PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

ESTUDO DAS MUDANÇAS NA CONCENTRAÇÃO DE VÁRIOS POLUENTES CAUSADAS POR FATORES ANTROPOGÊNICOS NO AR ATMOSFÉRICO (ESTUDO DE CASO)

STUDY OF CHANGES IN CONCENTRATION OF VARIOUS POLLUTANTS CAUSED BY ANTHROPOGENIC FACTORS IN ATMOSPHERIC AIR (CASE STUDY)

ანთროპოგენური ფაქტორებით გამოწვეული ატმოსფერული ჰაერის სხვადასხვა დამაბინძურებლების კონცენტრაციის ცვლილების კვლევა (კონკრეტული შემთხვევები)

Ketevan Kupatadze *
Ilia State University, Faculty of Natural Science and Medicine, Georgia

Tamari Edisherashvili
Ilia State University, Faculty of Natural Science and Medicine, Georgia

* *Corresponding author*
e-mail: ketevan_kupatadze@iliauni.edu.ge

Received 12 May 2025; received in revised form 09 June 2025; accepted 18 July 2025

RESUMO

Introdução: Um dos principais desafios ambientais globais é a poluição do ar atmosférico. Consequentemente, houve um aumento preocupante na incidência de doenças pulmonares e respiratórias em todo o mundo. É fundamental reconhecer que os poluentes primários liberados na atmosfera podem passar por uma série de reações químicas secundárias e terciárias influenciadas por vários fatores ambientais. **Objetivos**: O artigo apresentado é uma revisão da pesquisa realizada sobre mudanças na qualidade do ar durante protestos sociais, feriados ou eventos naturais na capital georgiana em 2023-2024. **Métodos**: A pesquisa foi realizada por meio de sensores instalados em diferentes distritos de Tbilisi. A investigação foi realizada dentro do projeto do programa NATO SPS REACT. **Resultados**: A poluição do ar atmosférico foi monitorada em quatro conjuntos de sensores estacionários nas Avenidas K. Cholokashvili, Rua Nutsubidze, Avenida Chavchavadze e na área da Velha Tbilisi. Foi investigada a mudança na qualidade do ar devido à queima de fogos de artifício e ao terremoto ocorrido. Os resultados são apresentados no artigo em forma de tabelas. **Discussão**: A concentração de todos os poluentes primários aumenta drasticamente em face da atividade antropogênica. A concentração de material particulado aumenta no período anterior ao terremoto. **Conclusões**: O Estudo de Caso comprovou a grande influência dos fatores antropogênicos e fenômenos naturais no aumento da concentração de poluentes no ar atmosférico.

Palavras-chave: .

ABSTRACT

Background: One of the major global environmental challenges is atmospheric air pollution. Consequently, there has been a concerning increase in the incidence of pulmonary and respiratory diseases worldwide. It is critical to recognize that primary pollutants released into the atmosphere can undergo a series of secondary and tertiary chemical reactions influenced by various environmental factors. **Aims**: The presented paper is a review of the research conducted on changes in air quality during social protests, holidays, or natural events in the Georgian capital in 2023-2024. Methods: The research was carried out through sensors installed in different districts of Tbilisi. The investigation was carried out within the NATO SPS program project REACT. **Results**: Atmospheric air pollution was monitored at four stationary sensor sets on K. Cholokashvili, Nutsubidze Street, Chavchavadze Avenues, and the Old Tbilisi area. The change in air quality due to the shooting of fireworks and the earthquake that occurred was investigated. The results are presented in the article in the form of tables. **Discussion**: The concentration of all primary pollutants increases sharply against the background of anthropogenic activity. The concentration of particulate matter increases in the period leading up to the earthquake. **Conclusions**: The Case Study proved the great influence of anthropogenic factors and Natural phenomena on increasing the concentration of pollutants in the atmospheric air.

Keywords: *Air monitoring, air pollution, pollutant agents, social events, natural events.*

რეზიუმე

შესავალი: ატმოსფერული ჰაერის დაბინძურება თანამედროვე მსოფლიოს ერთ-ერთ უმნიშვნელოვანეს ეკოლოგიურ გამოწვევად რჩება. ამ ფონზე, საგრძნობლად იზრდება სასუნთქი გზების და ფილტვის დაავადებების გავრცელება. მნიშვნელოვანია იმის გააზრება, რომ ატმოსფეროში წარმოქმნილი პირველადი დაბინძურებლები შეიძლება გარემო ფაქტორების გავლენით ჩაერთოს მეორეულ და მესამეულ ქიმიურ რეაქციებში, რაც კიდევ უფრო ამძაფრებს ეკოლოგიური ზემოქმედების მასშტაბს. **მიზანი**: წარმოდგენილი ნაშრომი მიმოიხილავს 2023-2024 წლებში თბილისის ტერიტორიაზე სოციალური პროტესტების, დღესასწაულებისა და ბუნებრივი მოვლენების დროს ატმოსფერული ჰაერის ხარისხში დაფიქსირებულ ცვლილებებს. **მეთოდები**: კვლევა ჩატარდა ქალაქ თბილისის სხვადასხვა უბანში განთავსებული სენსორების მეშვეობით. კვლევა განხორციელდა ნატოს პროგრამის – მეცნიერება მშვიდობისა და უსაფრთხოებისთვის – დაფინანსებით, REACT პროექტის ფარგლებში. **შედეგები**: ატმოსფერული ჰაერის დაბინძურების მონიტორინგი განხორციელდა ოთხ ლოკაციაზე განთავსებული სენსორების მეშვეობით: ჩოლოყაშვილის გამზირზე, ნუცუბიძის ქუჩაზე, ჭავჭავაძის გამზირსა და ძველი თბილისის ტერიტორიაზე. შეფასდა ჰაერის ხარისხში ცვლილებები ფოიერვერკების გამოყენებისა და მიწისძვრის დროს. მიღებული შედეგები წარმოდგენილია ცხრილების სახით. **დისკუსია**: ადამიანის საქმიანობის გააქტიურების ფონზე პირველადი დამაბინძურებლების კონცენტრაცია მკვეთრად იზრდება. შეწონილი ნაწილაკების (PM) მაჩვენებლების მატება დაფიქსირდა მიწისძვრამდე პერიოდში, რაც შესაძლოა განხილულ იქნეს, როგორც ერთგვარი წინასწარი ინდიკატორი. **დასკვნა**: განხილული შემთხვევების შესწავლამ ცხადყო როგორც ანთროპოგენური, ისე ბუნებრივი ფაქტორების მნიშვნელოვანი გავლენა ატმოსფერულ ჰაერში დამაბინძურებელი ნივთიერებების კონცენტრაციის ზრდაზე.

საკვანძო სიტყვები: *ჰაერის მონიტორინგი, ჰაერის დაბინძურება, დამაბინძურებელი აგენტები, სოციალური აქტივობა, ბუნებრივი მოვლენა.*

1. INTRODUCTION:

One of the major global environmental challenges is atmospheric air pollution. Consequently, there has been a concerning increase in the incidence of pulmonary and respiratory diseases worldwide (Kampa, 2008; Vallero, 2014).

It is critical to recognize that primary pollutants released into the atmosphere can undergo a series of secondary and tertiary chemical reactions influenced by various environmental factors. These reactions result in the formation of secondary and tertiary pollutants, which exhibit significantly greater atmospheric persistence compared to primary pollutants. Additionally, free radicals are generated during this process, which can further participate in diverse chemical reactions, contributing to the complexity and persistence of pollution (VanLoon, 2011; Williams, 2012).

Unfortunately, it is not always feasible to measure all types of pollutants during the planning phase of a study. Therefore, the investigation of primary pollutants allows us to infer the potential formation of secondary and tertiary pollutants that may arise as a result of photochemical reactions.

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These gases are subject to a certain thermodynamic equilibrium in the atmosphere. Theoretically, ammonia (NH_3) preferentially reacts with sulfur dioxide (SO_2), forming ammonium sulfate, which is stable in the atmosphere. Excess NH_3, however, reacts with nitrogen dioxide (NO_2), which, under humid conditions, forms nitric acid, leading to the formation of ammonium nitrate. Ammonium nitrate is less stable, and its formation depends on the relative abundance of NH_3 and NO_2. Consequently, a reduction in SO_2 emissions leaves more NH_3 available for ammonium nitrate formation and may also disrupt the balance between NH_3 and nitrogen dioxide (XU, 2020; Stewart, Saunders, 2019; Davide, 2018; Piga, 2009).

Measuring the concentration of particulate matter (PM) across all three size fractions is also important. Their composition may vary and is influenced by the intensity and nature of anthropogenic activities (Baldauf, 2008; Stefan, 2020).

An increase in the concentration and persistence of particulate matter (PM) in the air has been identified as one of the contributing factors to antibiotic resistance, an escalating global issue responsible for the deaths of millions of people each year (Solomon. 2008).

The composition of aerosols formed by PM particles is highly diverse (Zhenchao. 2023; Zinicovscaia. 2017).

In most cases, the emission of primary pollutants into the environment is driven by anthropogenic activities.

A particular scientific interest is the pollution associated with socially driven events. This study specifically focuses on such instances, examining the variations in pollutant concentrations during the use of pyrotechnics in public celebrations or protests, as well as the atmospheric response to natural phenomena such as earthquakes.

As part of the NATO SPS program REACT, four sets of sensors were installed in four central districts of Tbilisi to monitor air pollutants and study their changes depending on various events (Figure 1).

2. MATERIALS AND METHODS:

2.1. Materials

Atmospheric air pollutant observations were conducted continuously, with a focus on two specific case studies: monitoring sensitivity during localized mass events and during natural cataclysms (Kelly, 2017; Kupatadze, 2022; Karthik, 2020).

The monitoring system was based on a set of high-precision sensors and data logging infrastructure with the following components:

- **MicroMET3 multichannel datalogger (8 channels)**, compliant with World Meteorological Organization (WMO) standards
- **Dual power supply**: 220V AC and a 30W solar panel
- **12Ah buffer battery** for power stability
- **Local data transmission system**
- **Weatherproof IP65 enclosure**
- **Complete mounting kit** (cables, poles, brackets)

Monitored parameters included:

- **Meteorological sensors**: temperature, relative humidity, atmospheric pressure, wind speed, wind direction
- **Gas sensors**: sulfur dioxide (SO_2) and nitrogen dioxide (NO_2)
- **Particulate matter sensors**: PM_{10}, $PM_{2.5}$, and PM_1
- **Phonometer**: ambient noise levels

Sensor Calibration

Prior to deployment, all sensors underwent a two-step calibration process:

Factory Calibration: The sensors were initially calibrated by the manufacturer to ISO/IEC 17025 standards.

On-site Verification: Upon installation, gas and particulate sensors were co-located with a government-certified air quality monitoring station for 48 hours. Measured values were compared and adjusted using correction factors derived from linear regression analysis to ensure consistency with reference-grade instruments.

Meteorological sensors were verified using handheld calibrated instruments, and adjustments were made when discrepancies exceeded ±2% of standard values.

Calibration checks were performed monthly, and any sensor drift exceeding the acceptable tolerance prompted recalibration or replacement of the sensor.

Data Collection and Quality Control

Key data acquisition settings included:

- Local SD card data logging in .txt format, at **5-minute intervals**
- **Cumulative daily data files** are generated automatically
- **GSM-based remote transmission** with user-defined frequency settings
- **Desktop web interface** for real-time access and downloadable formats.

To ensure high data quality, the following protocols were implemented:

- **Automated plausibility checks** to flag out-of-range or missing data

- **Cross-validation** of key variables (e.g., temperature, humidity) with nearby meteorological stations
- **Redundant sampling** for selected parameters during peak pollution periods
- **Data smoothing filters** are applied to remove short-term anomalies caused by sensor noise or transmission error
- **Manual review** of flagged data sets every 24 hours

2.2. Methods

Location M187

The sensor is located on the territory of the Scientific Research Institute of Botany. The institute itself is located on top of the so-called old sulfur baths. This area is one of the famous tourist attractions and, therefore, is interesting for research purposes.

