

Article

# Ambient Air Quality as a Condition of Effective Healthcare Therapy on the Example of Selected Polish Health Resorts

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**Abstract:** This article discusses the importance of air quality for the organization and functioning of health resorts. Ten different types of resorts located in various regions of Poland were compared in terms PM<sub>10</sub> concentration. Additionally, comparative analysis of the high-PM<sub>10</sub> episodes was performed in three urban agglomerations located near the analyzed health resorts. The article also discusses formal, legal, and economic instruments that are the basis for legislative actions as tools for managing the air quality in the selected resorts. The analysis of the average annual concentrations in 2015–2019 did not show any exceedances of the PM<sub>10</sub> limit value for any of the health resorts studied. High PM<sub>10</sub> concentration values in 2018 were recorded for the number of days in exceedance of the limit value, especially in the health resorts of Uniejów, Ciechocinek, and Szczawno-Zdrój. Health resorts located in the south of Poland were identified as the most at risk in terms of the occurrence of limit value exceedances, information, and alert thresholds. It was concluded that the implementation of the so called “anti-smog” resolutions, including the development of financial support for changing the heating system to eliminate coal boilers and furnaces, is absolutely necessary for air quality improvement.

**Keywords:** air quality; ambient air; particulate matter; health resort

## 1. Introduction

Air quality is not only a factor directly and indirectly affecting health, but also an important factor determining quality of life (wellbeing). It is important both for the functioning of various human organs as well as for mental health and wellbeing. The subjective assessment of quality of life and level of mental stress may be conditioned by both long-term and short-term exposure to air pollution [1,2]. It is important both in the case of spa treatment and for the general public, in particular the inhabitants of urban agglomerations.

Air quality can also be considered in the context of ecosystem services. Natural elements, including those in cities, e.g., roadside trees or green areas, affect the level of air pollution. The absorption of gaseous and particulate matter pollutants is one of the regulating services provided by the environment, whose effectiveness and benefits have been estimated by research conducted around the world [3–5]. The parameters of the impact of various tree species growing in urban areas on air quality were determined e.g., in [6]. On the other hand, air quality also affects the level, quality, and value of ecosystem services provided by other natural elements, e.g., through its impact on biodiversity [7–9].

In the case of health resorts, often characterized by high natural values, the importance of air quality-related ecosystem services is of particular importance. This is connected with the need to control and ensure the highest possible level of air quality.

The problem of poor air quality in Poland concerns a significant part of the country, including selected health resort areas [10], which should exhibit a high level of environmental quality, in particular air quality [11]. Therefore, the improvement of air quality, especially in the areas of health resorts, should play the key role in the national strategy for reducing atmospheric air pollution, as well as in programs and activities carried out at regional and local levels.

In the case of the impact of the air polluted with suspended particles on human health, one can talk about long-term, chronic exposure (to relatively low levels of concentrations) and short-term, acute exposure (from several hours to several days of high or very high concentrations). Chronic exposure is associated with the risk of chronic diseases, while acute exposure may result in a rapid reaction of the body, especially for particularly sensitive groups of people [12]. Since the spa-treated patients often belong to this group, this paper discusses mainly the episodes of high and very high PM<sub>10</sub> concentrations. The episodes occur with varying frequency and intensity in different areas of the country. The emission of particulate matter (PM) pollution and the occurrence of specific, adverse meteorological conditions are responsible for their formation [13]. Their character is local, restricted to only selected places, or regional and even nationwide.

This study aims to analyze the main factors influencing the state of air, especially during the episodes, and its characteristics in selected health resorts in the last few years. The analysis was based on measurements of PM<sub>10</sub> concentrations, considering its importance for selected resorts and spa treatment. Selected data were compared with the situation in three large urban agglomerations. The analyses also included actions that are taken to improve air quality in various areas, especially in spas. In addition, recommendations regarding the use of forecasting and information tools to reduce health risks associated with pollution for patients and resorts residents were proposed.

Most of the research and studies on the health effects of air pollution with particulate matter, especially in relation to the sensitive population, refer to PM<sub>2.5</sub>. On the contrary, this study focuses on the issue of the pollution with PM<sub>10</sub> fraction, mainly due to the legal regulations in force in Poland regarding the limits for daily concentrations of PM<sub>10</sub>. Since the main subjects of the work are the episodes and short-term impact of particulate matter, e.g., on patients staying in spas for up to several weeks, the reference to the daily standards—the limit value level, the alert, and information thresholds—that are in place for PM<sub>10</sub> was included. In addition, the analysis was mainly based on the results of PM concentration measurements carried out within the official monitoring network. The available data resources for health resort areas in Poland are much richer in the case of PM<sub>10</sub> than PM<sub>2.5</sub>. This is due to various reasons. Compliance with the air quality standard for daily concentrations of PM<sub>10</sub> is a bigger problem in Poland than in the case of the standard for annual mean concentrations (both for PM<sub>10</sub> and PM<sub>2.5</sub>). Therefore, it must be subject to wider monitoring. It is also important from the perspective of informing the public about the exceedances of the limit level or the alert threshold for the daily PM<sub>10</sub> concentrations. In addition, PM<sub>10</sub> contains various types of substances that are subject to monitoring. It is mainly benzo(a)pyrene, but also, in the case of some locations, heavy metals. The differences in the amount of available data for both of these PM fractions also result from the historical development of the measurement network. Due to the fact that PM<sub>10</sub> was included in the air quality standard earlier, the scope of these measurements is wider in Poland.

