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Urban Air Quality Monitoring in Decarbonization Context; Case Study—Traditional Coal Mining Area, Petroșani, Romania

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Abstract: Humanity is a fossil-fueled civilization with a large influence on the environment. The World Health Organization (WHO) has pointed out that air pollution is now the single biggest environmental threat to human health. The air quality in Petroșani, a traditional mining region from the Jiu Valley bituminous coal basin, Romania, is rarely debated; however, it is not often investigated. In this paper, the main air pollution sources of Petroșani are identified and the performed measurements emphasize the air quality in the area of its transit road. The monitoring program set out the objectives, parameters, and points of the monitoring system, as well as the frequency and duration of the program and other monitoring parameters. The equipment used was provided by the National Institute for Research and Development in Mine Safety and Protection to Explosion from Petroșani, within an institutional partnership with the University of Petroșani. The monitoring of the air quality parameters was conducted from March to July 2020, at six points located on the road that crosses the city. It was thus possible to capture a variety of concentrations of the monitored parameters in different weather conditions to determine the air quality in this area. Based on the variation of the measured values in one of the most important historical Romanian bituminous coal mining basins, the preliminary results suggest a worsening of local air quality parameters in relation to the decarbonization process.

Keywords: decarbonization; bituminous coal; air quality; pollution source; monitoring; road traffic

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1. Introduction

The current geo-politic and economic context, with special reference to the military conflicts located at the national border of Romania, as well as around the world, brings to the attention of specialists the need to re-evaluate the strategies of the energetic and the non-energetic mining sector. The reopening of mines can mean tens of thousands of direct jobs and hundreds of thousands of jobs in related industries [1].

Regarding the energetic mining sector, the main challenge comes from the perspective of compliance with environmental requirements, which means that the use of bituminous coal is preferable in terms of lower environmental loads compared to the use of lignite [2].

The fastest solution and a first option, especially in a time of crisis, must be to rely on the existing infrastructure. From this perspective, in Romania there are only two power plants which use bituminous coal for energy production, the Mintia and Paroșeni thermal power plants (TPP), respectively, and both are located in Hunedoara County. Of these, Paroșeni TPP is currently in use and its future operation can be based either on the resources obtained by continuing the exploitation of bituminous coal locally in the mines from the Jiu Valley mining basin or on imported coal.

2. General and Local Context

Generally, the environmental analysis has the following objectives: to assess the current state of the environmental components; to establish the local and temporal trends; to evaluate the sources of pollution; and, last but not least, to make measurements to estimate the potential risks and environmental impact. Urban air pollution under certain weather conditions (temperature inversion) often causes smoke fog (smog). According to the Cambridge dictionary [3], this is a mixture of smoke, gases, and chemicals that makes the atmosphere difficult to breathe and harmful for health, especially in cities

The World Health Organization (WHO) has reported that the global burden of disease associated with air pollution exposure exacts a massive toll on human health worldwide: exposure to air pollution is estimated to cause millions of deaths and lost years of healthy life annually; there were 3.315 million deaths from air pollution only in first five months of this year [4]. The burden of disease attributable to air pollution is now estimated to be on a par with other major global health risks such as unhealthy diet and tobacco smoking, and air pollution is now recognized as the single biggest environmental threat to human health. Despite some notable improvements in air quality, the global toll in terms of deaths and lost years of healthy life has barely declined since the 1990s [5,6].

Increasing the air quality and dealing with unfolding climate change entail a massive decarbonization of society. Humanity has experienced three major energy transitions and is now struggling to kick off a fourth. First was the mastery of fire, which allowed us to liberate energy from the sun by burning plants. Second came farming, which converted and concentrated solar energy into food, freeing people for pursuits other than sustenance. During that second era, which ended just a few centuries ago, farm animals and larger human populations also supplied energy, in the form of muscle power. Third came industrialization and, with it, the rise of fossil fuels. Coal, oil, and natural gas each, in turn, rose to prominence, and energy production became the domain of machines, such as coal-fired power plants [7,8].

We are a fossil-fueled civilization whose technical and scientific advances, quality of life, and prosperity rest on the combustion of huge quantities of fossil carbon, and we cannot simply walk away from this critical determinant of our fortunes in a few decades, never mind years.

Complete decarbonization of the global economy by 2050 is now conceivable only at the cost of unthinkable global economic retreat or as a result of extraordinarily rapid transformations relying on near-miraculous technical advances [9].

Worldwide fossil fuel production has grown steadily in recent decades from 9.572 billion metric tons in 1990 to 15.503 billion metric tons in 2019 (up nearly 62 percent), followed by a slight decline, probably as a result of the SARS-CoV-2 pandemic in 2020, to 14,756 billion metric tons [10].

The European Union still relies heavily on fossil fuels to meet its energy needs, as illustrated by the ratio of fossil fuels to gross energy available (the total energy demand of a country or region). In 2020, fossil fuels accounted for 70% of the gross energy available in the EU, down from 71% in 2019. In the last three decades, this percentage has fallen significantly (by 13 percent compared to 1990) [11].

Other statistics show an interesting outlook for resources extracted or mined from the earth: over 33 billion tons of resources were extracted and over 22 billion tons of resources were mined from the earth only in the first five months of this year alone, of which almost 3 billion tons is coal [4].

In Romania, known bituminous coal deposits are only in the Middle Carpathians, in the Carpathian orogen, in both the Danubian and the Getic domains, but also in the post-tectonic intra-mountainous basins [12]. From all of these deposits, the active mines actually exist only in the Jiu Valley Mining Basin [13,14].

Petroșani is the most important city in the Jiu Valley bituminous coal mining basin (Figure 1). According to the statistics of the last decade, the reserves of bituminous coal in the Lonea, Livezeni, Vulcan, and Lupeni mining perimeters total about 361 million of tons. Of the total reserves, only the recoverable (proven) reserves are available for valorization, and that means about 154 million tons in these four perimeters [13,14].

