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ANALYSIS OF THE FACTORS CONTRIBUTING TO ENVIRONMENTAL POLLUTION IN THE SUBCARPATHIAN PROVINCE

The work presents an examination of Poland's environmental condition, with a focus on the contamination of air and surface waters by various chemical elements. The composition and quality of the air impact ecosystems, plant growth, the animal kingdom, and shape human living conditions. These factors play a significant role in driving global climate change. The repercussions of air pollution encompass phenomena such as smog, acid rain, ozone layer depletion, as well as impacts on industrial and municipal facilities, contributing to global warming. The article conducts an analysis of air pollution, surface water contamination, and electromagnetic radiation pollution in Subcarpathian, utilizing the city of Stalowa Wola and the Stalowa Wola county as case studies. This choice is informed by the fact that Stalowa Wola stands as one of the largest industrial cities in the Subcarpathian Voivodeship, suggesting that environmental pollution levels in this county might surpass those in other regions. The article also delineates the features of air and surface water pollution, along with electromagnetic radiation characteristics. It scrutinizes pollution sources in the mentioned county, explicates the causes of such pollution, and proposes strategies for environmental amelioration. The analysis of the environmental status of Stalowa Wola county during the years 2018 to 2020 is presented, accompanied by recommendations for initiatives that could enhance its condition. The research findings indicate that the condition of uniform segments of surface waters, as evaluated through conducted studies, is deemed poor. The discharge of wastewater from specific pollution points, particularly wastewater from municipal origins, emerges as the predominant cause of subpar water quality.

Keywords: Environmental Pollution, Air and Water Contamination, Global Climate Change, Industrial Pollution Analysis

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1. Introduction

In recent years, numerous member states within the European Union have confronted significant challenges related to the deterioration of air quality, pollution of both surface and groundwater, and the degradation of soil. These environmental issues have prompted substantial concerns, necessitating the implementation of comprehensive strategies for effective mitigation and improvement. Unfortunately, the complexities associated with environmental pollution are diverse and intricate.

Within the framework of our research, we are dedicated to conducting an in-depth analysis of environmental pollution, specifically within the Subcarpathian province. This commitment involves a meticulous examination of the various sources contributing to pollution in the air, surface waters, and the broader environment, with a particular focus on the emission of electromagnetic radiation. Our objective is to uncover the layers of intricacy inherent in pollution dynamics, providing a nuanced understanding. This understanding will, in turn, serve as the cornerstone for developing targeted and impactful measures to address and ameliorate the environmental challenges faced by the region.

The detailed investigation aims to provide a nuanced understanding of the diverse factors contributing to environmental pollution, enabling the development of targeted strategies for effective mitigation and environmental improvement in the Subcarpathian Province.

2. Factors Contributing to Environmental Pollution in the Subcarpathian Province

According to the European Environment Agency Report, approximately 40% of surface waters within the European Union maintain a good or very good status. In contrast, Poland exhibits a subpar ranking concerning river cleanliness, with only 10% of its rivers boasting a good or very good ecological status or potential. Notably, the southern region of Poland, characterized by numerous upland and mountain rivers, demonstrates discernible pollution, as swift currents transport various impurities downstream, ultimately affecting major rivers such as the Odra and the Vistula, which flow into the Baltic Sea [1].

Upon analyzing significant anthropogenic influences, the National Water Management Authority identified that in the Subcarpathian Voivodeship, the primary threats to surface water quality arise from point-source pressures associated with industrial and municipal pollution. Additionally, pollution from area sources, including diffuse sources, introduces further pressures. Monitoring the state of surface waters reveals that pollution from municipal sources is a major challenge for many homogeneous water bodies in achieving environmental goals. Furthermore, this monitoring confirms substantial water

pollution within the voivodeship, exacerbated by effluents from agricultural and urban areas, as well as unidentified point sources [2].

