UNIVERSITY OF PETROȘANI
DOCTORAL SCHOOL
DOCTORAL FIELD: MINES, OIL AND GAS

PhD THESIS

- summary -

AIR QUALITY MONITORING AND POLLUTANTS DISPERSION MODELING IN PETROSANI CITY IN THE CONTEXT OF DECARBONIZATION AND RESTRUCTURING OF THE MINING INDUSTRY

Scientific coordinator:
***Professor PhD.Eng.* Sorin Mihai RADU**

PhD Candidate:
***Eng.* Evelina REZMERIȚA**

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Summary

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Overview:

Air pollution is a complex phenomenon that involves a multitude of pollutants that can affect population health and environmental quality, depending on their concentration or duration, causing severe effects either through high concentrations in a short time or through low concentrations over a long period. This work addresses a highly topical issue regarding the complex mechanisms that operate post-restructuring in the Jiu Valley Mining Basin, with a special focus on air quality in Petroșani Municipality, in the context of decarbonization, knowing that this area has faced serious pollution problems over time (caused by the exploitation and processing of useful minerals).

The doctoral thesis highlights a pressing issue for Petroșani Municipality and the Jiu Valley, namely air pollution. Most previous studies suggest a reduction in impact and a general improvement in air quality as a result of the cessation of extractive activities, without considering the immediate lack of an alternative to coal as a primary energy resource locally and regionally. Without solid scientific arguments, other groups of authors, based rather on the interpretation of general theoretical aspects placed in an inadequate local context, either deliberately ignore or completely misunderstand the issue and the deep interactions between the industrial specifics of the area, geology, morphology, climate, and other elements defining this special geographical area, regarding the lack of alternative energy resources in the short and medium term. All these factors, coupled with an alarming increase in the number of oncology patients in the area, necessitate a different approach that highlights, through comparative studies, the influence of various air pollution sources and, where possible, quantifies them.

At various levels of detail, the documentation of the subject began about four years ago and was carried out individually or in groups that included other students and master's students or in groups of faculty or researchers, with different responsibilities and contributions from the author of the doctoral thesis, which resulted in the validation of research results at scientific symposia/conferences or through publication in established journals in the field.

Contemporary socio-economic realities highly expose and even make certain population categories vulnerable, as they have limited options due to the lack of specific infrastructure (the absence of a centralized heating system, lack of access to natural gas networks, etc.) regarding heating sources. All these are part of the historical neighborhoods of Petroșani Municipality (the former workers' colonies), real sources of air pollution due to the systematic use of waste from the second-hand clothing industry as fuel.

One of the most polluting industries is the textile/clothing and footwear industry. Their ecological footprint is caused by high consumption of energy, water, and chemicals, the generation of textile waste, and water contamination with microfibers resulting from washing. The textile/clothing and footwear industry generates 8-10% of global carbon

emissions, exceeding the combined emissions from aviation and maritime transport. Throughout the entire lifecycle of textile products, from fiber production to waste disposal, they generate multiple sources of pollution. Numerous studies show that reusing and recycling textiles have more environmental benefits than landfilling and incineration. For example, according to Dutch aWEARness's estimates, textile recycling can offer energy, water, and carbon dioxide savings of 64%, 95%, and 73%, respectively, compared to standard non-recycled textiles. This also reduces the consumption of raw materials by 61%, as waste is eliminated.

The comparative study of air pollution sources in Petroșani Municipality involves identifying and quantifying their proportions primarily for the design of concrete measures to improve air quality, with beneficial effects on population health. The pollution pattern that can be highlighted by this research is then applicable to other cities in the Jiu Valley affected by the restructuring of mining activities, so the expected effects of the decarbonization process can be applied locally and regionally. The thesis also aims, for the first time, to create a profile of the gases resulting from the burning of these wastes and to emphasize their interactions with human health.

Even though specific environmental engineering tools were generally used, the doctoral thesis is strongly anchored in the current realities of the Mining, Oil, and Gas field, dictated mainly by the need to undergo an accelerated decarbonization process by abandoning the exploitation and use of humic coals, specifically the anthracite from the Jiu Valley mining basin, as conventional fuels. The doctoral thesis is also an exercise in multidisciplinary and interdisciplinary integration of various knowledge from the fundamental domain of engineering sciences by using established or innovative specific tools, with direct implications in the restructuring process of the mining sector, which can especially lead to the identification of friendly alternatives in the use of solid fuels and achieving the general expected effect of decarbonization locally or regionally.

The study targeted two distinct components, referring on one hand to air quality monitoring and on the other to traffic monitoring on DN 66/E79, the section serving as a transit road (beltway) for Petroșani Municipality.