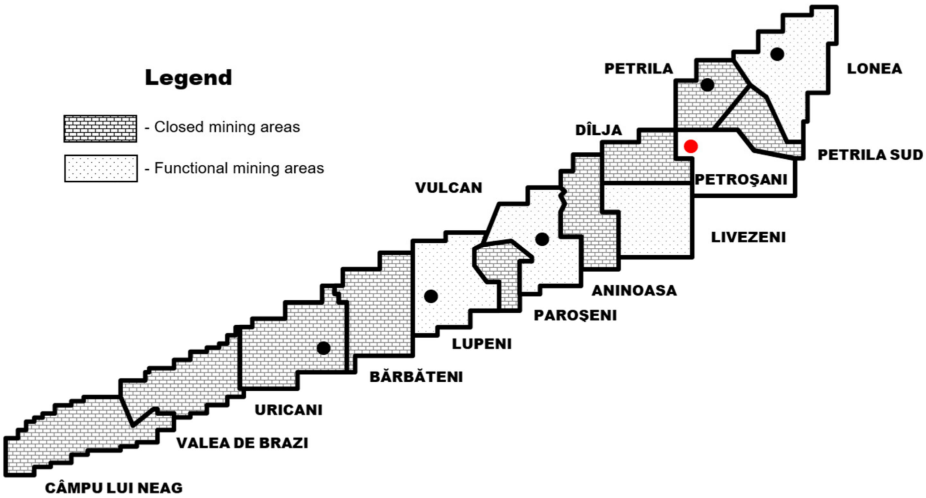


Figure 1. Location and status of mining perimeters in the Jiu Valley bituminous coal basin. (Petroșani is highlighted with a red dot, the other cities in the Jiu Valley are marked with black dots.).

Since the times of intensive mining activities, the inhabitants from Petroșani have been heating their homes mainly by using individual coal stoves, often through several pre-existing installations in each building, with all the released gases from the burning of fossil fuels being eliminated directly into the atmosphere without special filters installed in the chimneys of the houses. This practice is still encountered today, but now, in addition to coal, people also burn other materials (textile waste from secondhand stores and warehouses); thereby, the gases released into the atmosphere have a worsening effect on the air quality parameters.

With the simultaneous growth of urban scales and vehicle ownerships, on-road vehicles have the potential to overtake industrial and residential sectors as the dominant emission source [15–19]. The means of transport also contribute to the global pollution of the environment (air, soil, water) with a number of primary pollutants (carbon monoxide, nitrogen oxides, hydrocarbons, and particulate matter—PM), and they contribute to the genesis of secondary pollutants (tropospheric ozone, photochemical smoky fog, acid particles, and rain). Carbon dioxide emissions also contribute to the greenhouse effect, with well-known consequences which lead to climate change. The noise and vibration generated by road traffic come on top of the chemical emissions effects. [20]. On the other hand, transport infrastructure requires the occupation of large areas and contributes to habitat fragmentation and surface waterproofing [21,22]. Overall, transport is therefore a major source of environmental pressure and contributes to climate change, air pollution, and rising noise levels.

On these premises, the designed monitoring program was based on measurements in six monitoring points located along the transit road of Petroșani (Figure 2).

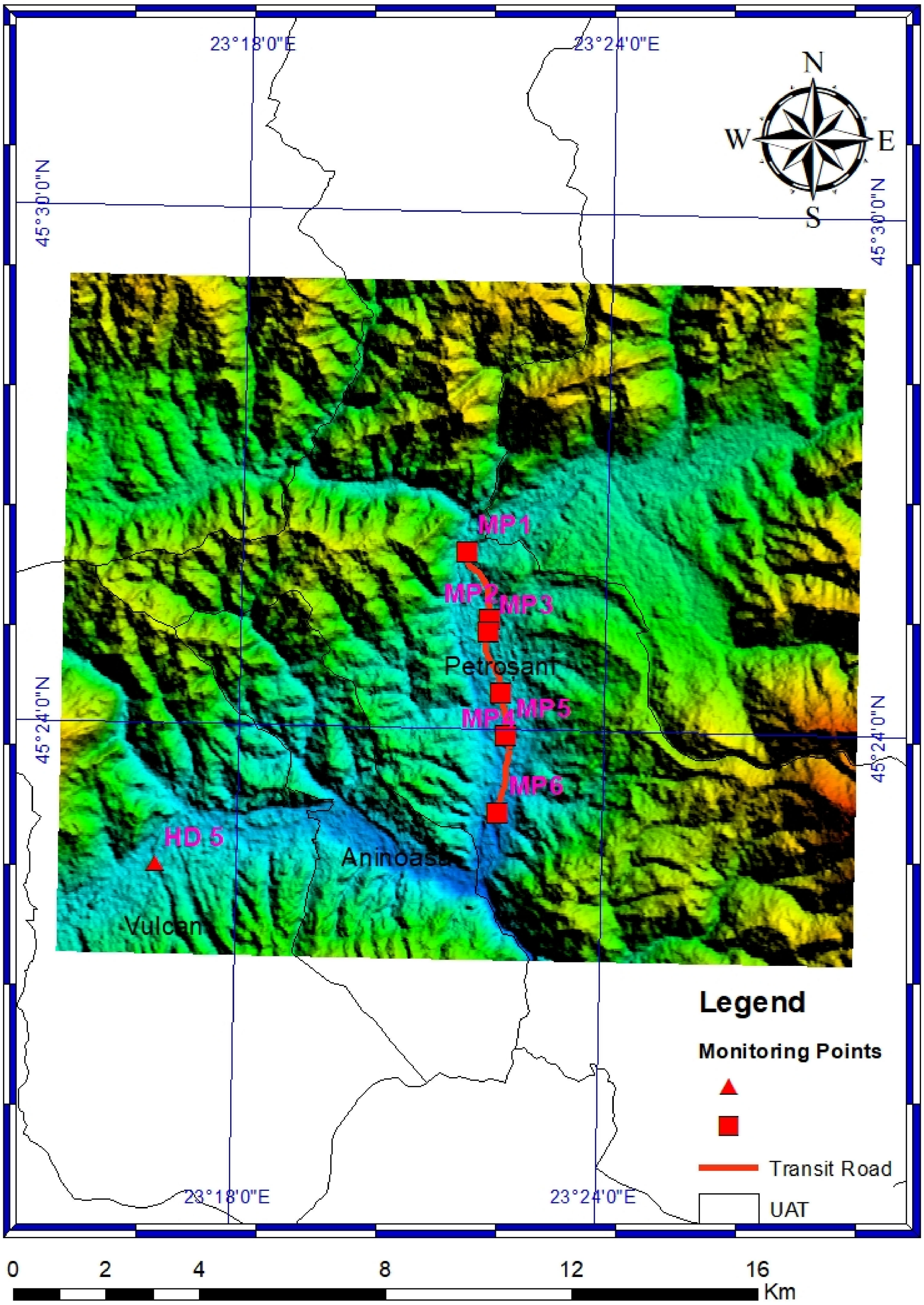


Figure 2. The DTM model of Petroșani area with transit road (red line), location of the monitoring points MP (red squares), and monitoring station HD 5 (red triangle) [23].