Data from the Central Statistical Office indicates an increase in the quantity of treated municipal sewage in the Subcarpathian Province in recent years. The quantity of untreated sewage has remained relatively constant for several years, hovering around 1 million m^3. The districts of Sanok, Łańcut, Krosno, Stalowa Wola, Jasło, Jarosław, Leżajsk, Mielec, Dębica, Rzeszów, the City of Rzeszów, the City of Przemyśl, and the City of Krosno generate the largest quantities of sewage.

As of the end of 2018, there were 228 biological municipal sewage treatment plants in the voivodeship. The Wisłoka, Wisłok, and San rivers bear the highest sewage loads in the region. The industrial structure in the province is characterized by considerable diversity, with almost 70% of industrial production in the food, chemical, electromechanical, and aerospace industries.

Special economic zones, Tarnobrzeska SSE Euro-Park Wisłosan and SSE Euro-Park Mielec, play a crucial role. The industrial sector has a relatively minor impact on surface water quality in the voivodeship, with notable impacts occurring locally in the basins of the Jasiołka and Wisłoka rivers (petrochemical industry), the Strwiąż river basin (mining industry), and the Trzebośnica river basin (chemical industry).

Industrial pressure may manifest in streams receiving substances particularly harmful to the aquatic environment, including priority substances, such as polycyclic aromatic hydrocarbons (mainly from petrochemical and mining industries) and atmospheric deposition. Alarming monitoring results of priority substances in waters across the Subcarpathian Provinceand the country reveal concentrations exceeding norms, encompassing polycyclic aromatic hydrocarbons and selected substances like heptachlor, brominated diphenyl ethers, and mercury, present in the tissues of aquatic organisms.

According to Central Statistical Office data, the quantity of industrial effluents discharged directly into waters requiring treatment has shown a decreasing trend in recent years, with over 90% originating from plants in specific counties and cities [2].

The composition and quality of air significantly impact ecosystems, plant production, the animal world, and human living conditions, primarily contributing to global climate changes [3]. Air pollution consequences encompass smog, acid rain, the ozone hole, and global warming. Smog, caused by unfavorable meteorological conditions and emissions from low emitters, is air pollution in the lower atmosphere. Acid rain refers to atmospheric precipitation with a pH below 5.6, resulting from the absorption of acidic air pollutants like SO_2 or NO_x. According to a report by the Regional Environmental Monitoring Department in Rzeszów, air quality measurements in 2020 for the Subcarpathian Province indicated that pollutants such as PM10, PM2.5, and benzo(a)pyrene exceeded permissible norms [4].

In the Subcarpathian Voivodeship, the predominant origin of air pollution stems from anthropogenic emissions. These emissions encompass linear emissions originating from transportation, surface emissions arising from the municipal sector, and point-source emissions emanating from industrial activities. Furthermore, the concentrations of pollutants in the region are substantially influenced by pollutants originating from various regions within Poland and pollutants transported from Ukraine along the eastern border of the voivodeship. The intricate interplay of these diverse emission sources underscores the complexity of the air quality challenges faced in the region, necessitating a comprehensive and region-specific approach to address the issue effectively.

Key local sources of pollution include chimneys from individually heated homes, and in areas adjacent to high-traffic roads, vehicular traffic plays a significant role. Due to the considerable height of industrial emitters, industries, especially professional power generation, largely export pollutants beyond the voivodeship's borders. Industrial facilities with low-emission sources and significant unorganized emissions can also directly impact air quality in their vicinity [4].

Emissions originating from vehicular traffic constitute a substantial portion of overall emissions, particularly in sizable urban centers. Pollutants associated with traffic activities, predominantly in the form of particulate matter, are primarily generated through the wear and tear of road surfaces, tires, and brakes, as well as the atmospheric dispersion of road-related contaminants. In 2020, nitrogen oxide emissions from road transport emerged as the leading contributor to air pollution, whereas point-source emissions played a predominant role in sulfur dioxide pollution. The pollution of benzo(a)pyrene, on the other hand, was attributed to emissions from the municipal and household sectors. The multifaceted sources of these emissions underscore the complexity of addressing air quality challenges related to traffic and the importance of comprehensive mitigation strategies.