## 2. The Organization of Spa Treatment in Poland

A health resort is the area where spa treatment is performed, which is separated for the use and protection of the natural healing resources located within its territory, and meets the requirements for which it has obtained the status of a spa [11]. In Poland, 45 towns or parts of them have been recognized as health resorts. Of them, 37% are located in the lowland area, 13.3% are coastal health resorts, and 31.1% are located in the foothills area. The remaining 17.8% are mountain resorts. A significant

number of the health resorts are located in southern voivodeships [10]. As many as 11 (i.e., 24.4%) Polish health resorts are located in Dolnośląskie Voivodeship, which reveals its significant potential for health treatment and recreation connected, inter alia, with its natural conditions, microclimate, and available resources, e.g., spa waters.

The health resorts operate based on received spa statuses. The conditions that the municipality must meet to obtain the status of a health resort for its town or part thereof are regulated by the Spa Act (Act of 28 July 2005 on spa treatment, health resorts, and protection zones of health resorts and health resort municipalities). To obtain and maintain the status of a health resort, municipalities must fulfil additional obligations, including those related to maintaining specific environmental requirements [14,15]. The status of a spa can be granted to an area that meets the statutory conditions, including, inter alia, deposits of natural medicinal resources and a climate with healing properties. To obtain the status of a spa, the municipality must prepare a health resort study which must be approved by the Minister of Health. Such a report is made at least once every 10 years. It includes, among others, certificates confirming the medicinal properties of natural healing resources and healing properties of the climate, as well as information on the state of air quality developed under the legal provisions on air quality assessment [10]. Besides, to protect therapeutic factors and natural deposits of healing resources, environmental values, and spa facilities, the “A”, “B”, and “C” spa zones are designated and defined in accordance with [11]:

- The “A” zone, for which the percentage of green areas is not less than 65%, covers the area where spa treatment resorts and facilities are located or planned, as well as other facilities for spa treatment or patient or tourist services, in a scope that does not hinder the functioning of the spa treatment, in particular: guesthouses, restaurants, or cafes.
- The “B” zone, for which the percentage of green areas is not less than 50%, includes the area adjacent to the “A” zone and surrounding it. It is intended for facilities that do not have a negative impact on the healing properties of the health resort or the protection zone of the health resort and are not burdensome for patients: service and tourist facilities, including hotels, recreational, sports, and municipal facilities, housing, and others related to meeting the needs of the people staying in this area; or it is part of the national park or nature reserve, or is a forest, sea, or lake.
- The “C” zone, for which the percentage of biologically active areas is not less than 45%, includes the area adjacent to the “B” zone and surrounding it, as well as the area that contributes to the preservation of landscape and climate values and the protection of deposits of natural medicinal resources.

Spa treatment is an integral part of the healthcare system in Poland. The role of spa treatment is to provide comprehensive medical care, to address the need to reduce morbidity and premature mortality due to cardiovascular diseases and chronic respiratory diseases, and to limit the health effects caused by harmful factors in the work and residence environment. In the course of most chronic diseases and after treatment of the acute phase of a large range of diseases, spa treatment is a recommended course of action [16] carried out in spa hospitals, spa sanatoriums, children’s spa hospitals, spa outpatient clinics, and natural medicine centers. An important fact considering spa treatment is that therapeutic directions for a given spa are determined by the Minister of Health (Table 1), which allows for an adequate qualification of a patient for spa treatment.

**Table 1.** Treatment directions for the spas selected for analysis.

No.	Spa Name	Therapeutic Directions for Spas/Treated Diseases										
		Lower and Upper Respiratory Tract	Cardiological and Hypertension	Peripheral Vessels	Orthopedic-Traumatic	Nervous System	Rheumatological	kidneys and Urinary Tract	Diabetes	Obesity	Osteoporosis	Others
1	Cieplice Śląskie Zdrój				x	x	x	x			x	x
2	Szczawno-Zdrój	x			x			x	x	x	x	x
3	Duszniki Zdrój	x	x		x				x		x	
4	Ustroń		x	x	x	x	x		x	x	x	
5	Rymanów-Zdrój	x	x		x			x				
6	Ciechocinek	x <sup>1</sup>	x	x	x	x	x		x	x	x	x
7	Uniejów			x	x	x	x					x
8	Konstancin-Jeziorna	x	x					x				
9	Sopot	x <sup>1</sup>	x					x				
10	Kołobrzeg	x	x		x	x	x		x	x	x	x

<sup>1</sup> Only applies to the upper respiratory tract (Source: Polish Ministry of Health [17]).