The duration of the designed monitoring program was three months, and the estimated outcome, as a result of weekly measurements, was twelve datasets. Due to the restrictions on every activity, as imposed by the authorities to combat the spread of the new COVID-19 virus, the initial program was disrupted, resulting in a total of five datasets of measurements, as follows: 7 March; 13 March; 18 May; 24 May (night); and 2 July 2020.

The equipment used for the air quality monitoring was provided by the National Institute for Research and Development in Mine Safety and Protection to Explosion Petroșani, through the existing institutional agreements between the research unit and the University of Petroșani. The results of all the measurements were processed, and the minimum, maximum, and average concentrations of all the monitored pollutants were determined.

3. Materials and Methods

3.1. Working Methodology

Environmental monitoring comprises a surveillance system, prognosis, and warning and intervention, which take into account the systematic assessment of the dynamics of the qualitative characteristics of the environmental factors, in order to know their quality status and ecological significance and the evolution and social implications of the changes produced. This is followed by the necessary measures [24]. The pollutant monitoring procedures are relatively well established and are based on a comparison with the acceptable limits of concentrations, based on the established knowledge at the time. This monitoring approach facilitates quantification that can be useful in environmental decision making [25]. In order to be able to use the data obtained from a monitoring system, the sampling and measurements were performed on the basis of the procedures, in accordance with the recognized and validated methods; these are the "Standard methods", which ensure the acquisition of the data of equivalent scientific quality. A number of factors must be also considered: the source and area of pollution, the type of pollutant, and the experiment purposes, such as the pollution spreading area, the level of pollution, or the short-term concentrations.

The monitoring points were located along the transit road that demarcates the historical areas/neighborhoods/peripheries (Colonie, Livezeni, etc.) from the other areas of the city. These points are the places of interference by the main sources of air pollution in Petroșani. These pollution sources are represented by the coal burning stoves used for home heating in the historical areas of the city (Colonie, Livezeni outskirts, etc.) and by the road traffic from the transit road (Figure 3).

(**a**) (**b**)

Figure 3. The two main sources of air pollution: (**a**) heating stoves and (**b**) road traffic.

Most of the pollutants emitted into the atmosphere from these two main sources have harmful influences on human health and the environment. In this respect, the monitoring points (MPs) were fixed at the main crossroads of the transit road; this resulted in five roundabouts and an intermediate point where the measurements were performed (Figure 4), as follows:

– MP_1 at the intersection of E79 with the entrance to the city of Petrila, at the roundabout from Dărănești;
– MP_2 at the intersection of E79 with the road to the Parâng Mountain Resort, at the roundabout from Victoriei Square;
– MP_3 at the intersection of E79 with Mihai Viteazul Street, at the roundabout next to the prosecutor's office attached to Petroșani Court;
– MP_4 at the intersection of E79 with December 1, 1918 Street, at the roundabout known as At the plane (La Avion);
– MP_5 on the E79 road, near the Livezeni Mining Exploitation;

– MP_6 at the intersection of E79 with the entrance to the Kaufland Supermarket, at the roundabout.

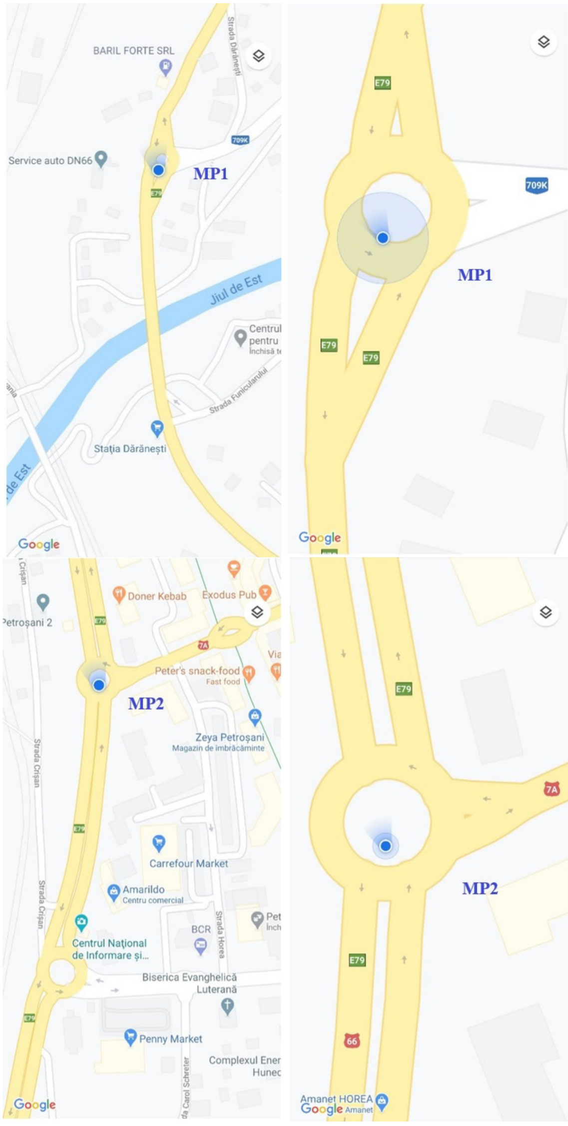
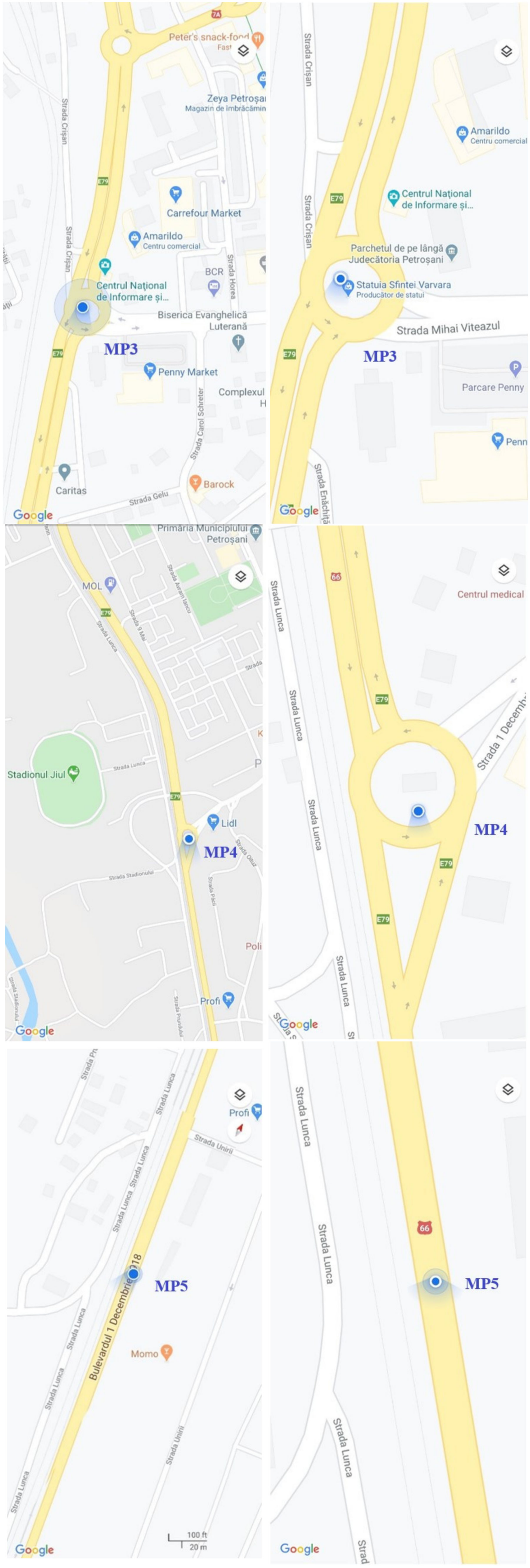