Location M188

The Seismology Research Institute, which is also affiliated with Ilia State University, has been selected as one of the locations for the aforementioned sensors. It's worth noting that all sensors are located on the territory of Ilia State University, which makes their protection more reliable. At the same time, these spots are also interesting from a research perspective.

Location M 185

The sensor is located directly next to the main building of Ilia State University, on the side of the road where G. Tsereteli Street meets Cholokashvili Avenue. The traffic is always busy in this area, and aside from the fact that the sensor is well-protected, it is also a critical place for monitoring.

Location M 186

The sensor is located on Chavchavadze Avenue, #32. It is one of the central and busiest areas in Tbilisi, with two large university buildings, cafes, restaurants, and shops. Therefore, it is very interesting from a research perspective.

The following chemical components were the main subjects examined: nitrogen dioxide, sulfur dioxide, PM 1, 2.5, and 10 particles. Meteorological parameters and noise level were also examined. The study was conducted in a case study format.

3. RESULTS AND DISCUSSION:

3.1. Results

The tables with results are presented in the appendix of the article (Tables 1-4).

3.2. Discussion

3.2.1. *Case study #1*: sensitivity during localized mass events

May 26 is Georgia's Independence Day. Preparations begin several days in advance, and the holiday is celebrated with a ceremonial parade, air show, and fireworks (Fig.2)

The main events take place on Rustaveli Avenue and in the historic center of Tbilisi, also known as Old Tbilisi. MM No.187 was installed in Old Tbilisi, and MM No.. 186 and 185 were installed in Vake, along Melikishvili Street, on the northwestern side, opposite Rustaveli Avenue. During the event, environmental sensors recorded several anomalous signals, including an increase in PM10, particularly on the morning of May 25, which reflected increased vehicle traffic and general setup in preparation for the festival. It is worth noting that on May 25, two stations in Vake and Old Tbilisi showed the same increase in PM10 (Table 1). However, on May 25, the signal peaked in Vake in the morning and in Old Tbilisi in the afternoon (Fig.3).

3.2.2. *Case study #2*: Another time when there are massive displays of fireworks is the New Year's Event.

Despite the demands of the majority of the population, the sale of fireworks in bulk is still not prohibited by law. Therefore, New Year's Eve (the night of the 31st of December) is very noisy. And still, physical injuries from gunshot wounds of both adults and young children are recorded annually. Another issue is the fear of noise in homeless animals.

At all four locations, the average data for December 31, 2023, and January 1, 2, 2024, varied as follows (Table 2).

At each location, there is a sharp increase and then a decrease in nitrogen and sulfur dioxide levels. The same can be said for PM particles. It should also be noted that the increase is observed at the dawn of January 1. (i.e., after celebrating and setting off fireworks all night). In the second half of January 2, the number decreases, although in some cases it remains stably elevated.

These data suggest that elevated levels of nitrogen and sulfur dioxide are involved in photochemical reactions to form secondary and tertiary pollutants. The increase in particulate matter is evidence that the metal ions released by fireworks remain stable in ambient air and have an impact on public health (Fig. 4a, b, c; 5a, b, c; 6a, b, c; 7a, b, c,d).

Similar changes were observed on the night of December 31, 2024. A significant increase in PM1 particles was particularly noticeable, posing a serious risk to human respiratory health. By 7:00 AM on January 1, 2025, the PM10 concentration had reached 110 ppm, exceeding the maximum permissible limit of 10 to 20 ppm.

For details on the key parameter variations, see Table #2.

3.2.3. Case Study #3: Sensitivity during a public protest

In Georgia, starting in November 2024, large-scale and prolonged public protests occurred. During these demonstrations, some groups set off fireworks, lit bonfires, and burned various objects. The protests were mainly concentrated in the central part of the city, making the data from sensors installed near these locations particularly interesting (Figs. 8a,b; and 9 a,b).

According to the obtained data (Table 3), primary pollutants have increased significantly, suggesting that secondary pollutants are also likely to rise in the following days.

3.2.4. Case study #4: sensitivity during natural events

The Tbilisi region is geologically active, and earthquakes happen quite frequently. On September 24, 2023, at dawn, two earthquakes occurred in Georgia. The epicenter of one of them was located near Tbilisi. The first earthquake, measuring 4.6 on the Richter scale, occurred at 08:00 local time and was clearly felt in the city. It originated 4 km from Tbilisi, towards the village of Lelubani (Mtskheta municipality), from a depth of 27 km. The earthquake was widely discussed on social networks, especially since many people reported hearing the accompanying noise.

According to the Earth Sciences and National Seismic Monitoring Centre, the epicenter of the earthquake was relatively deep, and characteristic sound waves accompanied its vertical spread.

At this point, all REACT sensors were recording, but none showed significant peaks in noise levels compared to the standard daily trend.

This may have been because the emissions were probably not particularly intense. It is worth noting that at 8:00, some other environmental parameters also changed, namely, the temperature increased and the humidity decreased. The most dramatic change was observed in the area of the Seismological Institute (LCMS No.188). The latter was probably a common occurrence associated with local heat exchange between land and atmosphere after sunrise (at 6:48 AM on September 24). There was also a rapid increase in PM10 levels at all stations, which is relatively difficult to explain.

While direct correlations between increased PM levels and earthquake prediction are not well-established, studies on atmospheric anomalies and gas emissions offer promising avenues for research into potential earthquake precursors. Continued interdisciplinary studies are necessary to further understand these complex relationships.

But a large body of scientific literature (Rosca. 2024; Akhoondzadeh. 2024; Chapman. 2020; Tehseen, Farooq. 2020; Van Quan, N.; Yang, H. 2017; Bogue.2012) supports the association of changes in various environmental parameters (such as temperature and soil moisture) due to anomalies with early signs of earthquakes, while others report increases in atmospheric particulate matter during/after earthquakes as a result of ground wave propagation.

Several studies have documented significant increases in PM levels following seismic events, primarily due to the release of dust and hazardous materials from damaged infrastructure.

A study on the 2023 earthquakes in Turkey observed a marked rise in $PM_{2.5}$ concentrations in the aftermath, attributed to debris and dust from collapsed buildings. Machine learning analyses of air quality data post-earthquake have confirmed these findings, highlighting the environmental impact of seismic events (Eryilmaz, Güzel, 2024). Some early experiments have shown that fracturing rocks under stress can release ozone gas, suggesting that monitoring ozone levels might aid in earthquake prediction (Baragiola. 2011).

On October 6, 2023, an earthquake was recorded again, this time in Telavi, 45 km from Tbilisi. Magnitude 4.2; Depth 32. This earthquake occurred further from Tbilisi but had about the same strength. The following data were recorded on sensors at all four locations on October 6 and 7. According to records, the amount of PM oxides and particles also increased in this case. The level of humidity was elevated (Table 4). The noise in this case is also recorded within the norms, although this is normal due to the large distance from the epicenter (Figures 10; 11a,b,c; 12a,b,c; 13 a,b,c,d; 14 a,b,c,d).

4. CONCLUSIONS:

The Case Study once again proved the significant influence of anthropogenic factors, particularly fireworks shooting, on increasing the concentration of pollutants in the atmospheric air. The concentration of nitrogen dioxide and particulate matter increases, which automatically entails:

1) synthesis of secondary pollutants (aldehydes) against the background of photochemical reactions in which nitrogen dioxide will take part.

2) stable retention of metal ions in the air emitted during fireworks shooting against the background of their attraction by PM particles.

Therefore, national decision-makers should develop restrictions to reduce the release of such fireworks.

Research has also shown that meteorological factors and changes in certain pollutants are linked to natural phenomena, such as earthquakes. It can probably be assumed that a more in-depth study of these data, along with other parameters, will provide, albeit a small hope, that it will be possible to predict this natural disaster in the future.

5. DECLARATIONS

5.1. Study Limitations

This study acknowledges several limitations that may affect the interpretation of results. First, the monitoring network was limited to four sensor locations within Tbilisi, which may not fully represent air quality variations across the entire metropolitan area. The study period, while covering significant events in 2023-2024, represents a relatively short timeframe for establishing long-term pollution patterns.

Sensor calibration, though conducted according to established protocols, was performed against government monitoring stations rather than laboratory-grade reference instruments, potentially introducing systematic measurement uncertainties. The case study approach, while valuable for documenting specific events, limits the generalizability of findings to other urban environments or different meteorological conditions.Additionally, the correlation between particulate matter increases and earthquake events requires more extensive research with larger datasets before definitive conclusions can be drawn about predictive relationships. The study focused primarily on primary pollutants, with secondary and tertiary pollutant formation being inferred rather than directly measured.

5.2. Acknowledgements

Special acknowledgment to the REACT Project team and the NATO Science for Peace and Security Programme for their support. The authors express gratitude to Ilia State University for providing secure installation sites and technical support. We thank the National Seismic Monitoring Centre of Georgia for providing earthquake data and the Tbilisi City Hall Environmental Department for access to reference monitoring data for sensor calibration.

5.3. Funding source

This research was conducted within the framework of the NATO SPS programme project REACT. Additional support was provided by Ilia State University. In accordance with the ethical guidelines of the publishing journal, which do not allow donations from authors with manuscripts under evaluation, publication costs were absorbed by the journal under their Platinum Open Access policy, through the support of the Araucária Scientific Association (https://acaria.org/).

5.4. Competing Interests

The authors declare no financial or non-financial competing interests that could have influenced the work reported in this paper. The research was conducted independently, and the findings represent the authors' objective analysis of the collected data.

5.5. Ethics Approval and Consent

This study involved environmental monitoring in public spaces and did not require ethics committee approval. All monitoring equipment was installed with appropriate permissions from Ilia State University and local authorities. No personal data were collected during the monitoring process.

5.6. Data Availability Statement

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request, subject to NATO SPS programme data sharing agreements. Summary data supporting the conclusions are included within the article's tables and figures.

5.7. Open Access

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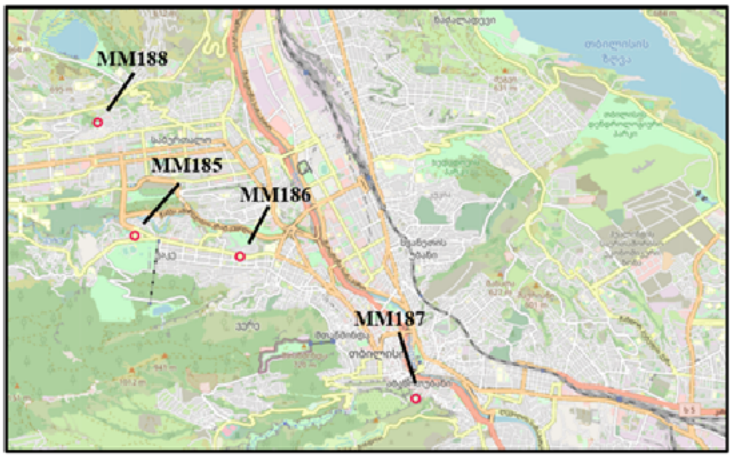