The spas have several therapeutic directions. Most of the analyzed health resorts (6 out of 10 spas) treat patients most vulnerable to particle pollution exposure, i.e., with respiratory tract diseases and cardiovascular diseases. Only the health resorts in Cieplice Śląskie Zdrój and Uniejów do not have a recognized therapeutic profile for hospitalization of patients with diseases with the highest sensitivity to air pollution.

While staying in a health resort, the patients are treated [16] inside the resort base facilities, whereas they usually spend their free time outside the buildings. The percentage distribution of time spent by patients inside and outside is individual and dependent on the duration of treatments, sleeping time, meals, or the season. This is related to the time of potential exposure to ambient air pollution.

Health effects relate to both long-term (over months or years) and short-term (over several hours or days) exposure to air pollution. Research results concerning long-term exposure show that the more pollutant concentrations increase, the greater is the risk of chronic respiratory and cardiovascular diseases, including asthma, chronic obstructive pulmonary disease, stroke, heart disease, and lung cancer [18]. People suffering from heart and lung diseases, the elderly, and children, are the most sensitive to the harmful effects of particulate matter pollution. For the elderly, high levels of particulate matter are associated with an increased risk of hospitalization and even death from lung and cardiovascular diseases. A prolonged exposure to high concentrations of particulate matter is conducive to the occurrence of chronic obstructive pulmonary disease, as well as a reduction in lung function and efficiency. In the case of the elderly, particle clearance might be less efficient or impaired by other dysfunctions [19]. There is also evidence of the link between long-term PM exposure and mortality, even at levels below current standards [20].

Short-term exposure to high levels of particulate matter may exacerbate the symptoms of lung disease, various allergic diseases (asthma, eczema, hay fever, conjunctivitis), and heart disease (increased blood clotting, arrhythmia), as well as increase susceptibility to respiratory infections [21]. There is evidence for adverse health effects of short-term exposure to PM<sub>2.5</sub> across a range of important health outcomes, diseases, and age groups with substantial variation between different regions of

the world [22]. The analyses presented in this paper focus mainly on the short-term impact of PM<sub>10</sub>, which is connected with relatively short periods of patients' stay in the spas. This type of influence is more important in the case of particularly vulnerable groups with specific diseases who are often among the people receiving spa treatment.

### 3. Air Quality Monitoring and Assessment System in Health Resorts

Ambient air quality monitoring in Poland is conducted by the Chief Inspectorate for Environmental Protection (CIEP), which is responsible for measuring the concentration of selected substances in the air and conducting air quality assessments. This task is performed as part of the State Environmental Monitoring (SEM), whose strategic program is developed by the Chief Inspector for Environmental Protection and approved by the Minister of Climate. Currently, the Strategic SEM Program adopted for the years 2020–2025 is in force [23]. The Act of 27 April 2001 on the Environmental Protection Law [24] and the Regulation of the Minister of the Environment of 8 June 2018 on assessing levels of substances in the air [25] are the main legal acts regulating the issues of air quality assessments in Poland, including the areas of health resorts. These provisions are consistent with the requirements set out in Ambient Air Quality Directives: 2008/50/EC [26] and 2004/107/EC [27] in force at the European Union level.

The assessment of air quality is made through measurements of selected air pollutant concentrations, supplemented by mathematical modeling and objective estimation techniques. Monitoring studies are conducted regularly, using standardized methods of data collection, gathering, and processing. An important feature of the SEM measurement network is the use of reference measurement methods or equivalent, as well as the implementation and maintenance of measurement quality assurance and control systems. Catering for the need to limit the negative impact of particulate matter on human health and the environment as a whole, provisions have been defined to control and limit the emission of pollutants, including particulate matter, its precursors, and selected components into the air. The PM<sub>10</sub> level has been set for two averaging times: calendar year and 24 h. In the first case, the standard is 40 µg/m<sup>3</sup>, while in the second case, it is 50 µg/m<sup>3</sup>, and the exceedances of this level are allowed no more than 35 times a year [28]. Due to the harmful effects of particulate matter on human health, alert thresholds for PM<sub>10</sub> concentration have been additionally determined in some countries. These values have not been regulated at the same level within the framework of European Union regulations, which is why different thresholds apply in different member states. In October 2019, the ordinance of the Minister of the Environment of 8 October 2019, amending the ordinance on the levels of certain substances in the air [29], came into force, which established 100 µg/m<sup>3</sup> as the information threshold and 150 µg/m<sup>3</sup> as the alert threshold for PM<sub>10</sub> concentrations in the air. In some other EU member states, these standards were set at a lower level.