Thus, air quality determinations were conducted in the Rusu area and the Parâng resort, the central-northern part of the municipality including the Brădet area and the Former Workers' Colony/Historical Center - to create a clear picture of the pollution levels in residential areas compared to natural areas, as well as comparisons between the air pollution levels in the central area and the historical neighborhoods of the municipality, and on the beltway - as this infrastructure element delineates the historical areas (the Colonie, Livezeni neighborhoods, etc.) from the rest of the city, being thus the place of interference of the main air pollution sources in Petroșani Municipality, while traffic studies were conducted at six distinct points on DN 66/E79.

The transit road of Petroșani Municipality, the most important settlement in the Jiu Valley, was considered relevant to capture the two main identified sources of air pollution, namely the gases and suspended particles resulting from burning in individual installations used for heating homes that are not equipped with pollutant retention systems, where often,

as fuel, significant amounts of waste from the second-hand clothing/footwear industry are burned (a common practice especially in historical areas, such as the Colonie, Livezeni neighborhoods, etc.), and the gases and suspended particles resulting from car traffic. The characteristic parameters of these two pollution sources are: CO, CO2, NO, NO2, SO2, PM1, PM2.5, PM10, PMTOTAL.

In the monitoring program conducted, the objectives and specific tasks of a monitoring system, monitored parameters, monitoring points, frequency, and duration of the monitoring program, and the equipment used for conducting this program were clearly established from the beginning. All operations and procedures regarding the collection, storage, processing, and interpretation of data were properly completed to obtain a clear picture and the necessary information to describe air quality.

The monitoring of pollutants was conducted in several stages, starting in 2020, from March to July inclusive, then resumed in February and July 2023.

Ultimately, 50 measuring/monitoring points resulted (42 exclusively for air quality determination, 6 for air quality determination and traffic studies, 1 additional point for air quality determination in the most polluted area of the historical neighborhood, and for comparison, 1 point represented by the Vulcan automatic station, HD-5, from the county air quality monitoring network), where all identified and described pollution sources in Chapter 2 were taken into consideration. These points also targeted several open construction sites in the area of former industrial platforms URUMP/UMIROM/GEROM S.A. under demolition for iron waste recovery and UPSRUEM SA, where a store dealing with the sale of building materials and home and garden products is being built.

The distribution of these measuring/monitoring points is as follows:

- 11 air quality determination points, numbered from 1 to 11, were placed in the Rusu/Parâng area;
- 26 air quality determination points, numbered from 12 to 37, were placed in the historical neighborhood/workers' colony;
- 5 air quality determination points, numbered from 38 to 42, were placed in the central-northern area of Petroșani Municipality and the Brădet area;
- 6 air quality determination points and traffic values, noted PM1-PM6, on DN 66/E79, the section serving as a transit road for Petroșani Municipality;
- 1 additional point for air quality determination in the most polluted area of the historical neighborhood;
- 1 point represented by the Vulcan automatic station, HD-5, from the county air quality monitoring network.

In the Parâng area, determinations were conducted in a single session, during winter, to capture any interference from pollution resulting from heating vacation homes/cabins in the area, while in the historical neighborhood, central-northern area, and Brădet area, measurements were conducted during the cold season, both at night and during the day, to capture fluctuations in pollutant or suspended particle concentrations when the population was forced to use heating sources and when this was not necessary. All these measurements

were conducted in 2023, while determinations on the transit road were conducted in 2020 and 2023 for air quality and 2023 for traffic studies.

The obtained data showed that although road traffic also has a proportion in the general balance of air pollution in Petroșani Municipality, the main source of pollution remains the significant number of households in the historical neighborhood/former workers' colony, where thermal agent production, cooking, and heating are carried out based on burning solid fuels in individual installations not equipped with pollutant retention systems. Often, conventional solid fuels (coal, wood, etc.) are replaced by the poorest inhabitants of this neighborhood with materials from the second-hand clothing/footwear industry, thus burning significant amounts of such waste. The phenomenon of burning clothing waste from the second-hand industry in the historical neighborhoods of the Jiu Valley is complex and alarming, having a detrimental impact on human health and the environment. Burning textile waste has become a common practice in the historical neighborhoods of the Jiu Valley, in the context where residents face a lack of alternative heating sources following the mine closures and the decarbonization process. Dramatic increases in atmospheric pollution levels were recorded compared to wood burning, for example. It is important to understand that the pollution generated by burning textile waste from the second-hand industry has a significant impact not only on the environment but also on human health. Increases in levels of certain noxious gases and suspended particles measured in homes where waste from the second-hand clothing/shoe industry is burned suggest, first and foremost, a major health risk to the residents of these buildings. At the same time, burning various materials identified in the structure of these wastes poses a significant risk to human health in the case of long-term exposure, both for the residents of the buildings where the practice is common and for the population of the surrounding neighborhoods (as evidenced by the determinations made in the historic district/worker colony, at points 12-37) as well as neighboring areas (as evidenced by the determinations made in the central-northern area of the municipality, at points 38-40).