Figure 1. Map of LCMS deployment across Tbilisi – Georgia

Figure 2. Celebration of Independence Day of Georgia

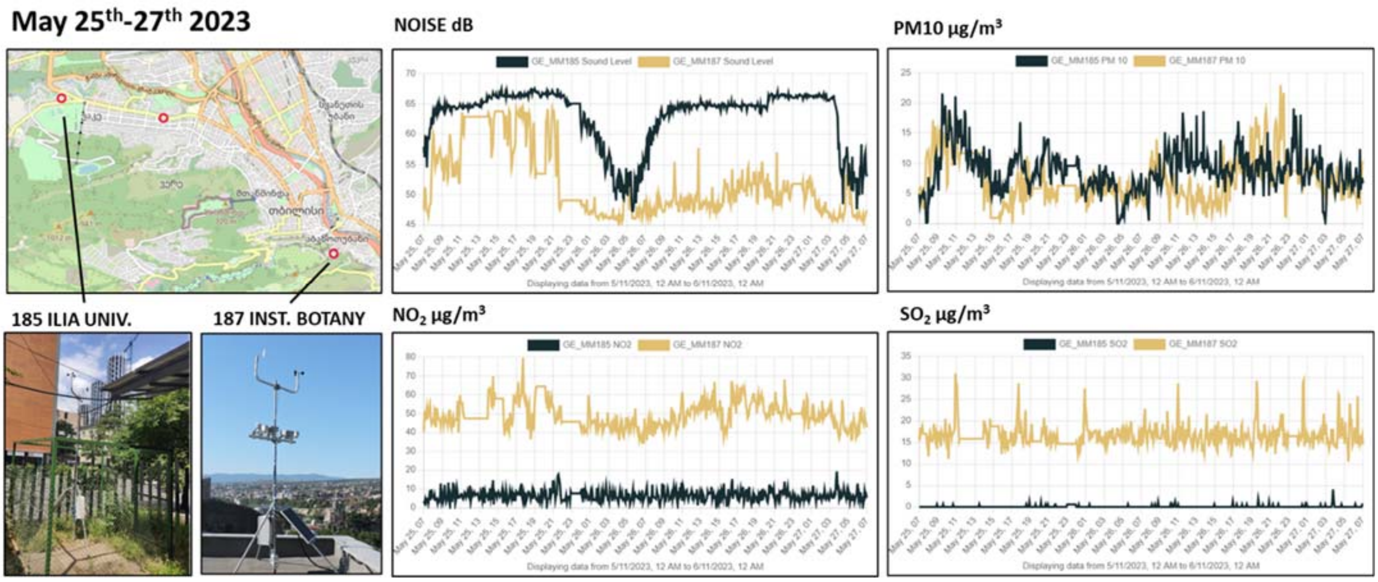
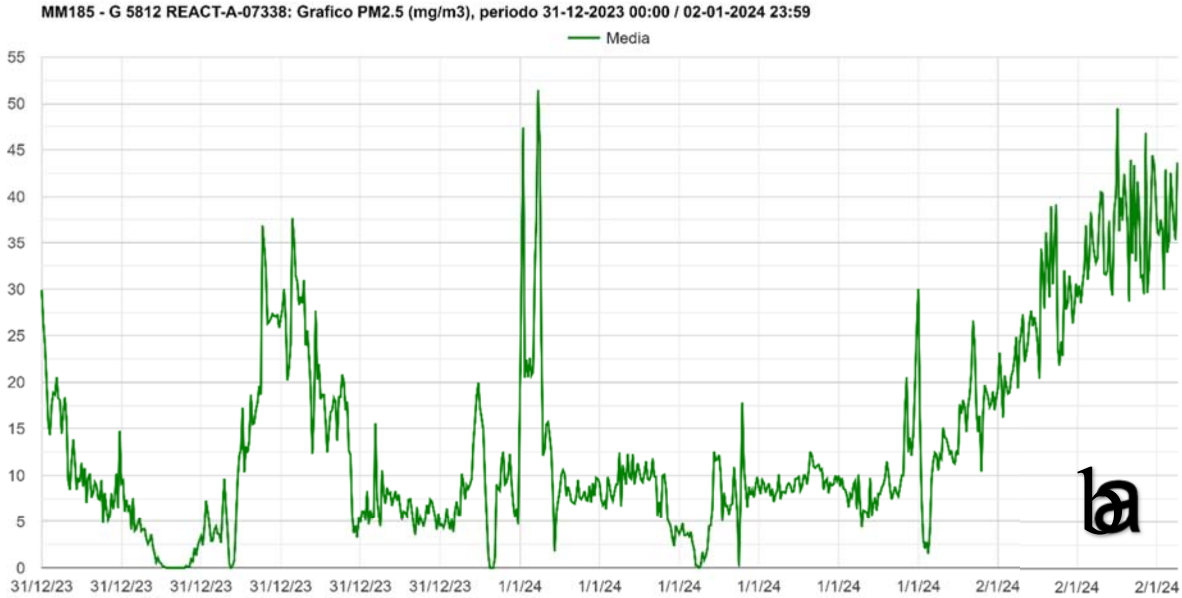
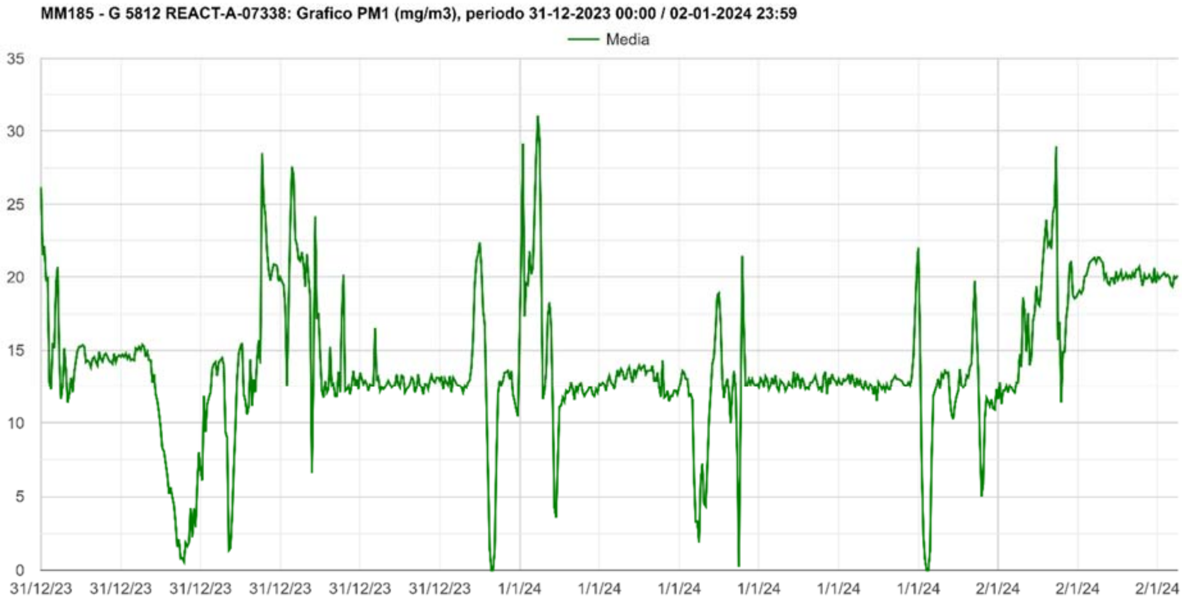


Figure 3. Evolution of selected environmental parameters as described by the LCMS of React deployed in Tbilisi during the Independence Day of Georgia in 2023


MM185 - G 5812 REACT-A-07338: Grafico PM2.5 (mg/m3), periodo 31-12-2023 00:00 / 02-01-2024 23:59
Media
55
50
45
40
35
30
25
20
15
10
5
0
31/12/23
1/1/24
2/1/24


MM185 - G 5812 REACT-A-07338: Grafico PM1 (mg/m3), periodo 31-12-2023 00:00 / 02-01-2024 23:59
Media
35
30
25
20
15
10
5
0
31/12/23
1/1/24
2/1/24

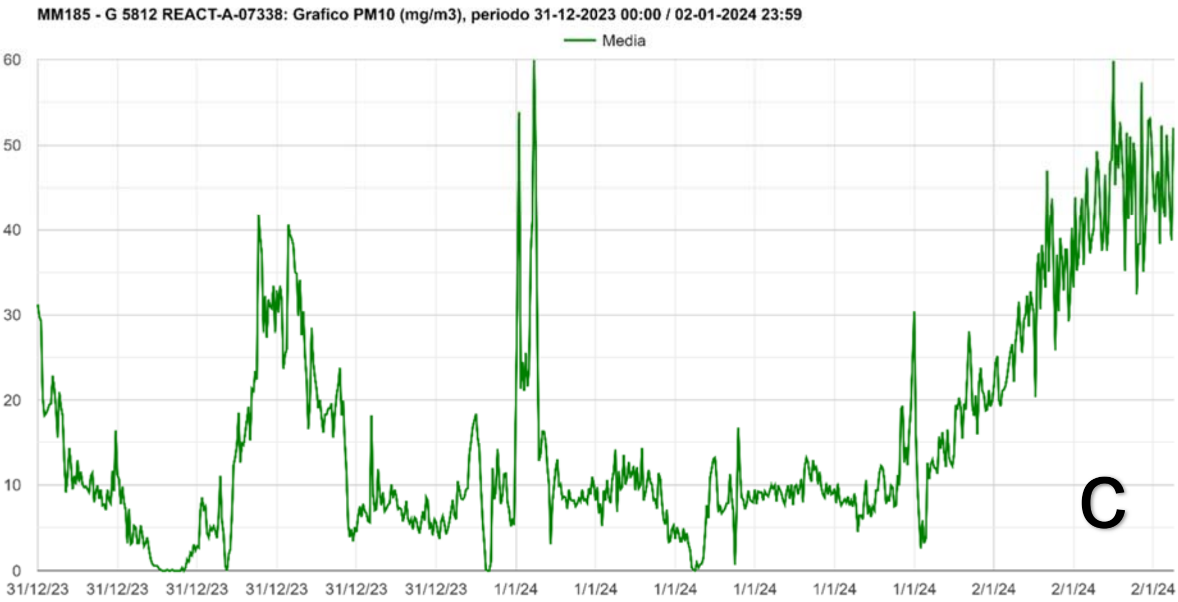


Figure 4-a,b,c. PM particle change at MM 185 location

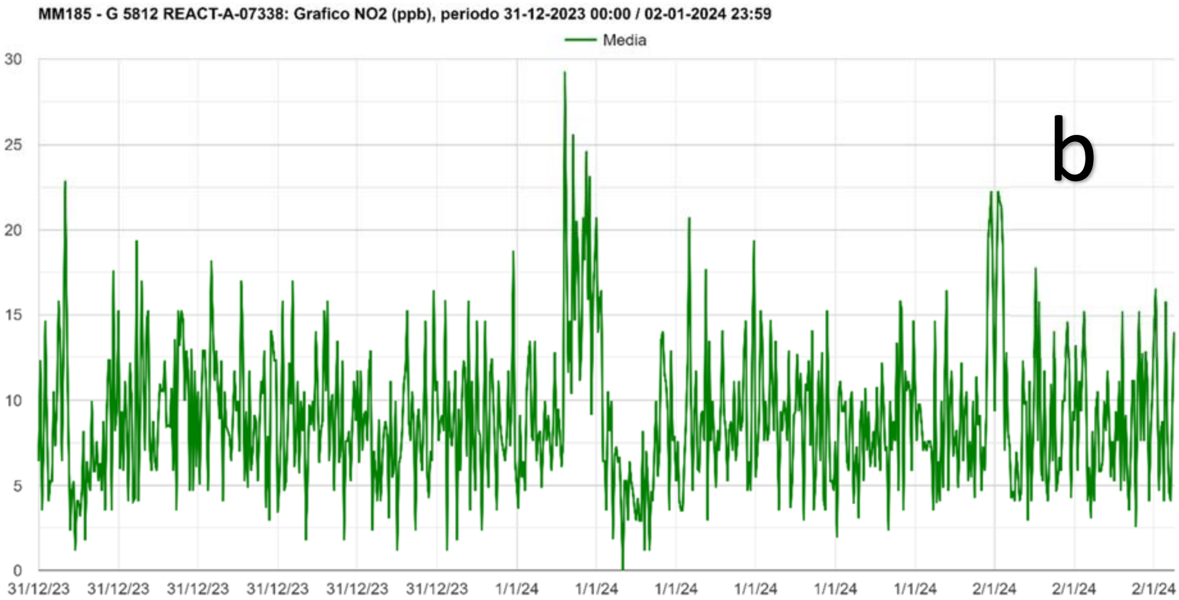
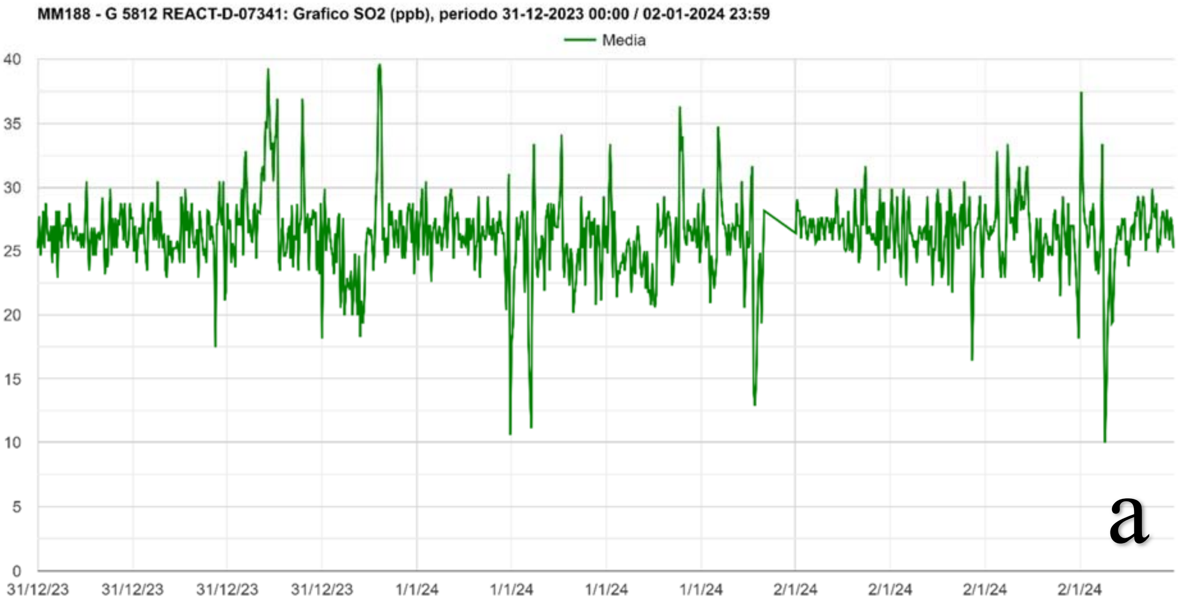