In total, there are currently 25 measuring stations within the SEMs in Polish health resorts, of which three are located in Lower Silesian health resorts: Czerniawa-Zdrój, Cieplice Śląskie-Zdrój, and Szczawno-Zdrój. The measurements by selected stations are carried out over long periods, which allows researchers and policy makers to assess the variability of pollutant levels over time. There are also mobile stations that conduct measurements, e.g., for one year, to recognize the problem of air quality in a specific area. Mathematical modeling is additionally used, enabling spatial analysis of the concentration of pollutants. Measurements of PM<sub>10</sub> concentration at CIEP measuring stations are carried out using the reference gravimetric method and automatic methods that have adequately demonstrated equivalence with the reference method. The latter allows the obtaining of results in near real-time mode, which is particularly important, e.g., due to the need to provide current information to the public and decision-makers, especially when the levels of pollution are high. Currently, the SEM measurements do not cover all spas. In some health resorts, outside of the SEM, upon order of, e.g., local governments, measurements of PM<sub>10</sub> concentration using low-cost sensors based on optical methods are also carried out. Their quality level is currently lower than in the case of the mentioned

SEM measurements. The stability of these devices and their behavior in various meteorological conditions is also problematic. Additionally, some of the spas are not included in any measurements.

#### 4. Research Methodology

This work refers to measurements of ambient air quality carried out as part of the State Environmental Monitoring (SEM) in 2015–2019. The source of the data is the CIEP Air Quality Portal [30], but the data from 2019 available for the time of the analyses should be treated as preliminary, needing final verification and approval by the CIEP. The analyses were performed for ten selected spas of various types (Table 2), whose location is illustrated in Figure 1. The summary also indicates the availability of measurement data (PM<sub>10</sub> concentration results) for individual spas and years. When parallel gravimetric and automatic measurements were carried out at a given location, and the available measurement series were comparably complete, the results obtained using the reference (gravimetric) method were taken into account.

**Table 2.** Summary of the analyzed health resorts and agglomerations and available data.

Voivodship	Spa/Agglomeration	Spa Type	2015	2016	2017	2018	2019	Synoptic Station
Dolnośląskie	Cieplice Śląskie-Zdrój	foothill	x	x	x	x	x	Jelenia Góra
Dolnośląskie	Szczawno-Zdrój	foothill	x	x	x	x	x	Jelenia Góra
Dolnośląskie	Duszniki-Zdrój	foothill					x	Kłodzko
Śląskie	Ustroń	foothill	x	x	x	x	x	Bielsko-Biała
Podkarpackie	Rymanów-Zdrój	foothill			x	x	x	Krosno
Dolnośląskie	Agl. Wroclawska	n/d	x	x	x	x	x	Wrocław-Strachowice
Kujawsko-Pomorskie	Ciechocinek	lowland	x	x	x	x	x	Toruń
Łódzkie	Uniejów	lowland			x	x	x	Łódź-Lublinek
Mazowieckie	Konstancin-Jeziorna	lowland			x	x	x	Warszawa-Okęcie
Mazowieckie	Agl. Warszawska	n/d	x	x	x	x	x	Warszawa-Okęcie
Pomorskie	Sopot	seaside	x	x	x	x	x	Gdańsk-Świbno
Zachodniopomorskie	Kołobrzeg	seaside				x	x	Kołobrzeg-Dźwirzyno
Pomorskie	Agl. Trójmiejska	n/d	x	x	x	x	x	Gdańsk-Świbno

(Source: own study based on SEM data, [30]).



**Figure 1.** Location of spas and agglomerations included in the analysis (Source: own study, using data from the state register of borders and the area of territorial division units of the country [31]).

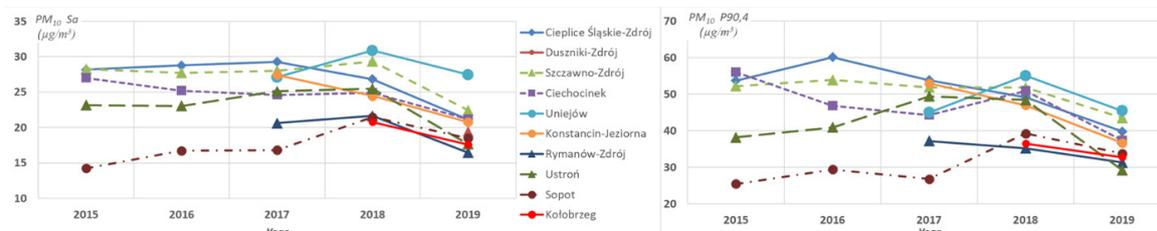
Comparatively, an additional analysis of the occurrence of episodes was carried out for three large urban agglomerations located in the vicinity of the analyzed spas of various types: Wrocław, Warszawa, and Trójmiasto Agglomerations. Due to monitoring in these agglomerations at several measuring stations, the methodology adopts the principle of averaging the concentration value for each analyzed day as a representation of the air quality situation in a given area. Due to the low representativeness of traffic stations, aimed at studying the direct impact of road transport in specific places, they were not included in the calculations. In the case of Trójmiasto Agglomeration, the station located in Sopot was excluded, and it was taken into account directly in the analysis of this spa.