Other pressures affecting the quality of surface waters stem from area sources, including polluted surfaces in urbanized areas and areas with unregulated sewage management. In cities such as Tarnobrzeg (Vistula watershed), Nowa Sarzyna, Leżajsk, Przemyśl, Stalowa Wola, Sanok (San watershed), Rzeszów, Krosno (Wisłoka watershed), Mielec, Dębica, Jasło (Wisłoki watershed), the most significant area sources of pollution are found. Unregulated sewage management particularly affects areas where surface waters exhibit above-norm concentrations of biogenic substances (tributaries: Strug, Stobnica, Miętus, Przykopa, Pielnica, Płowiecki, Murynia, Koniecpólka, Zgórska Rzeka, Brzeźnica, Zawadka, Budzisz, Wiktoriec tributary, Rzeka, Rudnia, Trzebośnica, Leszczynka, Mleczka Wschodnia, Mleczka, Markówka, Żołynianka, Stary Wisłok, Mikośka in the Łańcut municipality) and in poorly sewerage-equipped municipalities. The Subcarpathian Provinceis home to many small farms. In the counties of Ropczyce-Sędziszów, Przeworsk, Strzyżów, Sanok, Jasło, Krosno, Dębica, Lubaczów, Mielec, Przemyśl, Jarosław, and Rzeszów, potential pressures may arise due to the significant proportion of agricultural and arable land.

A review of hydromorphological conditions, conducted through the application of the Hydromorphological River Index, indicated that the majority of monitored watercourses within the Province exhibit favorable morphological conditions, characterized as either good or very good. These conditions pertain to streams with a low degree of transformation or those that remain unaltered. However, noteworthy challenges arise from detrimental hydromorphological influences, notably the transverse alteration of riverbeds, which impose substantial pressures on these water systems [2].

The increasing number of people using wireless services is environmentally unfavorable, leading to an increase in artificial sources of electromagnetic radiation. Consequently, levels of electromagnetic fields rise in the environment. The impact of non-ionizing electromagnetic radiation at radio frequencies on living organisms, including humans, is the subject of numerous scientific studies [5]. The International Agency for Research on Cancer has classified radiofrequency electromagnetic fields and low-frequency magnetic fields as possibly carcinogenic to humans. Therefore, continuous monitoring of electromagnetic field levels is crucial for human health and environmental protection.

For many years, people have been using installations and devices that are sources of electromagnetic fields. Every electrical device, such as a mobile phone, laptop, induction stove, refrigerator, hairdryer, or television, is a source of such fields. According to data from the Office of Electronic Communications, by the end of 2020, this authority issued 47 permits for television stations, 48 for radio stations, and 7528 permits allowing the use of radio devices for mobile telephony base stations operating in LTE, GSM, and 5G technologies, as well as stations in the Subcarpathian Province using CDMA technology (Table 1). The number of permits issued for base stations in 2020 was approximately 3.3% higher than in 2019. The distribution of base stations in the province is uneven, with most of them located in large cities [6].

Table 1. The number of mobile telephony base stations in the Subcarpathian Voivodeship

Station type	Number of Base Stations - as of the end of December 2020	
	2019	2020
5G 2100	0	73
5G 2600	0	1
CDMA 420	39	39
GSM 900	1 040	1 019
GSM 1800	877	889
LTE 800	655	698
LTE 900	21	21
LTE 1800	1 180	1 161
LTE 2100	530	697
LTE 2600	722	763
UTMS 900	1 274	1 224
UTMS 1800	15	15
UTMS 2100	935	928