The fact that the Jiu Valley is generally an intermontane depression with a high frequency of thermal inversion phenomena, which also hinders the dispersion of atmospheric pollutants, the natural environment, and the morphology of the terrain in the Municipality of Petroșani area favor the retention of atmospheric pollutants near the ground, persisting longer in the polluted areas.

PhD Thesis structure

The doctoral thesis is developed over 156 pages, includes numerous tables, graphs, photographs, plates, and annexes, and is structured into six chapters:

- **Chapter 1** refers to the description of the studied area, including details about the history and restructuring of mining, geology, morphology, climate, and other elements defining the Petroșani basin.
- **Chapter 2** involves a rigorous inventory of atmospheric pollution sources in the studied area, conducting comparative, classical - instrumental, and innovative studies to determine urban pollution sources in a mining area undergoing decarbonization,

with a special focus on air quality and human health in the Municipality of Petroșani, in the Jiu Valley mining basin.

- **Chapter 3** outlines the working methodology for the studies conducted and the specific equipment to be described in its subchapters, detailing the tools and technology used for air monitoring and the method of conducting traffic studies. Monitoring points were established considering the main pollution sources. These sources are represented, on the one hand, in historical areas (Colonie, Livezeni, etc.) by individual installations used for heating homes that are not equipped with pollution retention systems, where significant amounts of waste from the second-hand clothing/shoe industry are often burned as fuel, and on the other hand by road traffic on the transit road of the Municipality of Petroșani.
- **Chapter 4** includes the collection of air samples based on procedures in accordance with recognized and validated "standard methods" to guarantee the provision of scientifically equivalent quality data. It also presents all the results of these measurements considering the maximum allowable concentration according to STAS 12574-87.
- **Chapter 5** refers to European emission standards that define acceptable limits for exhaust emissions from new vehicles sold in EU and EEA member states. Subchapter 5.2 describes the procedure for conducting traffic measurements in the Municipality of Petroșani. The results of these measurements are represented in tables, thus recording the maximum traffic values.
- **Chapter 6** focuses on the dispersion of pollutants in the atmosphere to present a clearer picture of the pollution level, applying spatial modeling methodologies. These programs allow the interpretation of air quality up to tens of kilometers from the source. Various pollution scenarios can be observed visually using these dispersion programs, depending on weather conditions.

The doctoral thesis concludes with a series of conclusions and recommendations regarding the continuation of research on air pollution in the Municipality of Petroșani to minimize and control these pollution sources as much as possible, using well-established standard methods.

Contributions and future research directions

For a complete picture of atmospheric pollution in the Municipality of Petroșani, especially regarding the complex phenomenon highlighted in current research that refers to home heating by burning solid fuels, particularly significant amounts of waste from the second-hand clothing/shoe industry, in individual installations not equipped with pollution retention systems, a phenomenon commonly found in historical districts, especially in the former worker colony, it is recommended to continue research by:

- Creating profiles of gases resulting from the burning of waste from the second-hand clothing industry, determining their toxicity based on each identified material type, and whether there are increases in outdoor or indoor concentrations in buildings where such materials are used as fuel;

- Evaluating the consequences of these gases on human health;
- Precisely identifying the number of such sources;
- Quantifying the amount of waste used as fuel;
- Continuously monitoring atmospheric pollution concurrently with traffic studies;
- Raising public awareness about the risks they are exposed to/from burning waste as fuel;
- Sensitizing authorities to stop the phenomenon.
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Final Conclusion

Even though this doctoral thesis generally operated with specific Environmental Engineering tools, for which sufficient arguments were presented to support both the concerns and specific competencies through the completion of undergraduate and master's cycles, this work is strongly anchored in the current realities of the Mining, Petroleum, and Gas sector, driven by the necessity of an accelerated decarbonization process by abandoning the exploitation and use of humic coals as conventional fuels, specifically the bituminous coals in the Jiu Valley mining basin. The doctoral thesis is also an exercise in the multi and interdisciplinary integration of various knowledge from the Fundamental Field of Engineering Sciences using established or innovative tools specific to it, with direct implications in the restructuring process of the mining sector, which can especially lead to identifying friendly alternatives in the use of solid fuels and achieving the overall desired effect of decarbonization locally or regionally.

The innovative methods proposed in this doctoral thesis aimed, on the one hand, at formulating new theoretical concepts regarding atmospheric pollution in the context of decarbonizing traditional mining areas, with a special focus on the Jiu Valley and the Municipality of Petroșani, and on the other hand, creating prototypes/products/alternative models for monitoring traffic and atmospheric pollution, with significant cost reductions.