The frequency and intensity of the occurrence of PM<sub>10</sub> high concentration episodes were analyzed for several years, assuming the average 24 h threshold concentration of the episode (75 µg/m<sup>3</sup>), as well as the information level (100 µg/m<sup>3</sup>) and the alert level (150 µg/m<sup>3</sup>). A comparative analysis of the situation was carried out for various health resorts, as well as for selected areas outside health resorts (urban agglomerations). In all analyses, the principle of rounding data to integers when comparing with threshold values was adopted, similarly to the air quality assessments in force at the national and European Union level. According to this principle, e.g., the 24 h average concentration (S<sub>24</sub>) of 75.3 µg/m<sup>3</sup> (rounded to 75 µg/m<sup>3</sup>) does not exceed the threshold concentration of the episode.

To analyze the causes and course of episodes of high PM<sub>10</sub> concentrations, available information on meteorological conditions from synoptic stations and aerological surveys was used. Table 2 also contains a list of synoptic stations of the Institute of Meteorology and Water Management—National Research Institute (IMGW—PIB), the data of which were used for the analysis of the situation in individual spas and agglomerations.

## 5. The Analysis of the Occurrence of PM<sub>10</sub> Episodes in Health Resorts in Poland

The statistical parameters were calculated (some of which correspond to the standards in force in Poland) based on the available PM<sub>10</sub> concentration measurement results carried out in 2015–2019 at SEM stations in selected spas. The results of the analyses showed that the limit value level for the average annual concentration (Sa) was not exceeded (Figure 2, Table 3) in the areas of the studied health resorts during this period. There was also no clear trend in this indicator. In most of the analyzed health resorts, the highest Sa values occurred in 2018. A similar relationship was observed for the 90.4 percentile value calculated for the annual series of 24 h average values. This indicator is related to compliance with the standard for daily average concentrations with permitted 35 days of exceedances per year and allows for partial compensation of potential errors caused by the lack of completeness of the measurement series. In 2019, for the first time in the period under analysis, there was no exceedance of the limit value level by the 90.4 percentile in the areas of all spas and agglomerations included, specified for 24h mean PM<sub>10</sub> concentrations (50 µg/m<sup>3</sup>). Note that in the case of agglomerations, these are average data for all measuring stations operating in them, excluding traffic ones.



**Figure 2.** The values of average annual concentrations (Sa) and the 90.4 percentile for the examined spas in 2015–2019 (Source: own study based on SEM data [30]).

**Table 3.** Annual average PM<sub>10</sub> concentrations (Sa) and 90.4 percentile \* for the examined health resorts and agglomerations in 2015–2019.

Spa/Agglomeration	Annual Average Concentration Sa					Percentile P90.4				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Cieplice Śląskie-Zdrój	28.2	28.8	29.3	26.8	21.1	53.7	60.1	53.8	49.2	39.8
Duszniki-Zdrój					19.4					37.7
Szczawno-Zdrój	28.3	27.7	28.0	29.4	22.4	52.2	53.9	51.8	51.8	43.5
Rymanów-Zdrój			20.6	21.6	16.5			37.2	35.2	31.3
Ustroń	23.2	23.0	25.1	25.5	17.7	38.2	40.9	49.4	48.4	29.2
Ciechocinek	27.0	25.2	24.6	24.9	21.2	56.0	46.8	44.3	50.9	37.4
Uniejów			27.1	30.9	27.5			45.0	55.0	45.5
Konstancin-Jeziorna			27.4	24.5	20.8			53.0	47.0	36.7
Sopot	14.2	16.7	16.8	21.5	18.5	25.4	29.4	26.8	39.2	33.7
Kołobrzeg				20.8	17.6				36.5	32.7
Agl. Wrocławska	36.6	32.5	30.3	31.8	25.6	66.0	59.1	58.4	55.0	46.6
Agl. Warszawska	32.6	29.8	33.6	35.5	27.8	61.0	49.1	65.6	60.8	47.4
Agl. Trójmiejska	27.4	23.7	24.3	30.1	27.2	52.2	42.0	41.0	58.0	46.5

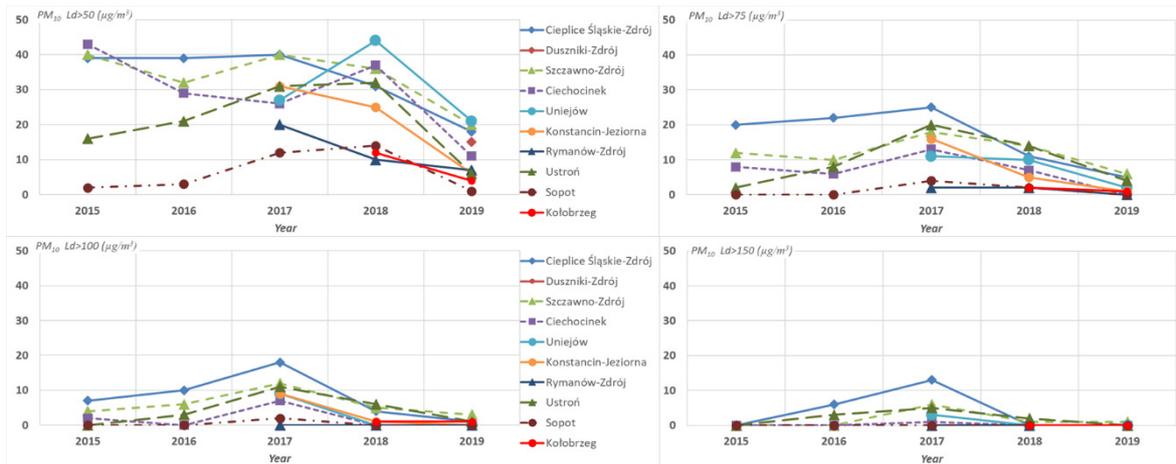
\* Percentile 90.4 values exceeding the Limit Value specified for average 24 h PM<sub>10</sub> concentrations (50 µg/m<sup>3</sup>) were distinguished (Source: own study based on SEM data [30]).