Figure 4. *Cont.*



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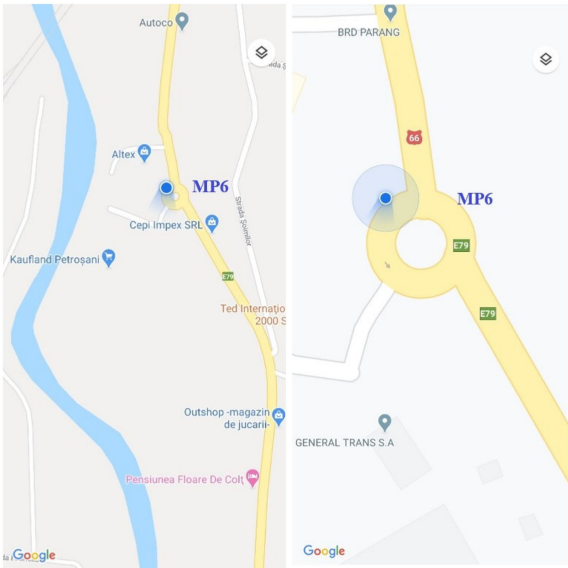


(**a**) (**b**)

Figure 4. Monitoring points on the E79 transit road: (**a**) general views and (**b**) details.

According to the No. 104/2011 law on ambient air quality, the sampling points were placed in such a manner as to avoid the microenvironment measurement effects, so that the obtained values resulted in being of proven relevance for the air quality. The sampling port was placed a few meters away from buildings, trees, or other obstacles, so that an area of 270° was clear from any interfering object; thereby, the air flow in the proximity of the sampler behaved normally.

It should be noted that the equipment used in this sampling study has small measuring ranges (0–30 ppm), being recommended (also by the manufacturer) for use in environmental measurements. Moreover, before the measurement, in order to ensure the accuracy of the results, each probe was calibrated with reference gas cylinders (the data are recorded in the laboratory documents). Moreover, the equipment has valid calibration certificates, and transient laboratory inspections are periodically performed with other similar equipment. Therefore, all the procedures regarding the accuracy of the data recorded are in table no. 1, as well as those regarding the microclimate parameters (table no. 2); they are held by the laboratory and are observed, validated, and accredited by the Romanian Accreditation Association (RENAR). After calibration of the instruments in the laboratory, the gas and the particulate matter sampling were placed at a height between 1.5–2 m from the ground (breathing height) [26]. The measurements were performed for 30 min at each monitoring point, both for the five monitored gases and for the particulate matter [27].

3.2. Monitoring Equipment

More devices from the GrayWolf Sensing Solutions, Shelton, CT, USA [28] and Kimo AMI 300 series [29] from the KIMO—A KGF Group company, Montpon, France were used in the monitoring activity, each of them having a certain measuring range. The measuring range represents the difference between the maximum and the minimum value which can be measured using each device.

The GrayWolf PC-4000 Particle/Mass Monitor Plus (Figure 5) measures particle sized/particulate matter (PM) from 0.3 µm to 25 µm, with a flow rate of 2.83 LPM (Litres Per Minute), which is the equivalent of 0.1 CFM (Cubic Feet Per Minute). It displays 6 size ranges simultaneously. The sizes 0.3 µm, 0.5 µm, 1.0 µm, 2.5 µm, 5 µm, and 10.0 µm are standard. Particulate matter PM 2.5, PM 10, and TSP (total suspended particulate) may also be concurrently displayed and logged. As a "stand-alone" instrument, it can be used as a portable device, or it can be integrated into a building's automation system [28].

Figure 5. Gray Wolf PC-4000 Particle/Mass Monitor Plus.