Figure 5-a,b,c. Change in NO_2 emission at locations MM 185; 186; 188


MM188 - G 5812 REACT-D-07341: Grafico SO2 (ppb), periodo 31-12-2023 00:00 / 02-01-2024 23:59
Media
40
35
30
25
20
15
10
5
0
31/12/23
31/12/23
31/12/23
31/12/23
1/1/24
1/1/24
1/1/24
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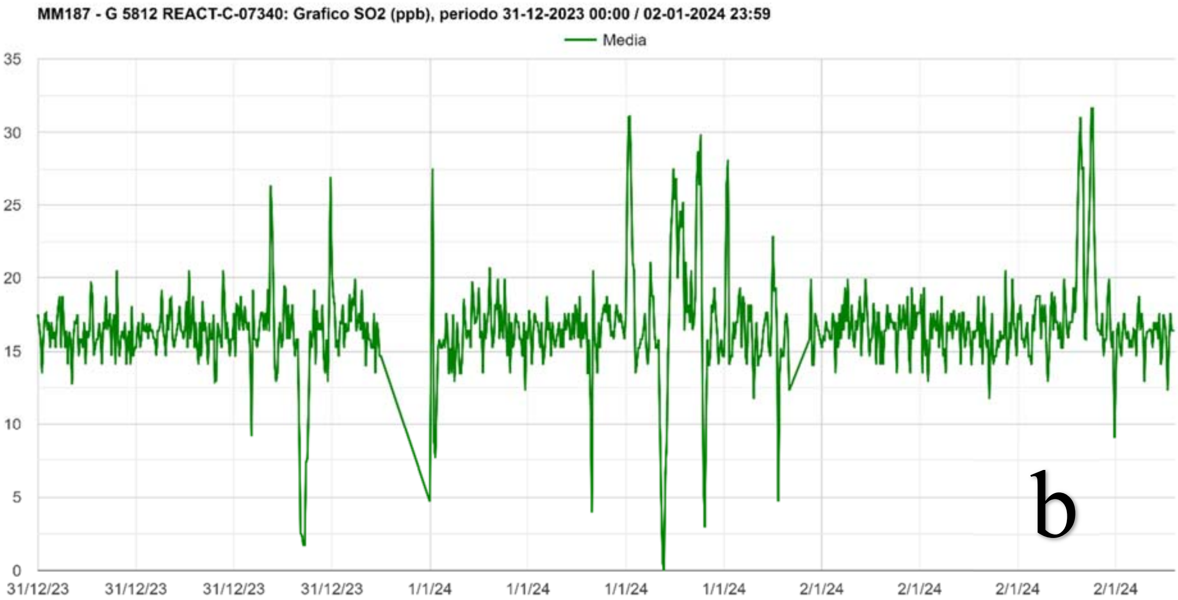
2/1/24
2/1/24
2/1/24
2/1/24
a


MM187 - G 5812 REACT-C-07340: Grafico SO2 (ppb), periodo 31-12-2023 00:00 / 02-01-2024 23:59
Media
35
30
25
20
15
10
5
0
31/12/23
31/12/23
31/12/23
31/12/23
1/1/24
1/1/24
1/1/24
1/1/24
2/1/24
2/1/24
2/1/24
2/1/24
b

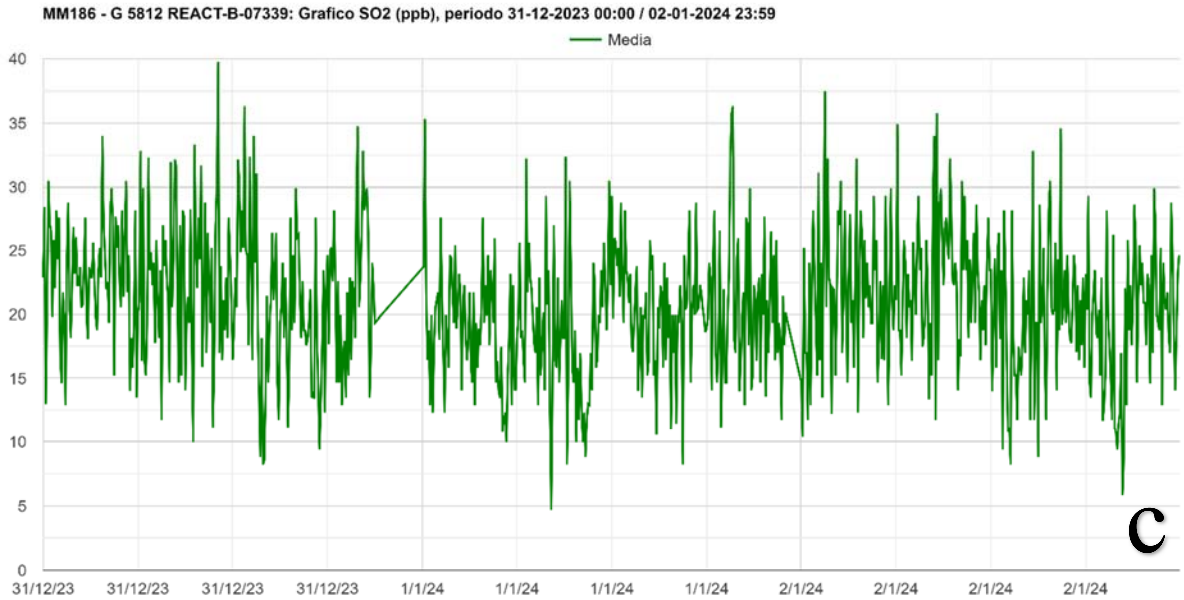
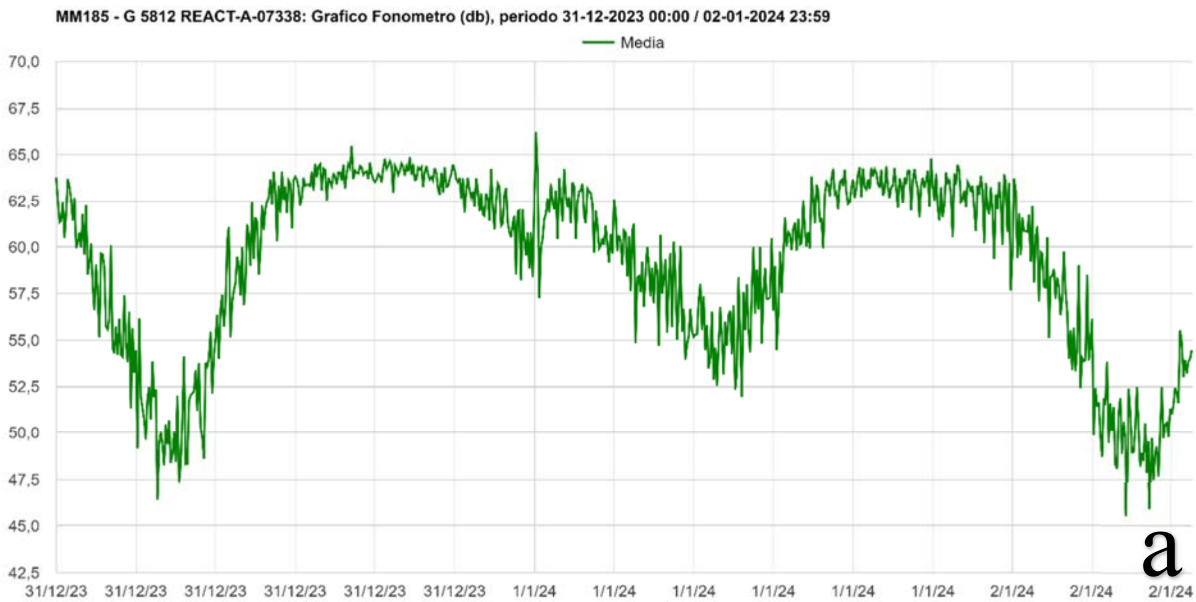
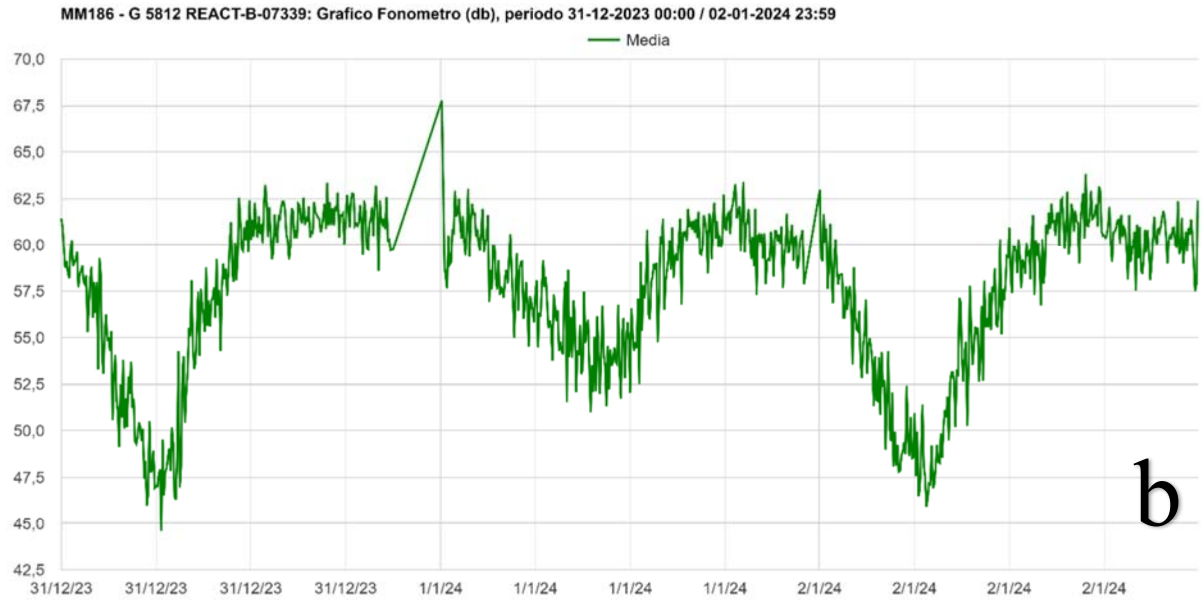
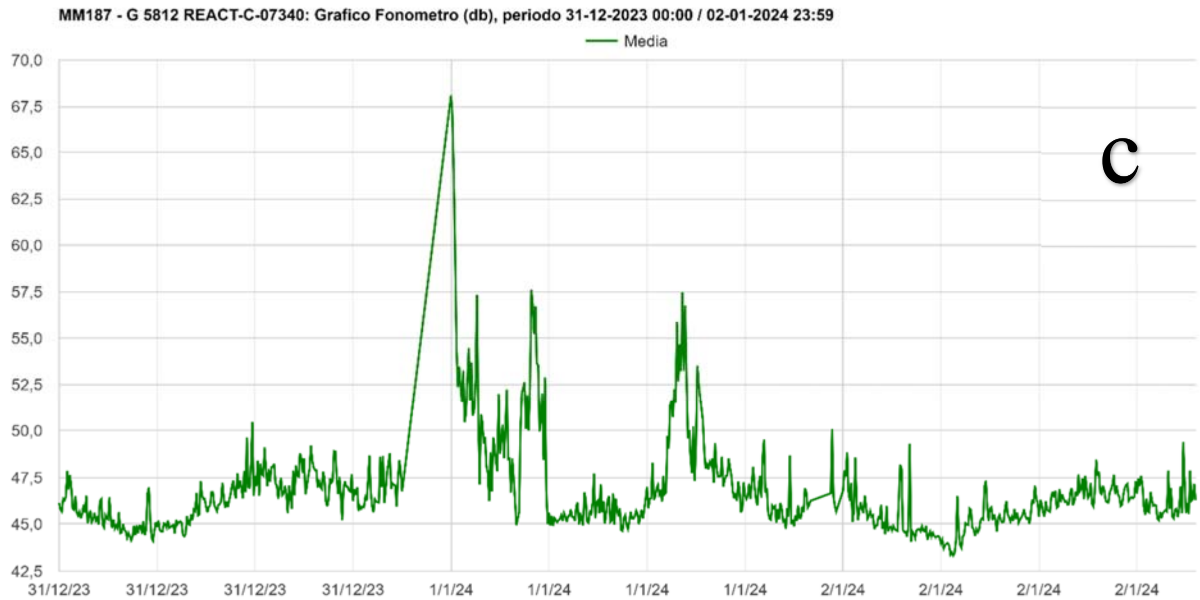