3. Assessment of the Environmental Condition in the Subcarpathian Province

The assessment of air pollution in the Stalowa Wola County was conducted at the national level, commissioned by the Chief Inspectorate of Environmental Protection through the Department of Atmospheric and Climate Modeling at the Institute of Environmental Protection – State Research Institute [7]. In 2018, the Stalowa Wola municipality recorded the highest average annual concentration of sulfur dioxide, reaching 6 μg/m^3, as determined by modeling results. In other municipalities within the Stalowa Wola County, concentrations ranged from 1 to 4 μg/m^3. The average annual concentrations of nitrogen dioxide, also determined through modeling, ranged from 9 to 14 μg/m^3, with the highest concentration observed in the Stalowa Wola municipality.

The regulation by the Minister of Environment dated August 24, 2012, pertaining to the levels of specific substances in the air, stipulates permissible one-hour and daily concentrations for sulfur dioxide at 350 μg/m^3 and 125 μg/m^3, respectively. For nitrogen dioxide, the permissible one-hour and average annual concentrations are set at 200 μg/m^3 and 40 μg/m^3, respectively [8].

Arsenic concentrations averaged 15% of the target level, while cadmium and nickel concentrations were at 8% of the target level, and lead stood at 2% of the permissible level. This leads to the conclusion that concentrations of these metals in PM10 suspended particulate matter did not surpass the prescribed limits. Exceedances of air quality standards for benzo(a)pyrene occur when the average annual concentration reaches 1.50 ng/m^3. The average annual concentration

of benzo(a)pyrene in PM10 suspended particulate matter, determined at the measuring station in Stalowa Wola, was 2.1 ng/m^3, constituting 210% of the target level. While the average annual concentration of benzo(a)pyrene in Stalowa Wola was the lowest among all urban sites in the Subcarpathian Voivodeship, permissible standards were nonetheless exceeded. Estimations based on modeling results further affirmed the exceedances of benzo(a)pyrene concentration throughout the entire Stalowa Wola County [7].

In 2018, the evaluation of consistent portions of surface waters extending from Murynia to the Łęg estuary revealed an unsatisfactory condition attributed to unfavorable chemical and compromised ecological factors. The assessment incorporated benthic macroinvertebrates as indicators for biological elements, while physicochemical elements were gauged using parameters such as nitrogen nitrite, Kjeldahl nitrogen, ammonium nitrogen, total organic carbon, and BOD_5 (biochemical oxygen demand). Within the chemical status classification, specific aquatic organisms were analyzed for heptachlor and brominated diphenyl ethers, and benzo(a)pyrene was identified in the water.

Similarly, in 2018, the status of uniform sections of surface waters in the Osa region was evaluated as poor, attributed to unfavorable chemical and weak ecological conditions. The classification considered benthic macroinvertebrates for biological elements, and for physicochemical elements, it included CHT-Mn (total chromium), OWO (substances causing water color), CHTCr (total chromium). In the chemical status classification, mercury and brominated diphenyl ethers were identified in selected aquatic organisms [7].

In 2018, measurements of electromagnetic field levels were conducted at four designated points. The highest level of electromagnetic field was recorded at the measurement point in Stalowa Wola on Dmowskiego Street, 9, while the lowest level was recorded at the measurement point in Stalowa Wola in Osiedle Hutnik, Wańkowicza Street, 69. Permissible levels of electromagnetic fields in the environment, as well as the methods for checking compliance with these levels (Journal of Laws of 2003, No. 192, item 1883), set the permissible value of the electric field component at 7 V/m for frequencies ranging from 3 MHz to 300 MHz and from 300 MHz to 300 GHz [8]. Based on the measurement results, it can be asserted that the values of electromagnetic field levels at all measurement points were within the acceptable range, ranging from 0.16 to 0.55 V/m. It is anticipated that these values will persist at the same acceptable levels in the foreseeable future, maintaining a consistent adherence to established standards.