When using Direct Sense II smart probes, the air monitoring probes accommodate from two up to eight smart sensors into a single hand-held device. It is possible to select 25 different aspects of indoor air quality, TVOCs (Total Volatile Organic Compounds), carbon dioxide (Nondispersive Infrared—NDIR—CO_2 Sensors), carbon monoxide, ozone, nitrogen dioxide, ammonia, sulfur dioxide, chlorine, hydrogen sulfide, humidity (%RH), temperature (°C), and many others. The Direct Sense II probes (Figure 6) connect to Gray Wolf's Advanced Sense® meters, which enable additional parameters, such as particulates, differential pressure, air velocity, and formaldehyde [28].

Figure 6. The Direct Sense II probes and Gray Wolf's Advanced Sense® meters.

The Kimo AMI 300 is a multifunction device which is used to measure pressure, temperature, humidity, air velocity and air quality. This kit (Figure 7) is the ideal tool for any maintenance and commissioning engineer [29].

Figure 7. The multifunction device KIMO AMI 300.

Features:

- Manometer—used for pressure and airflow measurement;
- Thermo-hygrometer—used for testing dew point, wet temperature, enthalpy and absolute temperature;
- Air quality probe—used for measuring the level of CO in a space;
- Current/voltage module;
- Thermometer—thermocouple and thermocouple temperature probes.

4. Results

Particular attention is paid to the activity of monitoring, maintaining, and improving air quality as it is the fastest way to understand the transport of pollutants in the environment. At the European and international level, air pollution has become a permanent concern. The monitoring process was carried out along the transit road of the municipality with the aim of capturing the two identified sources of air pollution—released gases from burning stoves and exhaust gases from car traffic. Air sampling aims at the analysis of either the gaseous compounds or the pollutant compounds present in the atmosphere in the form of solid particles [25]. The following parameters were measured: CO, CO_2, NO, NO_2, SO_2, PM_1, $PM_{2,5}$, PM_{10}, and TSP. The monitoring points were located at five roundabouts and at an intermediate point on the transit road of Petroșani because this transit road is the line that delimits the historical areas/neighborhoods/outskirts (Colonie, Livezeni, etc.) from the rest of the city. Following the performance of the measurements, sets of 30 values were obtained for each monitored parameter at each of the six measurement points. All these sets of values were centralized; the most representative in assessing the air quality are the maximum values measured during the entire monitoring project. The exceedances of the values in the regulations [27] are marked with bold font in Table 1.

Table 1. Maximum of measured values.

Parameter	Monitoring Point / Date	7 March 2020	13 March 2020	18 May 2020	24 May 2020 * (Night)	2 July 2020	M.A.C.
CO [mg/m^3]	MP1	1.00	4.50	2.40	-	5.30	6.0 mg/m^3
	MP2	1.20	3.00	3.40	-	2.30	
	MP3	1.40	1.20	2.30	0.40	2.00	
	MP4	1.80	1.20	0.00	0.90	0.00	
	MP5	1.30	0.50	4.10	-	3.80	
	MP6	1.10	1.80	2.60	-	1.30	
CO_2 [mg/m^3]	MP1	565.00	1081.00	682.66	-	948.00	**
	MP2	505.00	824.00	748.55	-	1046.00	
	MP3	458.00	828.00	774.17	549.06	1015.0	
	MP4	492.00	1002.00	724.76	580.17	1061.0	
	MP5	475.00	964.00	770.51	-	966.00	
	MP6	1624.0	766.00	768.68	-	1025.0	
NO [mg/m^3]	MP1	0.30	0.30	0.00	-	0.09	**
	MP2	0.30	0.30	0.00	-	0.08	
	MP3	0.30	0.30	0.00	0.00	0.10	
	MP4	0.31	0.30	0.00	0.00	0.02	
	MP5	0.30	0.30	0.00	-	0.04	
	MP6	0.30	0.30	0.00	-	0.04	
NO_2 [mg/m^3]	MP1	0.12	0.12	0.07	-	0.20	0.3 mg/m^3
	MP2	0.11	0.11	0.13	-	0.20	
	MP3	0.10	0.11	0.11	0.12	**6.00**	
	MP4	0.15	0.10	0.12	0.14	**4.20**	
	MP5	0.11	0.10	0.17	-	**11.40**	
	MP6	0.13	0.11	0.13	-	**4.90**	
SO_2 [mg/m^3]	MP1	0.12	0.11	0.18	-	0.02	0.75 mg/m^3
	MP2	0.08	0.00	0.53	-	0.00	
	MP3	0.04	0.00	0.40	0.20	0.00	
	MP4	0.06	0.00	0.30	0.06	0.00	
	MP5	0.03	0.00	0.26	-	0.00	
	MP6	0.04	0.00	0.23	-	0.00	
PM_1 [mg/m^3]	MP1	0.02	0.04	0.01	-	0.01	**
	MP2	0.06	0.01	0.01	-	0.01	
	MP3	0.02	0.02	0.01	0.00	0.01	
	MP4	0.01	0.01	0.03	0.01	0.01	
	MP5	0.02	0.01	0.01	-	0.01	
	MP6	0.02	0.02	0.00	-	0.01	
$PM_{2.5}$ [mg/m^3]	MP1	0.03	0.17	0.03	-	0.03	**
	MP2	0.06	0.10	0.03	-	0.10	
	MP3	0.02	0.12	0.07	0.01	0.08	
	MP4	0.03	0.06	0.03	0.01	0.03	
	MP5	0.03	0.06	0.02	-	0.03	
	MP6	0.04	0.10	0.02	-	0.04	
PM_{10} [mg/m^3]	MP1	0.04	1.54	0.26	-	0.29	**
	MP2	0.06	1.11	0.19	-	0.54	
	MP3	0.03	0.51	0.43	0.03	0.64	
	MP4	0.20	0.26	0.17	0.02	0.09	
	MP5	0.04	0.40	0.09	-	0.17	
	MP6	0.08	0.83	0.10	-	0.09	
TSP [mg/m^3]	MP1	0.04	**1.55**	0.26	-	**0.54**	0.5 mg/m^3
	MP2	0.06	**1.12**	0.19	-	**0.97**	
	MP3	0.04	**0.52**	0.43	0.04	**1.10**	
	MP4	0.20	0.27	0.18	0.04	0.34	
	MP5	0.04	0.41	0.11	-	0.47	
	MP6	0.08	**0.83**	0.11	-	0.43	

* Determinations performed at night to capture air quality at a lower level of road traffic values; ** parameters without normative.

