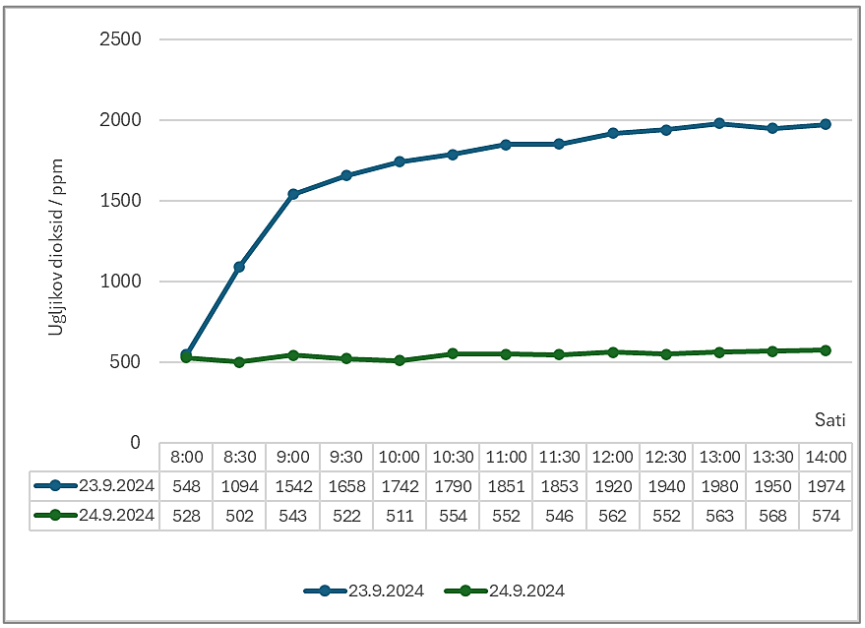

Figure 10 Period of intensive measurement of carbon dioxide concentration in the geography classroom, September 23 and 24, 2024

The data shown in the graph shows that the carbon dioxide concentration on September 23, 2024 ranged from a low of 548 ppm at 8:00 a.m. to a high of 1974 ppm at 2:00 p.m. A steady increase in carbon dioxide concentration was observed throughout the day, indicating an increase in carbon dioxide in the classroom. The values exceeded the recommended levels, indicating poor air quality.
On September 24, 2024, the carbon dioxide concentration ranged from a low of 528 ppm at 8:00 a.m. to a high of 574 ppm at 2:00 p.m. During the measurement, the carbon dioxide concentration was maintained at a low and stable level. The values remained within the recommended levels, indicating good air quality. Analysis of the carbon dioxide concentration data in the geography classroom during two days of intensive measurement shows the important influence of aeration and ventilation on indoor air quality.

Figure 11 shows a graphic representation of the measured carbon dioxide values in Vruljica Park on February 17, 2025. The measurement time is from 8:00 to 14:00, every 30 minutes. The measurements were carried out at the GLOBE biometric station Vruljica Park in the part of the park where the Aleppo pine forest predominates. The park is surrounded by a public road and built-up facilities.

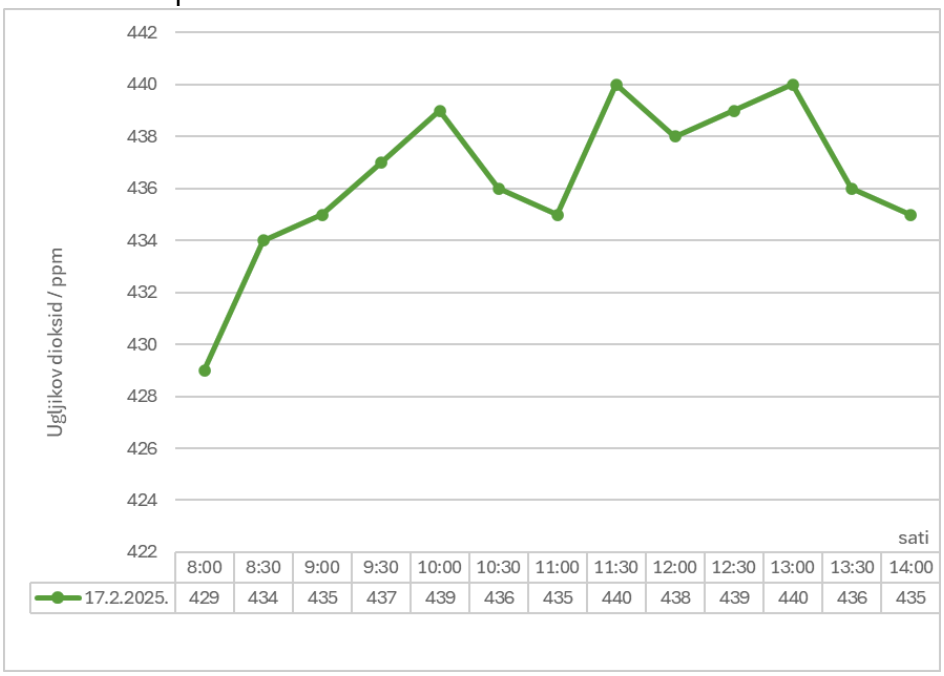

Figure 11 Measured carbon dioxide values in Vruljica Park, February 17, 2025

The graph in Figure 11 shows the measured data in Vruljica Park. The measured carbon dioxide values show the lowest value of 429 ppm, and the highest measured value is 435 ppm. According to the carbon dioxide level categories for open space, the air in the park is moderately polluted because all measured values are between 350 ppm and 450 ppm. The air is slightly polluted, and the measured carbon dioxide concentration is within the limits for open space.