Figure 6-a,b,c. Change in SO_2 emissions at MM186;187;188locations




MM186 - G 5812 REACT-B-07339: Grafico Fonometro (db), periodo 31-12-2023 00:00 / 02-01-2024 23:59
Media
70,0
67,5
65,0
62,5
60,0
57,5
55,0
52,5
50,0
47,5
45,0
42,5
31/12/23
31/12/23
31/12/23
31/12/23
1/1/24
1/1/24
1/1/24
1/1/24
2/1/24
2/1/24
2/1/24
2/1/24
b


MM187 - G 5812 REACT-C-07340: Grafico Fonometro (db), periodo 31-12-2023 00:00 / 02-01-2024 23:59
Media
70,0
67,5
65,0
62,5
60,0
57,5
55,0
52,5
50,0
47,5
45,0
42,5
31/12/23
31/12/23
31/12/23
31/12/23
1/1/24
1/1/24
1/1/24
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2/1/24
2/1/24
2/1/24
2/1/24
c

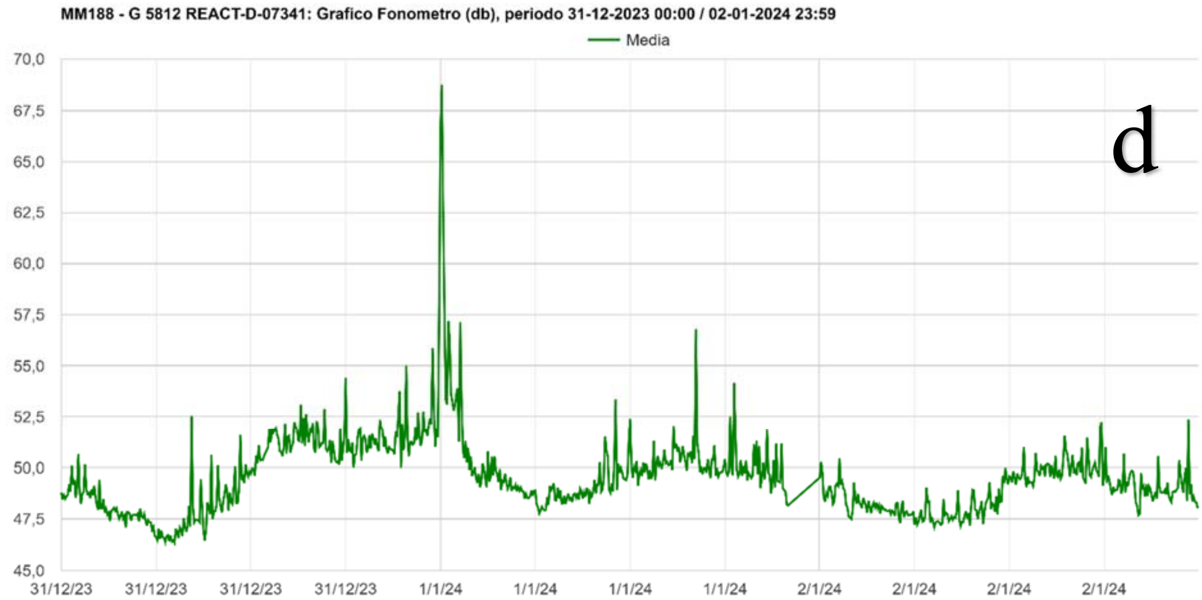
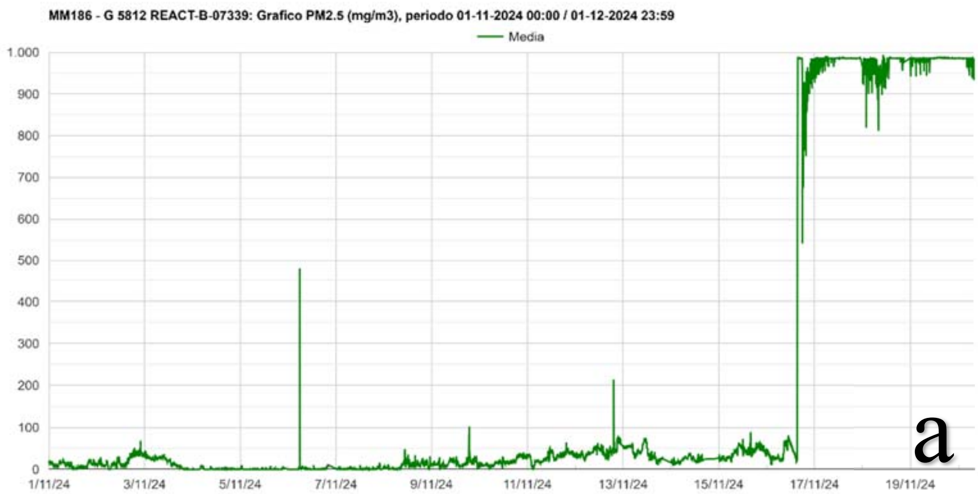


Figure 7-a,b,c,d. Noise change at all four locations



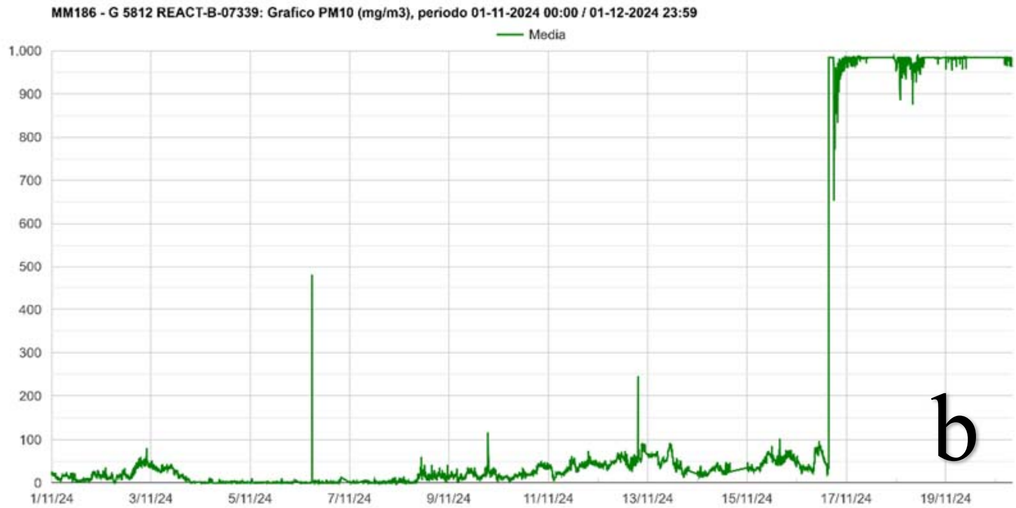
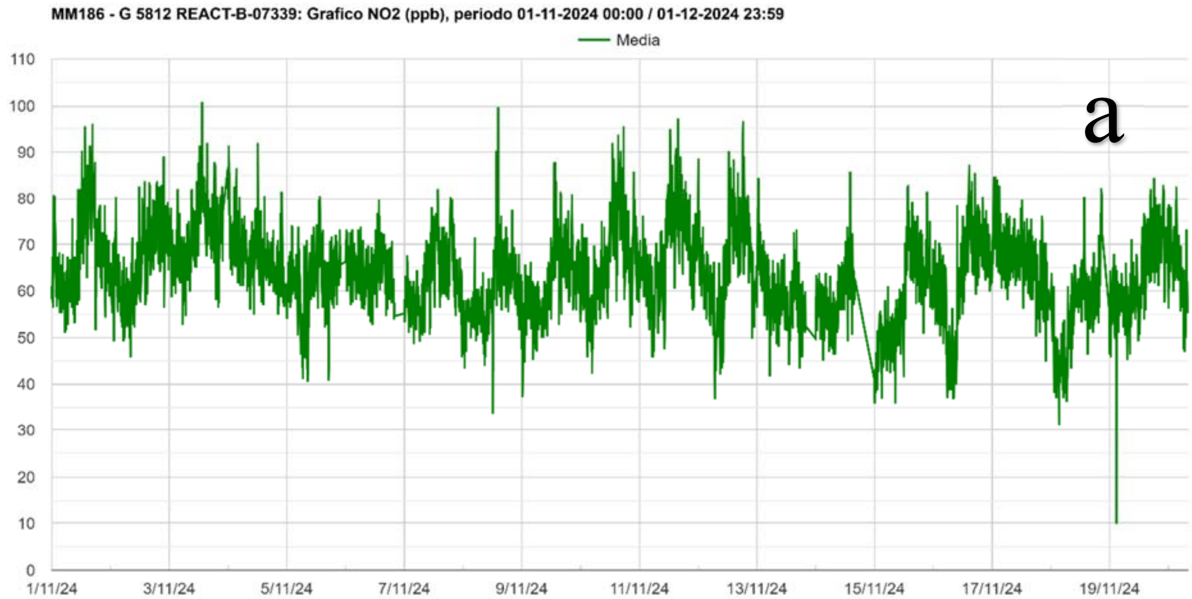