The highest annual average concentrations occurred at measuring stations in the health resorts of Cieplice Śląskie-Zdrój, Szczawno-Zdrój, and Uniejów, while the lowest were noted in Sopot and Kołobrzeg. Similar relations are observed in other Polish cities. In Poland, higher concentrations of air pollution are found in the southern part of the country, while lower in the northern [32–34]. In mountainous and foothill regions, there are difficult pollution dispersion conditions; besides, the problem is compounded by the industrial nature of large areas of southern Poland, rich in hard coal and lignite. In turn, the northern part of the country is characterized by proper conditions of dispersion of pollutants and relatively low industrialization. The density of emission sources from the municipal and household sector (related mainly to solid fuel heating of individual buildings and the functioning of small boilers) is also important. These types of fuel combustion processes outside the industry are the main source of the PM<sub>10</sub> emissions in Poland, responsible for 46.5% of the total emissions of this pollution [35]. Their impact shaping air quality can also be significant in the areas of spas located in the lowlands. For example, in 2018 and 2019, Sa in the Uniejów health resort was higher than Sa in Trójmiasto Agglomeration and only slightly lower than in other agglomerations included in the analysis. In this case, air quality is probably shaped by local emission sources, and it is not conditioned by topographic conditions affecting the possibilities of pollutant dispersion.

The PM<sub>10</sub> concentration indicators recorded in Lower Silesian spas are annually one of the highest in relation to other resorts.

In a direct comparison of the number of days exceeding the limit value (50 µg/m<sup>3</sup>), relatively high concentration values can also be observed in 2018, especially in the areas of Uniejów, Ciechocinek, and Szczawno-Zdrój (Figure 3, Table 4). When raising the threshold for counting days to the episode, information, and alert thresholds, a significant increase (for the analyzed period) in the number of exceedances in 2017 is noticeable, in which relatively long episodes of high PM<sub>10</sub> concentrations occurred in most of the country. They occurred mainly in January and February. Analyses carried out at the National Health Fund indicate the occurrence of periods with high PM<sub>10</sub> concentration in 2017 to be of the reasons for the increase in the number of deaths in Poland that year by 3.77% compared to the previous year. This increase concerned primarily January (by as much as 23.5%

compared to 2016) and February. Among the unfavorable factors, besides PM air pollution, was low air temperature [36]. For example, during the first two weeks of January in 2017, compared to the same period in 2016, the number of admissions to the Military Institute of Medicine in Warsaw related to asthma, chronic obstructive pulmonary disease, and atrial fibrillation increased, respectively, by 142%, 133%, and 33% [37]. This is similar to other studies which confirm the combined effect of the epidemiological threats and environmental risk factors on the level of mortality in metropolitan areas. For instance, in Milan (Italy), seasonal influenza combined with high air pollution and cold temperature caused excess mortality in the winter of 2016–2017 [38].



**Figure 3.** The number of days above the considered thresholds for PM<sub>10</sub> (50, 75, 100, and 150 µg/m<sup>3</sup>) for the examined health resorts in 2015–2019 (source: own study based on SEM data [30]).

**Table 4.** The number of days with exceedances of the limit value (L > 50), episode threshold (L > 75), information (L > 100), and alert threshold (L > 150) in the examined spas and agglomerations in 2015–2019.

Spa/Agglomeration	L > 50					L > 75					L > 100					L > 150				
	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Cieplice Śląskie-Zdrój	39	39	40	31	18	20	22	25	11	5	7	10	18	4	1	0	6	13	0	0
Duszniki-Zdrój					15					4					1					0
Szczawno-Zdrój	40	32	40	36	20	12	10	18	14	6	4	6	12	5	3	0	0	6	1	1
Rymanów-Zdrój			20	10	7			2	2	0			0	0	0			0	0	0
Ustroń	16	21	31	32	6	2	8	20	14	4	0	3	11	6	1	0	3	5	2	0
Ciechocinek	43	29	26	37	11	8	6	13	7	0	2	0	7	0	0	0	0	1	0	0
Uniejów			27	44	21			11	10	2			9	0	0			3	0	0
Konstancin-Jeziorna			31	25	6			16	5	1			9	1	0			0	0	0
Sopot	2	3	12	14	1	0	0	4	2	0	0	0	2	0	0	0	0	0	0	0
Kołobrzeg				12	4				2	1				1	1				0	0
Agl. Wroclawska	56	44	47	45	23	17	12	18	10	5	5	6	7	3	2	2	0	2	0	0
Agl. Warszawska	46	25	41	51	10	10	6	16	7	0	2	0	8	0	0	0	0	0	0	0
Agl. Trójmiejska	13	5	11	21	6	1	0	3	4	0	0	0	1	0	0	0	0	0	0	0