Moreover, in the present monitoring project the meteorological conditions were taken into account (Table 2); these were, respectively, wind speed and direction and pressure; humidity and temperature; the geographical conditions in the area where the sources and receivers were located; and the landforms and the land use.

Table 2. Measured average values of atmospheric conditions.

Parameter	Monitoring Point \ Date	7 March 2020	13 March 2020	18 May 2020	24 May 2020 * (Night)	2 July 2020
V [m/s]	MP1	0.311	0.363	0.576	-	1.012
	MP2	0.161	0.398	0.728	-	1.455
	MP3	0.496	1.354	0.415	0.272	1.386
	MP4	0.331	1.508	0.840	0.237	0.828
	MP5	0.156	1.380	1.180	-	0.909
	MP6	0.194	0.408	0.455	-	2.962
P [hPa]	MP1	936.9	937.9	944.4	-	940.3
	MP2	936.8	937.2	944.6	-	941.2
	MP3	935.7	937.1	945.6	947.0	941.2
	MP4	937.2	939.0	949.0	950.0	943.4
	MP5	939.0	940.1	949.0	-	944.5
	MP6	940.4	941.2	952.1	-	945.6
W [%RH]	MP1	59.95	38.53	43.14	-	42.89
	MP2	68.28	40.02	31.13	-	41.99
	MP3	76.43	36.55	25.72	64.01	37.43
	MP4	82.19	34.00	31.36	70.69	42.57
	MP5	77.66	34.76	25.31	-	36.58
	MP6	75.63	38.45	27.42	-	38.40
T [°C]	MP1	8.8	19.0	8.0	-	28.0
	MP2	8.4	20.2	11.0	-	29.0
	MP3	9.3	22.1	12.0	11.0	29.6
	MP4	6.8	23.2	13.0	11.0	29.6
	MP5	9.0	22.6	14.0	-	30.3
	MP6	8.0	20.9	14.0	-	31.1

* Determinations performed at night to capture air quality at a lower level of road traffic values.

The total suspended particulate (TSP) concentrations recorded on 13 March exceeded the maximum allowed concentrations (MAC), as related to the norms taken into account, with an average recorded atmospheric humidity of 37% and an average temperature of 21 °C. The maximum allowed concentrations of the TSP were also exceeded on 2 July, with an average value of atmospheric humidity of 40% and an average temperature of 29.6 °C, which was most likely due to heavy traffic (road trains) on the transit road of Petroșani. In this context, it seems that the only source of the increase in nitrogen dioxide concentrations are the internal combustion engines using fossil fuels as a result of car traffic. The maximum values of 24 May, during the night measurements performed at the two monitoring points, MP3 and MP4, respectively, show significant decreases compared to the values determined during the day monitoring, which suggests that a lower level of traffic values at the time of the measurements has a positive effect on air quality. In order to measure the ecological impact generated by road traffic, several case studies were carried out in Petroșani (Romania) on the impact of road traffic on the population by using an improved ecological footprint calculation method [30]. The measurements performed in 2017 revealed a relatively high value of ecological footprint generated by road traffic for Petroșani. As a consequence, Petroșani town hall recommended annual monitoring of the road traffic ecological footprint. The synergy of the road traffic with the new environmental objectives for sustainable development requires new correlations between the inputs of the instruments measuring road traffic pressures on ecosystems and the environmental targets [30].

For comparison, presented below are the results of the closest station of the National Air Quality Monitoring Network (RNMCA). This network is dedicated to public information in real time regarding the air quality parameters, monitored in over 100 stations all over Romania [31]. The single monitoring station of RNMCA in the Jiu Valley bituminous coal basins, named HD-5, is located about 2 km from Paroșeni TPP, in Vulcan city. We chose to bring into the discussion the values provided by the HD-5 automated station, not necessarily for comparison with the measured values, but to especially highlight the reduced influence of the Paroșeni TPP on local air quality parameters in the context of the recent activity decline due to the decarbonization process. In this automated station, not all the parameters monitored in the current study performed in Petroșani can be found. Therefore, the CO_2, PM_1, $PM_{2.5}$, and TSP values are missing, but even so, the comparison is conclusive for all the other values (Table 3).

Table 3. Values provided by automated HD-5 station.

Parameter \ Date	7 March 2020	13 March 2020 *	18 May 2020	24 May 2020 (Night)	2 July 2020 *	M.A.C.
CO [mg/m^3]	0.82–1.07	0.94–1.25	1.47–1.59	1.43–1.47	0.15–0.44	6.0 mg/m^3
CO_2 [mg/m^3]	-	-	-	-	-	**
NO [mg/m^3]	0.01–0.02	0.01–0.03	0.01–0.03	0.01–0.02	0.01–0.02	**
NO_2 [mg/m^3]	0.01–0.02	0.01–0.02	0.01–0.02	0.02	0.01–0.02	0.3 mg/m^3
SO_2 [mg/m^3]	0.01	0.01–0.04	0.01	0.01	0.00	0.75 mg/m^3
PM_1 [mg/m^3]	-	-	-	-	-	**
$PM_{2.5}$ [mg/m^3]	-	-	-	-	-	**
PM_{10} [mg/m^3]	0.02	0.01–0.04	0.01–0.03	0–0.01	0.02	**
TSP [mg/m^3]	-	-	-	-	-	0.5 mg/m^3

* In these days, the Paroșeni TPP was in working order, generating about 3000 MWh electricity daily out of the approximately 107,000 MWh produced in 2020 [32]; ** Parameters without normative.

As can be seen in Figure 8, the maximum allowed concentrations—the red line on the charts, was exceeded in the case of NO_2 and TSP at certain monitoring points under specific weather circumstances.