In the year 2019, modeling results indicated that sulfur dioxide levels peaked at 5 μg/m^3, as per the findings reported in reference [9]. Across the various municipalities encompassed by the Stalowa Wola County, concentrations exhibited a spectrum, ranging from 2.20 to 4.82 μg/m^3. Furthermore, nitrogen dioxide concentrations, derived from modeling outcomes, displayed variability within the range of 7 to 14 μg/m^3, representing proportions of 18% to 35% in relation to the established standard, as detailed in Table 2.

Table 2. Distribution of Average Annual Concentrations of Sulfur Dioxide and Nitrogen Dioxide in 2019 in the Stalowa Wola County Area (own elaboration based on [9])

Municipality name	Range of concentrations	
	Sulfur dioxide [ug/m^3]	Nitrogen dioxide [ug/m^3]
Zaklików	2.20-3.52	7.00-10.05
Radomyśl nad Sanem	2.92-3.52	7.49-14.00
Zaleszany	2.92-3.52	7.49-14.00
Pysznica	2.92-4.82	7.00-14.00
Stalowa Wola	2.92-5.00	7.49-14.00
Bojanów	2.92-3.52	7.49-10.05

Based on the comprehensive findings, it has been ascertained that the average annual concentration of sulfur dioxide, along with the average annual and one-hour concentrations of nitrogen dioxide, remained within the allowable limits [9]. The automatic station situated in the city of Nisko, Subcarpathian Voivodeship, reported the highest average annual concentration of sulfur dioxide in 2019 at 4.0 μg/m^3, and nitrogen dioxide reached 11.0 μg/m^3 [10]. Notably, the maximum average annual concentration of sulfur dioxide in the Stalowa Wola district exceeded that in Nisko by 1 μg/m^3, while for nitrogen dioxide, the maximum average annual concentration in the analyzed district was 3.0 μg/m^3 higher. At the measurement point in Stalowa Wola, the average annual concentration of PM10 was recorded at 25 μg/m^3, representing 63% of the permissible concentration. Alarmingly, there were 23 days with daily concentrations exceeding 50 μg/m^3, and the highest daily concentration reached 98 μg/m^3, surpassing the permissible norm by a significant 196%. Modeling results estimated the maximum average annual concentration of PM10 to be 28 μg/m^3. In the areas of Pysznica and Kłyżów, the highest estimated average annual concentration of PM2.5 was 20 μg/m^3 [9].

Comparing 2019 to 2018, there were declines in PM10 concentrations and an 8-day reduction in the number of days with daily concentrations exceeding 50 μg/m^3. The average annual concentrations recorded at the measurement point in Stalowa Wola in 2019 for arsenic, cadmium, nickel, and lead were 17%, 8%, 5%, and 2%, respectively, of the respective target or permissible levels, indicating successful adherence to regulatory standards. In 2019, the concentrations of cadmium and lead remained unchanged, arsenic increased, and nickel decreased. However, the average annual concentration of benzo(a)pyrene in PM10 suspended particles, based on measurements in Stalowa Wola, was determined to be 2 ng/m^3, representing 200% of the target level. Modeling results indicated that throughout the Stalowa Wola district, benzo(a)pyrene concentrations ranged from 0.4 to 3.0 ng/m^3 [9].

In 2019, the state of the uniform parts of Jodłówka surface waters was evaluated as poor due to unfavorable chemical and ecological conditions, with biological and physicochemical elements taken into consideration. Similarly, the state of the uniform parts of Dąbrówka surface waters in 2019 was considered poor, utilizing similar criteria for evaluation. The measurements of electromagnetic field levels conducted in 2019 at three points revealed the highest level at the measurement point in Stalowa Wola, os. Pławo ul. Poniatowskiego, 33, while the lowest level was recorded at the measurement point in Stalowa Wola, os. Widok, ul. Niemcewicza, 2. Notably, these measurements did not exceed permissible levels. In 2019, a decrease in electrical field component values was noted in the Stalowa Wola district compared to 2018, with a difference of 0.15 V/m for the highest recorded value and 0.06 V/m for the lowest recorded value.