Figure 8-a,b. Change of PM 2,5 and PM10 particles



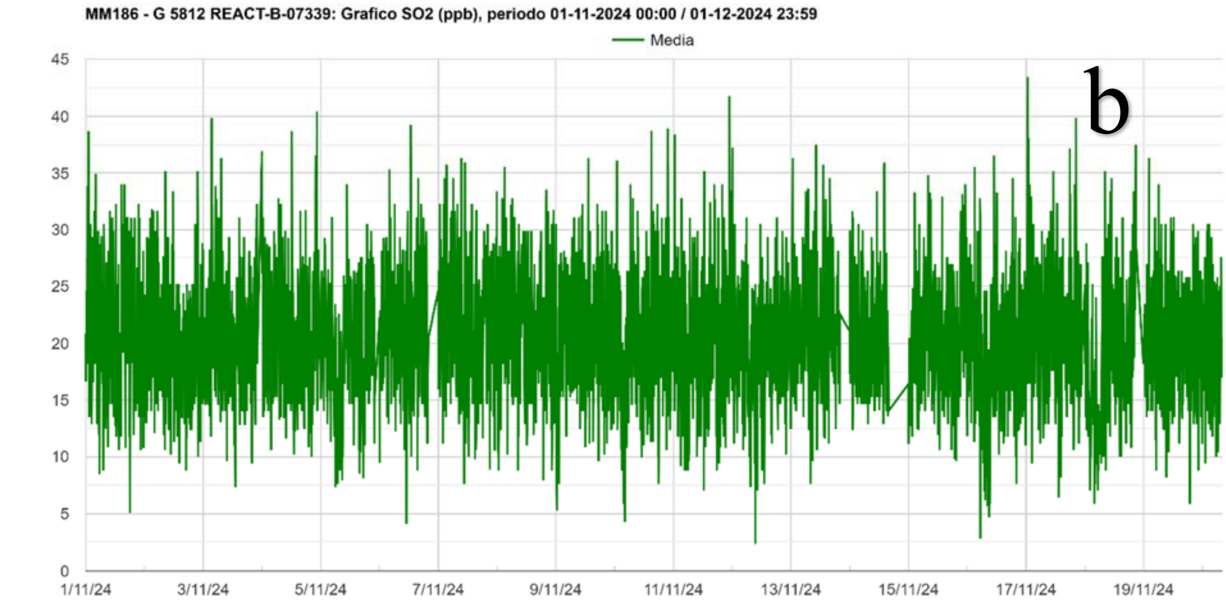


Figure 9-a,b. Change of NO_2 and SO_2

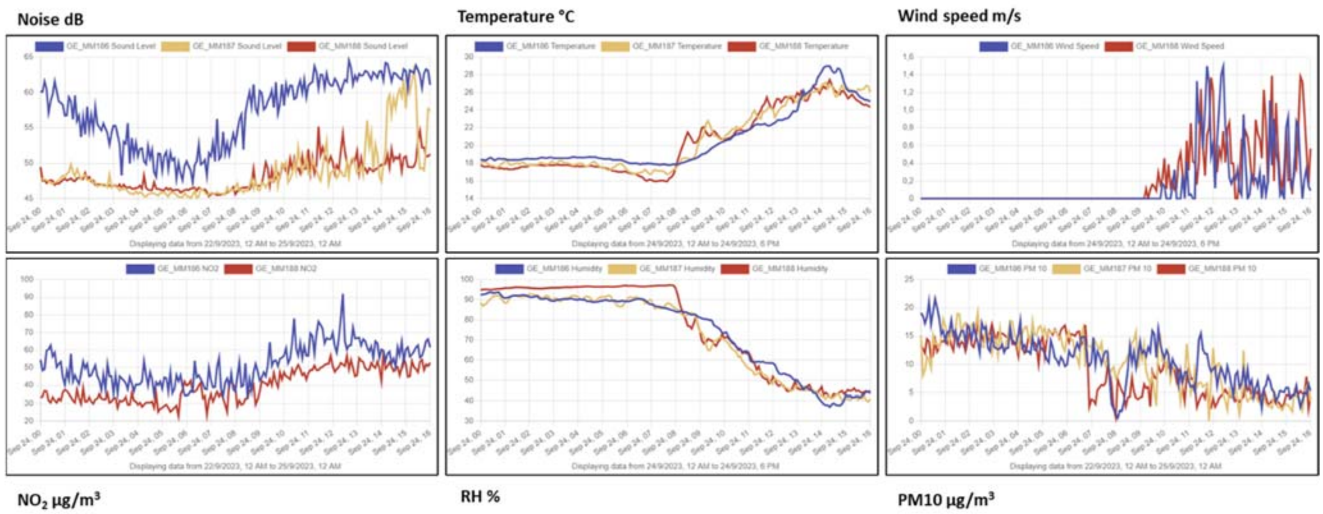
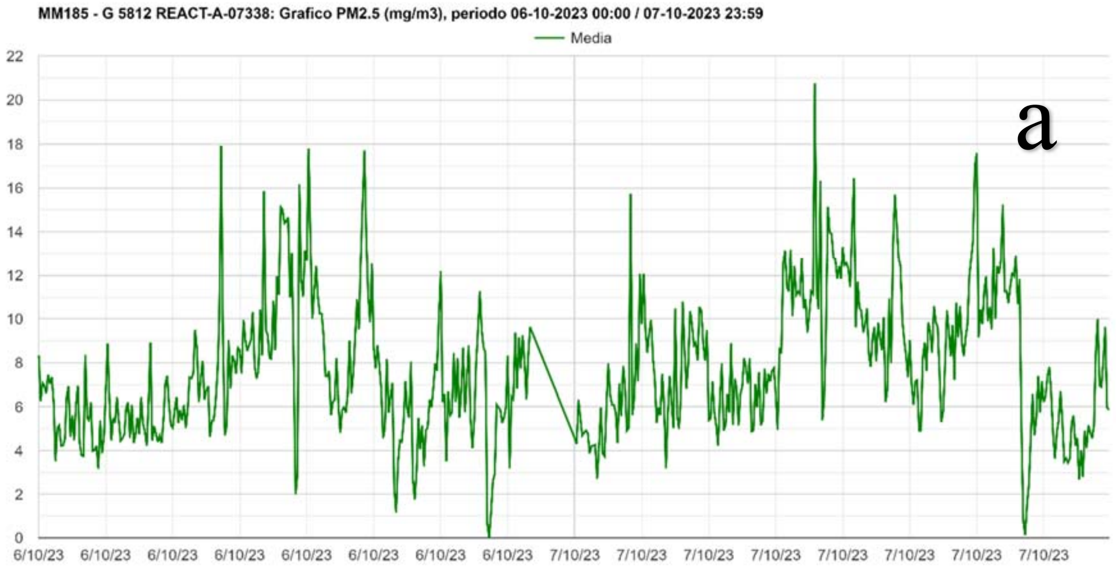
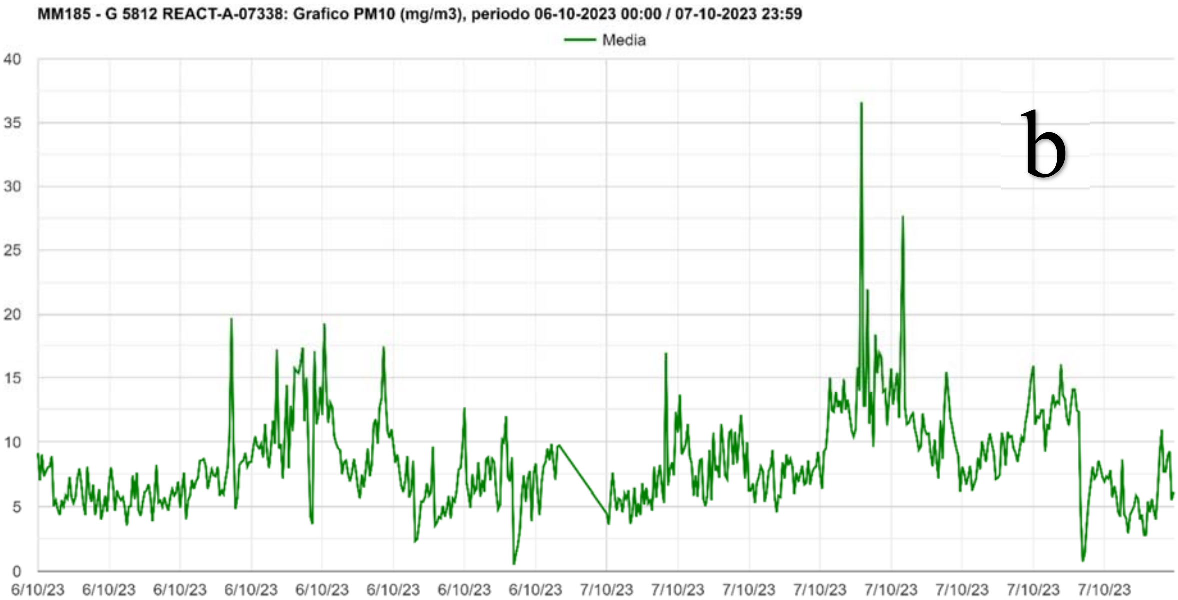


Figure 10. Evolution of selected environmental parameters as described by the LCMS of React deployed in Tbilisi during the earthquake of September 24th 2023


MM185 - G 5812 REACT-A-07338: Grafico PM2.5 (mg/m3), periodo 06-10-2023 00:00 / 07-10-2023 23:59
Media
a
0
2
4
6
8
10
12
14
16
18
20
22
6/10/23
7/10/23


MM185 - G 5812 REACT-A-07338: Grafico PM10 (mg/m3), periodo 06-10-2023 00:00 / 07-10-2023 23:59
Media
b
0
5
10
15
20
25
30
35
40
6/10/23
7/10/23

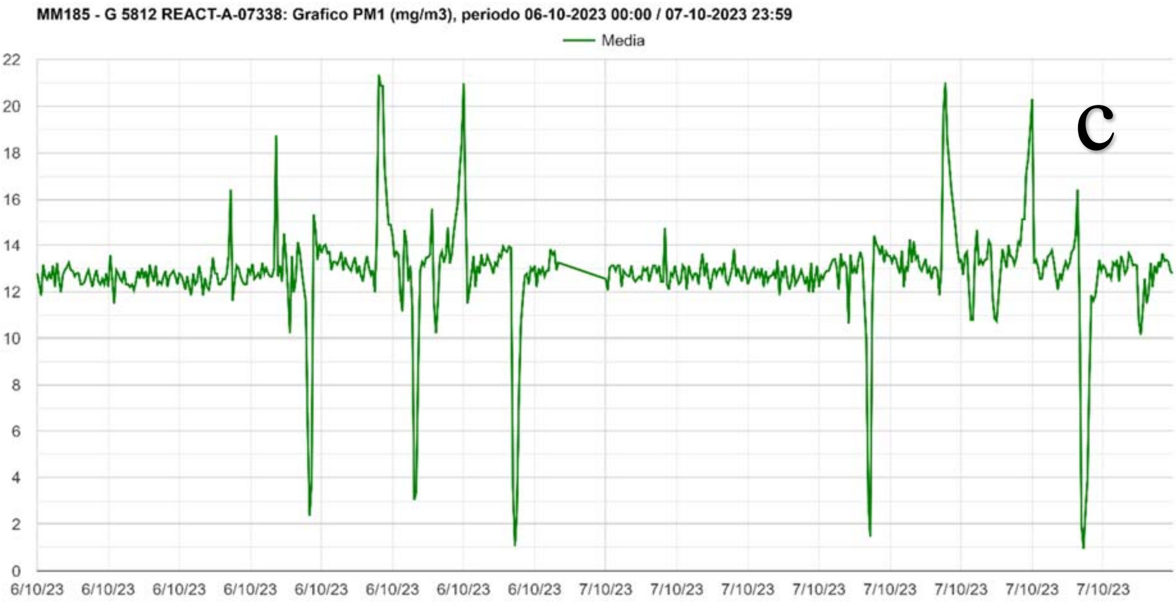
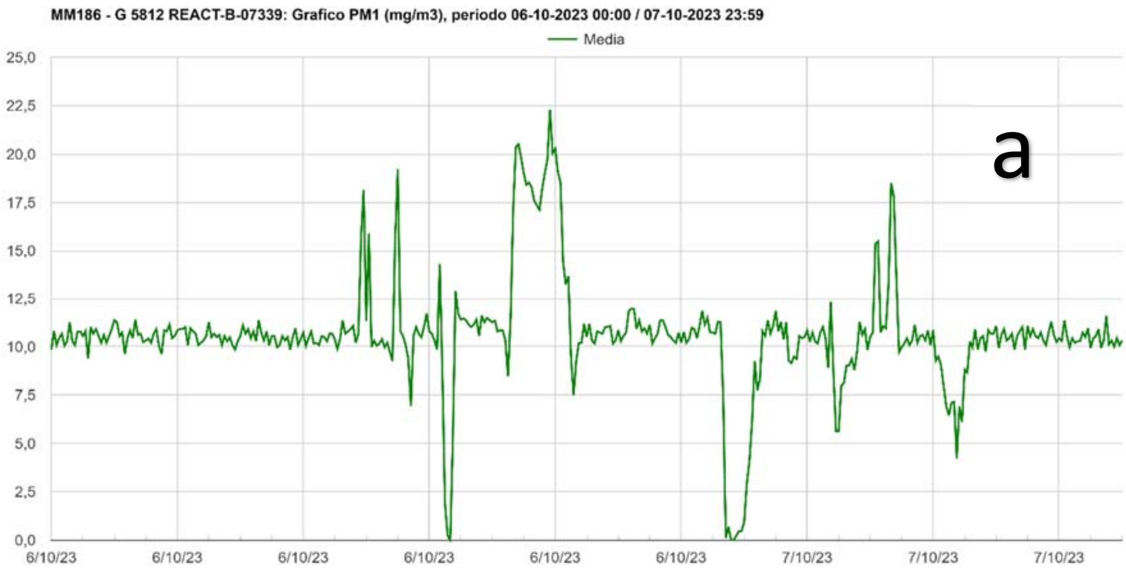