Discussion and conclusions

Carbon dioxide is important for natural processes such as photosynthesis and maintaining temperature on Earth. Elevated levels affect poor air quality and human health. It is important to monitor carbon dioxide levels in closed spaces such as kindergartens and schools, because children spend a large part of the day there, and high concentrations can negatively affect their health.

Research conducted on school premises (classroom, school hallway, school kitchen and school hall) showed large differences in carbon dioxide levels. The differences depend on airing, ventilation, the presence of people, human activities and the presence of plants in the space. The highest carbon dioxide values were recorded in the school kitchen during meal preparation, when several gas stoves are used simultaneously. The school kitchen is a small area in which there is a ventilation system and the possibility of airing. However, the technical staff does not carry out these measures sufficiently. An intensive measurement period was carried out in the geography classroom over two days, one without airing and the other with airing and ventilation. The results obtained showed that airing and ventilation significantly reduce the level of carbon dioxide in the space. These results should raise awareness among students, teachers and technical staff about the importance of airing of the space in which they are located. The lowest values were recorded in the school hall. The school hall and the school gym are large areas with good air flow, which contributes to maintaining a lower concentration of carbon dioxide. Regular ventilation, as well as the presence of plants in the hall, further improve air quality. Therefore, the presence and activities of students in these areas did not significantly affect the increase in carbon dioxide levels.

Measurements in Vruljica Park showed a moderate level of air pollution, with measured carbon dioxide values ranging from 350 to 450 ppm. The air is slightly polluted, and the measured carbon dioxide concentration is within the limit values for open space. Built structures, traffic and human activities affect the increase in carbon dioxide levels in the city park. However, green areas in cities are important in reducing carbon dioxide levels and improving air quality. Plants use carbon dioxide from the air during the process of photosynthesis and produce oxygen, thereby reducing the concentration of this gas in the atmosphere. Therefore, it is important to plant plants in settlements because this way air quality improves.
By processing and analyzing the data obtained during the research, we reached the following conclusions:

- Indoor carbon dioxide concentration is variable: The study showed significant differences in carbon dioxide levels in different school areas, which are influenced by the presence of people, human activities, airing, ventilation and the presence of plants in the area.

- Airing and ventilation systems are important for reducing carbon dioxide concentrations: Intensive classroom measurements confirmed that airing and ventilation significantly reduce carbon dioxide levels. This highlights the importance of regular airing of indoor spaces. A comparison of data obtained during the winter and summer months confirms this claim. During the winter months, when windows are more often closed due to low air temperatures, carbon dioxide concentrations are higher. Conversely, during the summer months, when windows are more often open due to higher air temperatures, carbon dioxide concentrations are lower.

- Human activities affect indoor carbon dioxide levels:The highest levels of carbon dioxide were recorded in the school kitchen during meal preparation. This indicates the influence of human activities on indoor carbon dioxide concentrations.

- Green spaces improve air quality: Measurements in Vruljica Park showed lower values of carbon dioxide concentration in the air. This shows the impact of green spaces on reducing carbon dioxide concentration and improving air quality in settlements.

We confirmed the hypotheses:

- The concentration of carbon dioxide in the air is highest in the classroom during classes due to poor ventilation and in the kitchen during meal preparation. The school hall and the school gym have lower values of carbon dioxide concentration in the air due to larger space and better airing of the space.

- The concentration of carbon dioxide on school premises is higher during the winter compared to the summer due to frequently closed windows and lower flow of fresh air.

- Well-aired premises have lower concentrations of carbon dioxide compared to those where airing and ventilation are irregular or inadequate.

Based on the results obtained in this study, the student recommendation is that indoor spaces should be aired as often as possible, devices for measuring air quality should be installed in all school premises, as well as ventilation systems or air purification devices. Also, pots with plants should be placed in school premises that will reduce carbon dioxide concentration and improve air quality. In this way, the school will create a more comfortable and healthier space for students and teachers.

Literature and sources:

1. Ambient (outdoor) air pollution, https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health, approach February 10, 2025
2. Johnson D., 2010. Climate change and schools,https://www.se-2.co.uk/files/se2/uploads/Carbon%20Management%20Strategy_As%20published.pdf, approach January 18, 2025.
3. Earth System Data Explorer, https://larc-mynasadata-2df7cce0.projects.earthengine.app/view/earth-system-data-explorer, approach January 15, 2025
4. Energetika i okoliš, https://enerpedia.net/index.php/ENERGETIKA_I_OKOLI%C5%A0#Efekt_staklenika, approach March 24, 2025
5. GLOBE priručnik za mjerenja – Istraživanje atmosfere https://www.globe.gov/documents/10157/36350278/atmosfera.PDF/431e60c6-cb5a-4dbb-a5f7-589c3752205b, approach March 24, 2025
6. Household air pollution, https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health, approach February 10, 2025
7. Hrvatska enciklopedija, Ugljikov dioksid, https://www.enciklopedija.hr/clanak/ugljikov-dioksid, approach January 18, 2025.
8. Smanjenje emisija ugljičnih plinova: ciljevi i mjere EU-a, https://www.europarl.europa.eu/topics/hr/article/20180305STO99003/smanjenje-emisija-ugljicnih-plinova-ciljevi-i-mjere-eu-a, approach January 18, 2025.