Moving into 2020, modeling results indicated that the highest average annual concentration of sulfur dioxide occurred in the Stalowa Wola and Pysznica municipalities. In other municipalities of the Stalowa Wola district, the average annual concentrations ranged from 2.0 to 4.0 μg/m^3 (Table 3). The highest average annual concentration of nitrogen dioxide, based on modeling results, occurred in the Stalowa Wola and Pysznica municipalities. In the Stalowa Wola district, the average annual concentrations ranged from 7.0 to 12.0 μg/m^3, constituting 18 to 30% of the permissible values (Table 3). These results offer a comprehensive perspective on the air quality dynamics and pollutant concentrations, informing ongoing efforts for environmental management and improvement in the region.

Table 3. Distribution of average annual concentrations of sulfur dioxide and nitrogen dioxide in 2020 in the Stalowa Wola district (own elaboration based on [9])

Municipality name	**Range of concentrations**	
	sulfur dioxide [ug/m^3]	**sulfur dioxide [ug/m^3]**
Zaklików	2.0-2.5	7.0-9.0
Radomyśl nad Sanem	2.0-3.0	7.0-10.0
Zaleszany	2.0-3.0	7.0-10.0
Pysznica	2.0-4.0	7.0-12.0
Stalowa Wola	2.0-4.0	7.0-12.0
Bojanów	2.0-3.0	7.0-9.0

The continuous decline in the annual average concentrations of sulfur dioxide in the Stalowa Wola district, decreasing by 1 μg/m^3 each year from 2018 to 2020, underscores positive trends in air quality management. Conversely, nitrogen dioxide exhibited stability in its maximum annual average concentrations between 2018 and 2019 but demonstrated a noteworthy decrease by 2 μg/m^3 in 2020.

The annual average concentration of PM10 in Stalowa Wola, recorded at 23 μg/m^3, represents 58% of the permissible level, indicating a significant adherence to regulatory standards. However, the presence of 11 days with daily concentrations surpassing 50 μg/m^3, and a maximum daily concentration of 69 μg/m^3, exceeding the norm by 138% [11], signals sporadic air quality challenges that warrant closer attention. Estimations derived from modeling results project a range of 16 to 27 μg/m^3 for the maximum annual average concentration, constituting 40 to 68% of the norm, providing a comprehensive overview of potential variations.

In 2020, at the monitoring station in Stalowa Wola, the maximum value of the annual average concentration of PM10 demonstrated a notable reduction of 7 μg/m^3 compared to 2018, and the maximum value of PM2.5 decreased by 1 μg/m^3 compared to 2019. This consistent decline in both PM10 and PM2.5 concentrations since 2018 indicates successful efforts in mitigating particulate matter pollution.

Analysis of metal concentrations within PM10 particles revealed that, in 2019, levels of arsenic, cadmium, nickel, and lead were 10%, 10%, 7%, and 2% of their respective target or permissible levels. This underscores effective management practices preventing the exceedance of specified limits. In 2020, the concentration of metals in PM10 showed variations: arsenic concentration reached its lowest point, cadmium concentration peaked, nickel concentration was higher than in 2019 but lower than in 2018, and lead concentration remained constant over the three years. However, the average annual concentration of benzo(a)pyrene in PM10 particles exceeded the permissible level, reaching 2.0 ng/m^3 [11]. Modeling results indicated that benzo(a)pyrene concentrations throughout the Nisko district ranged from 0.3 to 3.0 ng/m^3, as outlined in Table 4. This comprehensive analysis provides insights into the nuanced dynamics of air quality and pollutant concentrations in the region over the analyzed period.