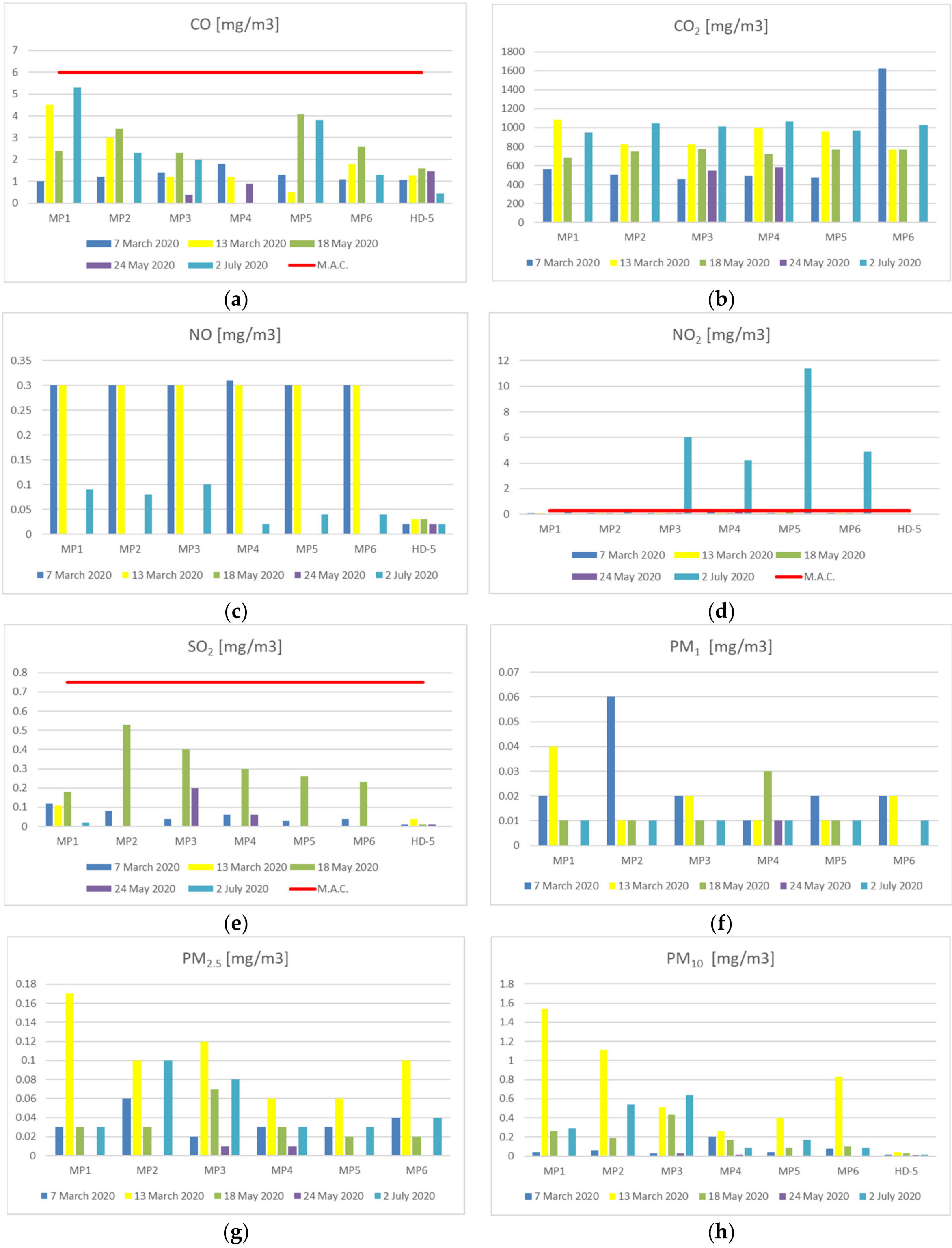
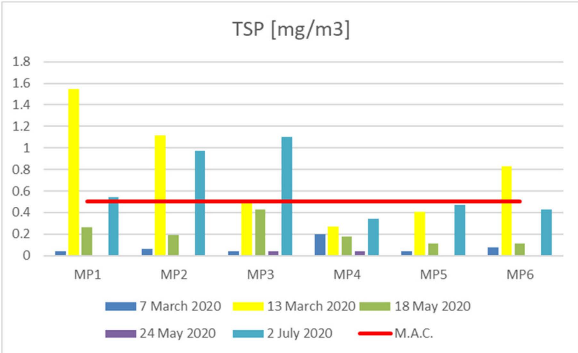


Figure 8. *Cont.*



(**i**)

Figure 8. Maximum of measured values of CO (**a**), CO_2 (**b**), NO (**c**), NO_2 (**d**), SO_2 (**e**), PM_1 (**f**), $PM_{2\cdot5}$ (**g**), PM_{10} (**h**) and TSP (**i**) at the monitoring points on the E79 transit road and at the automated station HD-5.

The values of the atmospheric conditions provided by the HD-5 automated station are pretty similar to the values provided by the measurements performed on the transit road of Petroșani city (Table 4).

Table 4. Values of atmospheric conditions provided by the HD-5 automated station.

Parameter \ Date	7 March 2020	13 March 2020	18 May 2020	24 May 2020 (Night)	2 July 2020
V [m/s]	0–3.8	0.2–5.7	0.4–3.6	0.1–3.1	0.3–3.0
P [hPa]	933.4–935.1	936.1–941.1	948.6–949.6	944.2–946.3	939.9–941.7
W [%RH]	62–99	52–99	79–99	93–99	58–99
T [°C]	5.1–12.3	3.6–20.7	14.1–22.2	10.7–14.4	17.1–28.6

For total compliance, all the values were taken from the daily statistics generated by the HD-5 automatic station for the same time slots as the measurements performed on the transit road of Petroșani city. We can note that, for the most part, the values measured by the HD-5 automated station are lower than those measured in the current study on the transit road of Petroșani, which suggests a reduced influence of the Paroșeni TPP on the local air quality parameters.

5. Discussion

The mining industry in the Jiu Valley had and still has a significant influence on the environmental pollution factors, both by the discharge of noxious substances into the atmosphere and the large quantities of waste produced, as well as by their variety. Air pollution is a complex phenomenon involving a multitude of pollutants that can cause alterations in the health of the population and in the quality of the environment, causing serious effects, depending on the concentration or duration, acting either through high concentrations for a short period or through reduced concentrations for a long period [25,33].

Currently, the technology that Paroșeni TPP benefits from allows it to operate within the environmental standards in force, both in the production phase and in terms of waste storage (ashes).