Figure 11-a,b,c. PM particle change at MM 185 location



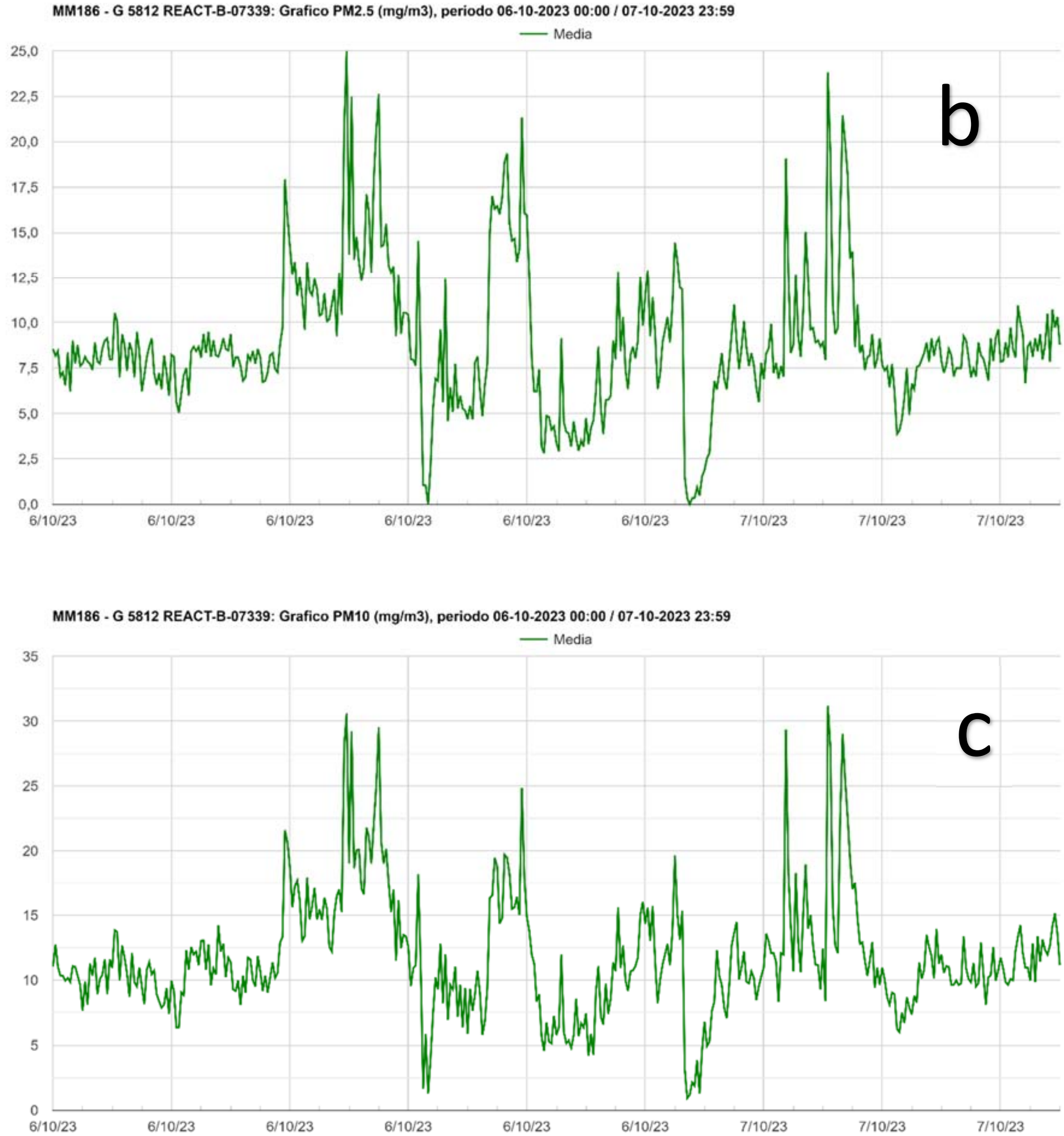
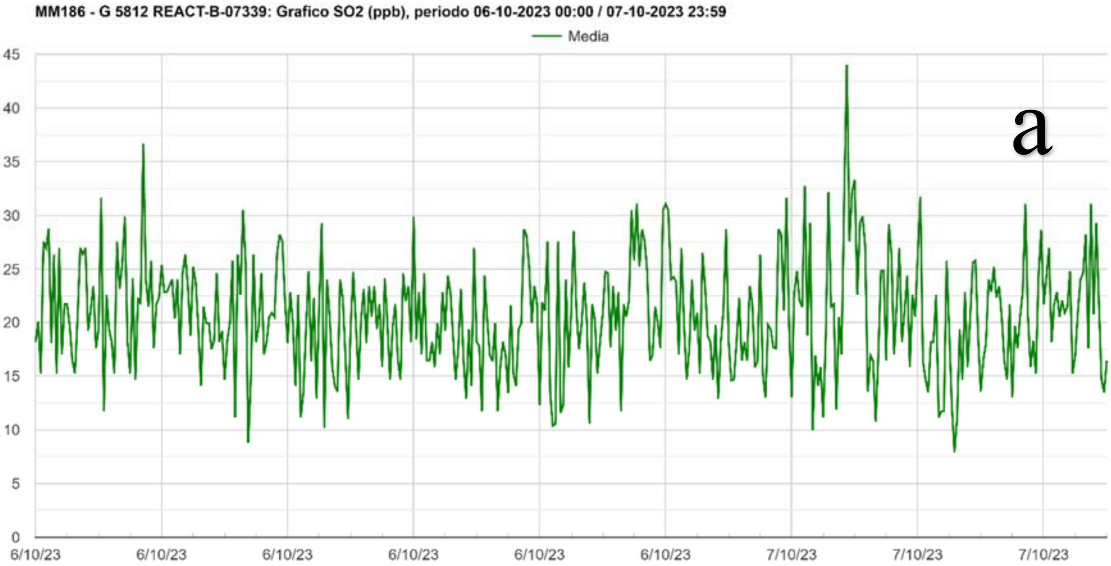
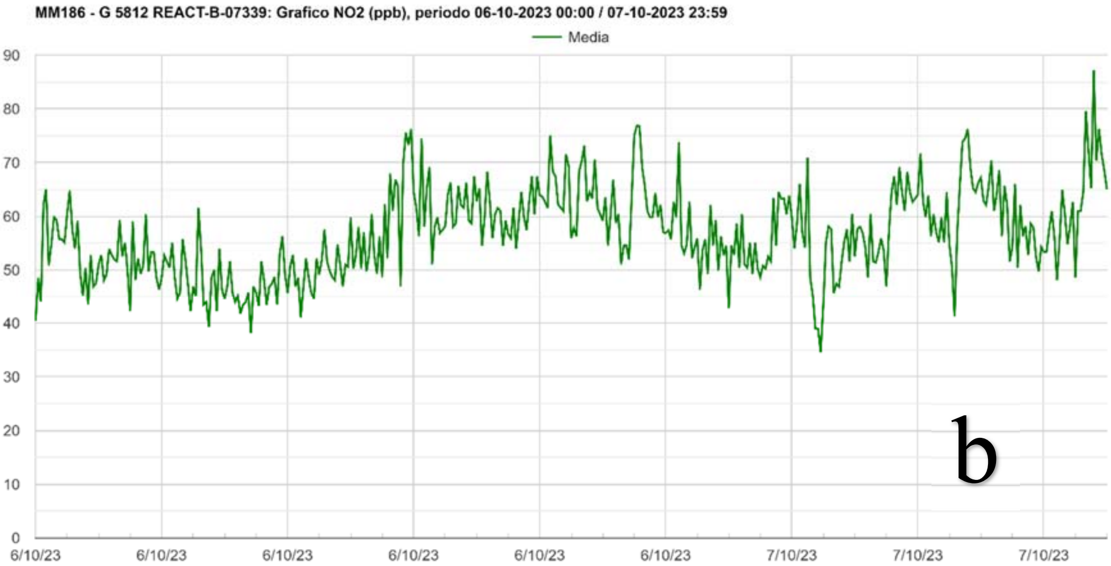
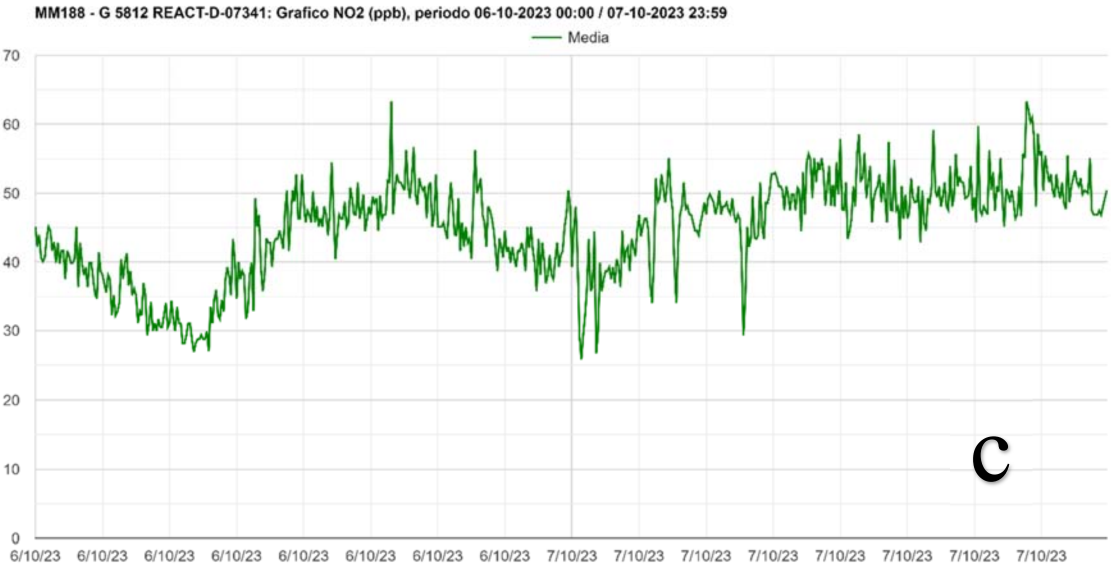