Table 4. Distribution of average annual benzo(a)pyrene concentrations in 2020 in the Stalowa Wola district (self-developed based on [11])

Municipality name	**Range of benzo(a)pyrene concentrations [ng/m^3]**
Zaklików	0.3-1.49
Radomyśl nad Sanem	0.3-1.49
Zaleszany	0.61-2.00
Pysznica	0.3-3.00
Stalowa Wola	0.61-3.00
Bojanów	0.3-1.49

The concentrations of benzo(a)pyrene surpassed permissible values in the municipalities of Zaleszany, Pysznica, and Stalowa Wola. Conversely, in the remaining municipalities within the Stalowa Wola district, the concentration of benzo(a)pyrene varied within the range of 0.3 to 1.49 ng/m^3.

Analysis based on modeling results in 2020 revealed that, within the Stalowa Wola district, there were a maximum of 5 days during which ozone levels surpassed the designated target value. This significant observation was specifically documented in the municipality of Bojanów. Furthermore, a comprehensive examination of the three-year average illustrated a variation in the number of days with 8-hour maximum ozone concentrations, ranging from 2 to 10 days, spanning the period from 2018 to 2020 (refer to Table 5). This valuable dataset provides insights into the temporal variability of ozone concentrations, contributing to a more nuanced understanding of air quality dynamics in the region.

In-depth analysis of the modeling results for the year 2020 pinpointed that, within the Stalowa Wola district, ozone levels exceeded the predetermined target on a maximum of 5 days. This noteworthy finding was particularly evident in the municipality of Bojanów. Additionally, a thorough examination of the three-year average showcased fluctuations in the number of days with 8-hour maximum ozone concentrations, ranging from 2 to 10 days, across the period from 2018 to 2020 (refer to Table 5). This comprehensive dataset offers valuable insights into the temporal variability of ozone concentrations, enhancing our understanding of the intricacies of air quality dynamics in the region.

Table 5. Number of days exceeding the ozone target value in the Stalowa Wola district in 2020 and in the years 2018-2020 (self-developed based on [11])

Municipality name	**Range of days in 2020**	**Range of days in 2018-2020**
Zaklików	0-3	2-10
Radomyśl nad Sanem	0-3	2-10
Zaleszany	0-3	7-10
Pysznica	0-3	4-10
Stalowa Wola	0-3	4-10
Bojanów	0-5	7-10

Adhering to established regulatory standards, the designated target level for this particular substance within the ambient air was successfully attained in the calendar year 2020.

In the year 2020, a comprehensive assessment of electromagnetic field levels was undertaken through measurements conducted at four designated points. Among these, the measurement point situated at Stalowa Wola, os. Rozwadów, ul. Rozwadowska, 37, registered the highest recorded level, while the measurement point at Stalowa Wola, os. Piaski, ul. Głowackiego, 18A, exhibited the lowest level. It is noteworthy that the electric field component demonstrated a value falling below the lower sensitivity threshold of the measuring probe [11]. Upon scrutinizing the findings obtained in 2020 in relation to previous years, a discernible pattern emerges. The overall trend suggests that electromagnetic

field levels persist at a low magnitude. Specifically, the maximum recorded value of the electromagnetic field level in 2020 is lower than the corresponding value in 2018 but surpasses the level noted in 2019. Conversely, the minimum recorded value in 2020 represents the nadir when compared to the three years subjected to analysis. This data indicates a relative stability in electromagnetic field levels, with slight fluctuations observed over the assessed period.