Caprișoara tailing pond is located near the city of Vulcan in the western Jiu Valley, in the Meridional Carpathian Mountains, and stores the ashes from the Paroșeni TPP. Previous research has developed various climate scenarios to model the PM dispersion generated by the Caprișoara tailings pond and the effect on the city of Vulcan in the Jiu Valley.

According to that research, the contribution of the Caprișoara tailings pond to PM generation in Vulcan is limited to periods when the wind blows from the south and south-southwest, with an above-average intensity in the conditions of a turbulent atmosphere, which happens during the summer storms [33].

The national energy picture shows variable shares of the use of different resources, with nocturnal/diurnal and seasonal oscillations and percentages exceeding 30% for coal in the winter months and decreasing to below 15% in the summer months (Figure 9) [34].

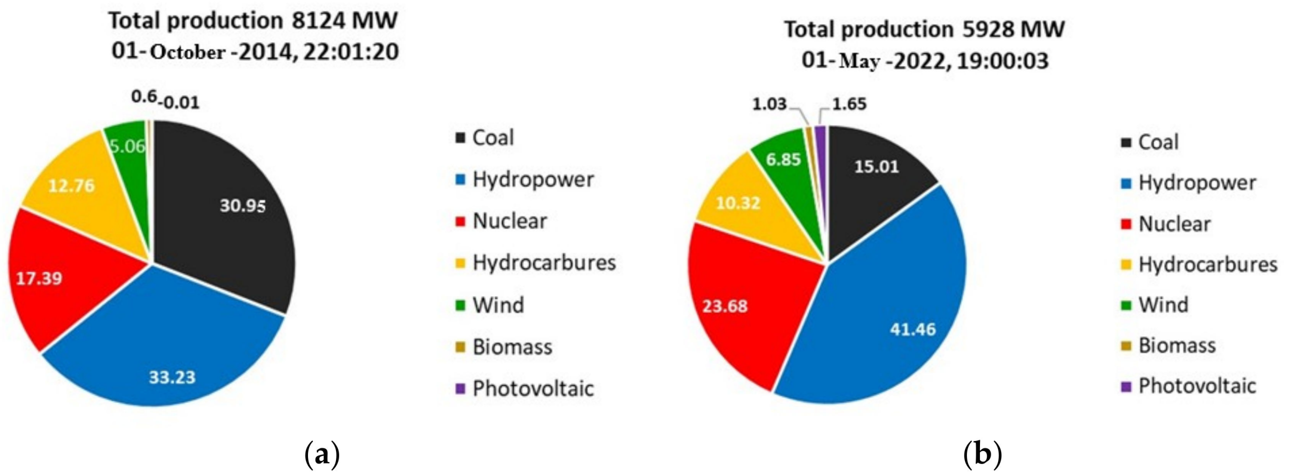


Figure 9. The share of energy sources in Romania on (**a**) 1 October 2014 and (**b**) 1 May 2022.

In 2020, the Romanian energy industry produced 53.74 TWh of various resources, of which fossil fuels accounted for almost 35% (gas 18.17%, coal 16.55%, fuel oil 0.11%). The Paroșeni TPP produced in 2020 about 107,000 MWh, which means 0.2% of the total electricity production in Romania [35].

Over the last decade, bituminous coal has contributed about 5 to 7 percent to the electricity sector [13,14], but in the current context of Romanian energy resources the bituminous coal represents 1–2% and sometimes under one percent. From an ecological perspective, the share of bituminous coal participation must be increased at the expense of lignite usage.

6. Conclusions

Based on the performed measurements, we found that at humidity above 50% and low temperatures (6–9 °C) there were no exceedances of the values of the monitored parameters related to the norms taken into account. In the case of average humidity and temperatures (between 30–40% and 19–23 °C), there were in some places exceedances of total particulate matter, while at medium humidity (36–43%) and high temperatures (28–31 °C) there were sometimes exceedances of both NO_2 and total particulate matter. This suggests that the dispersion of pollutants is influenced by the weather. Due to the exceeding of the limit values for NO_2 only in the warm season, its origin from the burning in stoves of different types of fuels can be excluded. Thus, it turns out that the internal combustion engines (ICE) are responsible for the high values of this parameter, as a result of road traffic. In order to improve the air quality control and management in Petroșani, considering all that was presented in this case study, to obtain a clearer picture of the share of the two main sources of air pollution, it is recommended that the monitoring activities during all the seasons in different weather conditions be intensified and that there should even be continuous monitoring, corroborated with the modeling of the pollutant dispersion and with more road traffic studies.

The comparison between the values provided by the HD-5 automated station and the measured values in the current study on the transit road of Petroșani suggested a reduced influence of the Paroșeni TPP on local air quality parameters.

Based on the variation of the measured values in one of the most important historical Romanian bituminous coal mining basins, the preliminary result suggests a decrease in local air quality parameters related to the decarbonization process. The Paroșeni TPP's activity diminished but the combustion of non-compliant materials (textile waste from secondhand stores and warehouses) in individual stoves has increased and the gases released by the combustion process are eliminated directly (without special filters installed in the chimneys of the houses) into the atmosphere with a negative effect on local air quality.

The current geo-politic and economic context has brought to the attention of specialists the need to also re-evaluate the strategies of the energetic and non-energetic mining sector.

In energetic mining sector, even if it is expected that the decarbonization process will slow down, diminish, or even stop, fossil fuel burning still remains a necessity. Until the regaining of energy independence, the finding of an energetic alternative at the expense of the simple shutting down of the thermal power plants is preferred. This is an opportunity for those regions rich in fossil fuels and especially coal. Moreover, it is more important to renounce the use of stoves for home heating even if they burn coal or non-compliant materials, but first of all, the local, regional, or central authorities must find optimal solutions before the decommissioning the fossil fuel industry, in order to not compel the population affected by poverty to improvise heating solutions, which can have much higher environmental costs for all of us.

Regarding the energetic mining sector, the main challenge comes from the perspective of compliance with environmental requirements, which means that the use of bituminous coal is preferable in terms of lower environmental loads compared to the use of lignite. In Romanian energetical resource usage, from an ecological perspective, the share of bituminous coal participation must be increased at the expense of lignite usage.

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