Figure 12-a,b,c. PM particle change at MM 186 location


MM186 - G 5812 REACT-B-07339: Grafico SO2 (ppb), periodo 06-10-2023 00:00 / 07-10-2023 23:59
Media
45
40
35
30
25
20
15
10
5
0
6/10/23
7/10/23
a


MM186 - G 5812 REACT-B-07339: Grafico NO2 (ppb), periodo 06-10-2023 00:00 / 07-10-2023 23:59
Media
90
80
70
60
50
40
30
20
10
0
6/10/23
7/10/23
b


MM188 - G 5812 REACT-D-07341: Grafico NO2 (ppb), periodo 06-10-2023 00:00 / 07-10-2023 23:59
Media
70
60
50
40
30
20
10
0
6/10/23
7/10/23
c

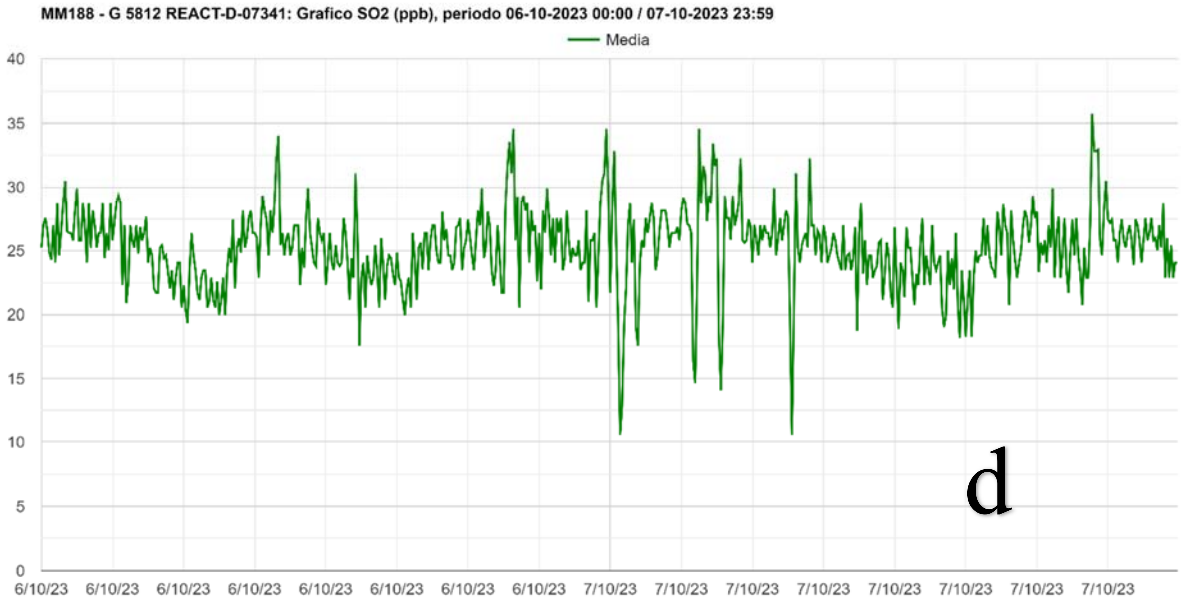
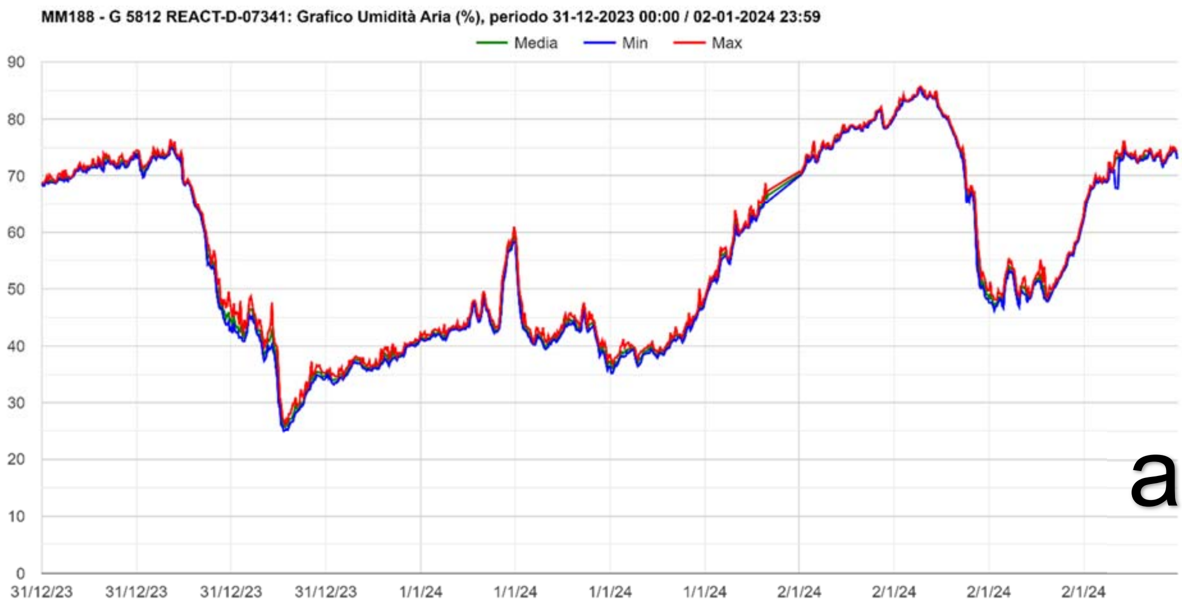


Figure 13-a,b,c,d. Change in NO_2 and SO_2 emissions at MM 186 and 188 locations




MM187 - G 5812 REACT-C-07340: Grafico Umidità Aria (%), periodo 31-12-2023 00:00 / 02-01-2024 23:59
Media
Min
Max
80
70
60
50
40
30
20
10
0
31/12/23
31/12/23
31/12/23
31/12/23
1/1/24
1/1/24
1/1/24
1/1/24
2/1/24
2/1/24
2/1/24
2/1/24
b

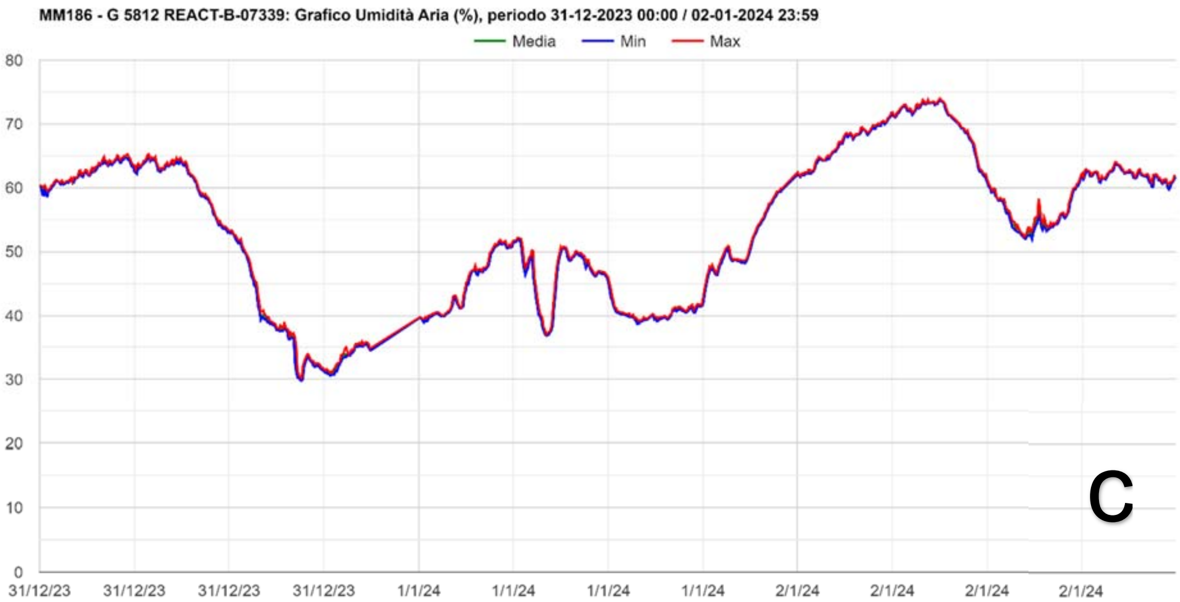

MM186 - G 5812 REACT-B-07339: Grafico Umidità Aria (%), periodo 31-12-2023 00:00 / 02-01-2024 23:59
Media
Min
Max
80
70
60
50
40
30
20
10
0
31/12/23
31/12/23
31/12/23
31/12/23
1/1/24
1/1/24
1/1/24
1/1/24
2/1/24
2/1/24
2/1/24
2/1/24
c

Figure 14-a,b,c,d. Humidity change on October 6 and 7 at all four locations

Table 1. *At all four locations, the average concentration of pollutant agents for May 26th , 2023 celebration; Source: the author*

Chemical and meteorological parameters	**MM 185**	**MM 186**	**MM 187**	**MM188**
T	7-12 C0	5-16 C0	5-14 C0	4-12 C0
Humidity	91%	81%	72%	71%
Wind	5m/s	4,2 m/s	5m/s	6,2 m/s
NO_2	45 ppm	86 ppm	90%	85ppm
SO_2	2,0 ppm	32ppm	42ppm	41ppm
PM1	32mg/m3	47 mg/m3	35 mg/m3	232 mg/m3
PM2,5	45 mg/m3	89 mg/m3	123 mg/m3	105 mg/m3
PM10	57 mg/m3	98mg/m3	110 mg/m3	145 mg/m3
Noise	67db	67,5 db	68 db	70db

Table 2. *At all four locations, the average concentration of pollutant agents for December 31, 2023, and January 1, 2, 2024*
Source: the author

Chemical and meteorological parameters	**MM 185**	**MM 186**	**MM 187**	**MM188**
T	6-14 C0	6-14 C0	5-12 C0	3-15 C0
Humidity	92%	75%	80%	85%
Wind	9m/s	3,4 m/s	3m/s	5,5 m/s
NO_2	30 ppm	90 ppm	85%	75ppm
SO_2	3,0 ppm	40ppm	40ppm	40ppm
PM1	33mg/m3	40 mg/m3	27 mg/m3	994 mg/m3
PM2,5	54 mg/m3	80 mg/m3	120 mg/m3	119 mg/m3
PM10	60 mg/m3	90 mg/m3	145 mg/m3	138 mg/m3
Noise	67db	67,5 db	68 db	70db

Table 3. *The average concentration of pollutant agents in November-December 2024, location M186*

Chemical and meteorological parameters	**MM 186**
T	4-20 C0
Humidity	95%
Wind	5-10m/s
NO_2	60-140 ppm
SO_2	4-44 ppm
PM1	2-70mg/m3
PM2,5	5-1000 mg/m3
PM10	965-1000 mg/m3
Noise	60-70db

Table 4.
The average concentration of pollutant agents on October 6th 2023, in all locations

Chemical and meteorological parameters	**MM 185**	**MM 186**	**MM 187**	**MM188**
T	6-14 C0	6-14 C0	5-12 C0	3-15 C0
Humidity	92%	75%	80%	85%
Wind	9m/s	3,4 m/s	3m/s	5,5 m/s
NO_2	30 ppm	90 ppm	85%	75ppm
SO_2	3,0 ppm	40ppm	40ppm	40ppm
PM1	33mg/m3	40 mg/m3	27 mg/m3	994 mg/m3
PM2,5	54 mg/m3	80 mg/m3	120 mg/m3	119 mg/m3
PM10	60 mg/m3	90 mg/m3	145 mg/m3	138 mg/m3
Noise	67db	67,5 db	68 db	70db