4. Conclusions

The air quality criteria levels for nitrogen dioxide, sulfur dioxide, ozone, PM2.5, and PM10 between 2018 and 2020 have been consistently maintained. Despite the fact that the permissible values for these indicators have been adhered to, their actual values have experienced a decrease since 2018. The criteria levels have also been sustained for carbon monoxide, benzene, nickel, cadmium, lead, and arsenic. Instances of exceeding permissible air quality standards from 2018 to 2020 were associated with the annual average concentration of benzo(a)pyrene. Furthermore, the concentration of benzo(a)pyrene has shown a decline compared to 2018. The contamination from PM10 particulate matter and benzo(a)pyrene predominantly arises from surface emissions, particularly from the municipal-domestic sector. The individual heating of homes contributes to the surpassing of permissible daily concentrations of PM10 and annual concentrations of benzo(a)pyrene. Homes are heated using high-emission and energy-inefficient heating devices, and living spaces in old buildings necessitate a high demand for heat. Inadequate fuel combustion, substandard solid fuels, and a lack of public awareness regarding the adverse effects of air pollution may also play a contributory role. In addition to individually heated homes, local heating plants, leaf burning, waste incineration, grass burning, emissions from garbage dumps, and emissions from parking lots may be additional contributing factors.

Between 2018 and 2020, the condition of uniform sections of surface waters, as evaluated through conducted studies, was deemed poor. The primary cause of poor water quality is the discharge of wastewater from specific pollution sources, particularly municipal ones. The impact of industrial wastewater emissions on water quality is relatively lower. The industrial sector is primarily concentrated in the city of Stalowa Wola. The quality of surface waters may be influenced by industrial wastewater from the Huta Stalowa Wola – Wodociągi Sp. z o.o. facility, cooling water from TAURON Wytwarzanie S.A. – Elektrownia Stalowa Wola branch, and municipal wastewater treated by the Miejski Zakład Komunalny Sp. z o.o. at the Municipal Sewage Treatment Plant.

Projections derived from extensive monitoring studies suggest that electromagnetic field levels are unlikely to undergo significant changes. There may be slight increases in specific areas. A substantial rise in the intensity of electromagnetic fields in the environment could result from an expansion in the permissible radiation power emitted by transmitting devices, such as cell phone base stations, antennas, and transmitters of TV and radio stations. Addressing challenges such as environmental education, sustainable resource management, and the implementation of innovative technologies in communication and industry is essential to ensure that environmentally friendly initiatives in the region yield tangible results in the future.

References

[1] State Water Holding Polish Waters: Water is not a garbage dump; thus, let's preserve the purity of water – for us and for healthy ecosystems. https://www.wody.gov.pl/aktualnosci/2567-wody-to-nie-smietnik-dlatego-dbajmyo-czystosc-wod-dla-nas-i-dla-zdrowych-ekosystemow, Accessed on: May 20, 2022.

[2] The State of the Environment in the Subcarpathian Voivodeship: Report 2020.

[3] Kuchcik M., Milewski P.: Air Pollution in Poland – State, Causes, and Effects. KPZK Studies. 2018, Volume 182, Part II.

[4] Annual Assessment of Air Quality in the Subcarpathian Voivodeship: Provincial Report for 2020.

[5] Tomasz Rybak: Electromagnetic Radiation. https://wios.rzeszow.pl/cms/upload/edit/file/stan_srodowiska_2011/raport_2011_r5.pdf.

[6] Assessment of the Level of Electromagnetic Fields in the Environment in 2020 in the Subcarpathian Voivodeship – developed based on measurements made by the Environmental Protection Inspectorate.

[7] The State of the Environment in the Stalowa Wola District in 2018, as Determined by Research Conducted as Part of the State Environmental Monitoring.

[8] Regulation of the Minister of the Environment on the Permissible Levels of Electromagnetic Fields in the Environment and Methods of Verifying Compliance with These Levels (Journal of Laws of 2003 No. 192, item 1883).

[9] The State of the Environment in the Stalowa Wola District in 2019, as Determined by Research Conducted as Part of the State Environmental Monitoring.

[10] The State of the Environment in the Municipality and City of Nisko in 2019, as Determined by Research Conducted as Part of the State Environmental Monitoring.

[11] The State of the Environment in the Stalowa Wola District in 2020, as Determined by Research Conducted as Part of the State Environmental Monitoring.

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