(Source: own study based on SEM data, [30]).

In the context of air quality, foothill spas stand out among the analyzed health resorts, including Cieplice Śląskie-Zdrój, Szczawno, and Ustroń, where exceedances of the episode, information, or alert thresholds occurred most frequently. The exceedances of the information threshold occurred in 2017 in

the mentioned spas more often than in the case of urban background stations in the agglomerations included in the study.

Table 5 presents a summary of the selected indicators characterizing episodes of high PM<sub>10</sub> concentrations in the spas and agglomerations studied in 2015–2019: maximum length of the episode with a value above 75 µg/m<sup>3</sup> in days (MDE), number of episodes longer or equal to 3 days (LE3d), and the maximum average daily concentration per year (MAXS24). Again, the highest values of all parameters were found in 2017, which was characterized by long episodes of PM<sub>10</sub> concentrations. The longest episode took seven days and was recorded in Szczawno-Zdrój health resort, whereas the episodes in urban agglomerations were shorter than in spas (except for Rymanów-Zdrój). Additionally, in 2017, episodes longer than three days occurred more often compared to other years.

**Table 5.** Indicators characterizing episodes of high PM<sub>10</sub> concentrations in the analyzed spas and agglomerations in 2015–2019.

Spa/Agglomeration	2015			2016			2017			2018			2019		
	MDE	L E3d	MAX S24												
Cieplice Śląskie-Zdrój	4	3	119	3	3	195	5	3	230	5	1	131	2	0	107
Szczawno-Zdrój	3	1	135	3	2	131	7	2	231	4	1	175	5	1	157
Duszniki-Zdrój													4	1	118
Ustroń	1	0	83	3	1	162	6	4	216	5	2	239	3	1	150
Rymanów-Zdrój							1	0	94	1	0	83	0	0	70
Agł. Wrocławska	5	2	199	4	1	143	5	3	236	4	2	143	3	1	106
Ciechocinek	2	0	114	2	0	97	5	3	170	2	0	88	0	0	64
Uniejów							6	2	190	3	1	94	1	0	98
Konstancin-Jeziorna							4	1	150	1	0	105	1	0	82
Agł. Warszawska	2	0	113	2	0	99	4	3	141	2	0	95	0	0	72
Sopot	0	0	69	0	0	58	4	1	108	1	0	78	0	0	53
Kołobrzeg										2	0	106	1	0	104
Agł. Trójmiejska	1	0	80	0	0	75	1	0	102	2	0	91	0	0	67

(Source: own study based on SEM data [30]).

## 6. The Episodes of High PM<sub>10</sub> Concentrations in 2019

2019 was the warmest year in the history of measurements carried out in Poland at meteorological stations, and according to the thermal classification developed by IMGW-PIB, it can be considered extremely warm for all regions of the country [39]. Such conditions were reflected in the PM<sub>10</sub> concentration levels recorded at all measuring stations that year—the values of the annual characteristics of the data series (e.g., average and exceedances) were lower than in the previous year.

The fact that the concentration of suspended particulate matter depends on the air temperature is well known. It is recognized that the lower the temperature, the higher the concentration of PM [40–42]. Air temperature affects the concentration of pollutants in the air in two ways: by changing the demand for heating in households and, consequently, the level of pollutant emissions from the municipal and household sector [43] and participation in the development of conditions conducive to their dispersion (which is related to the height of the mixing layer) [44]. Vertical agitation, which dilutes the particles in the boundary layer, is affected by the change in temperature and wind with altitude. More clearly, vertical mixing is observed in the hot season: higher air temperature promotes air mixing. On the other hand, temperature affects chemical reactions that occur between PM particles. Higher temperatures accelerate reactions, creating more products that can separate into different particle phases; however, it should be emphasized that these products tend to remain in the gas phase when the temperature is too high [45,46].

### 6.1. Episodes in All Spas Included

When comparing the correlation between the average daily PM<sub>10</sub> (S24) concentrations and the daily values of selected meteorological indicators in the spas and agglomerations studied in 2019, the highest negative correlation with the minimum daily temperature is clearly observed (Table 6). It is the strongest in the areas of spas and agglomerations located in the southern part of the country.

**Table 6.** Coefficients of correlation of the average daily PM<sub>10</sub> concentrations with the daily values of selected meteorological indicators in the examined spas and agglomerations in 2019.

Spa/Agglomeration	Maximum Daily Temperature (°C)	Minimal Daily Temperature (°C)	Average Daily Temperature (°C)	Daily Precipitation Sum (mm)	Wind Duration ≥10 m/s (hours)	Average Daily Wind Speed (m/s)	Average Daily Relative Humidity (%)	Average Daily Pressure at Sea Level (hPa)
Cieplice Śląskie-Zdrój	−0.31	−0.52	−0.44	−0.14	−0.09	−0.30	0.17	0.14
Szczawno-Zdrój	−0.27	−0.47	−0.39	−0.18	−0.04	−0.29	0.09	0.20
Duszniki-Zdrój	−0.27	−0.50	−0.39	−0.19	−0.10	−0.29	0.00	0.26
Ustroń	−0.30	−0.33	−0.32	−0.13	−0.14	−0.25	0.11	0.14
Rymanów-Zdrój	−0.26	−0.31	−0.29	−0.14	−0.09	−0.20	−0.07	0.21
Agl. Wroclawska	−0.25	−0.42	−0.32	−0.17	−0.05	−0.26	0.16	0.12
Ciechocinek	−0.31	−0.36	−0.33	−0.11	0.15	−0.17	0.22	−0.01
Uniejów	−0.16	−0.30	−0.21	−0.15	−0.14	−0.28	0.03	0.09
Konstancin-Jeziorna	−0.36	−0.43	−0.39	−0.14	−0.13	−0.28	0.25	0.12
Agl. Warszawska	−0.27	−0.39	−0.32	−0.16	−0.06	−0.25	0.14	0.10
Sopot	0.19	0.16	0.18	−0.03	0.04	−0.07	0.08	−0.12
Kołobrzeg	−0.04	−0.18	−0.12	−0.10	−0.24	−0.28	−0.05	−0.01
Agl. Trójmiejska	0.09	0.00	0.05	−0.12	0.07	−0.05	−0.07	−0.03

(Source: own elaboration based on data from the SEM [30,47]).

The occurrence of episodes of high concentrations of PM<sub>10</sub> in the areas of the spas and agglomerations studied in 2019 (with S24 > 75 µg/m<sup>3</sup>) was not as numerous as in the previous years (Table 7). Peak episodes occurred mainly in January, which, depending on the region, was characterized by normal or slightly cool thermal conditions, compared to long-term conditions [39]. The minimum temperature on episode days was always below 0 °C, and in 53% of cases, the average daily wind speed was lower than 1.5 m/s. In almost all these days, no precipitation was observed (Table 7).

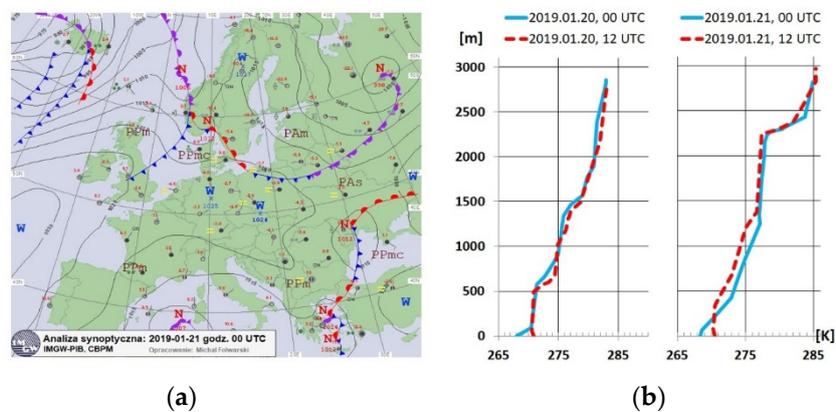
### 6.2. Case study of the PM<sub>10</sub> Episode in 2019

The PM<sub>10</sub> pollution episode that was the longest and covered the largest area occurred on 19–23 January 2019. Available measurement data indicate that it covered, among others, Szczawno-Zdrój, Duszniki-Zdrój, Ustroń, and Wroclaw Agglomeration. Single days with high PM<sub>10</sub> concentration also occurred at the health resorts of Uniejów and Konstancin-Jeziorna. The conditions prevailing on the selected day of the episode (21st January) are illustrated in Figure 4. These are: a synoptic map of Europe and charts of the vertical potential air temperature profile, obtained based on the results of aerological surveys carried out in Legionowo (data from the Wroclaw station for the given days is not available).

**Table 7.** Summary of episodes of increased PM<sub>10</sub> levels in 2019.

Spa/Agglomeration	Date	S24	Maximum Daily Temperature (°C)	Minimal Daily Temperature (°C)	Average Daily Temperature (°C)	Daily Precipitation Sum (mm)	Average Daily Wind Speed (m/s)
Cieplice Śląskie-Zdrój	5 February 2019	107	1.9	−16.7	−6.3	0	1.9
	7 February 2019	98	7.7	−12.5	−4.6	0	1.5
	11 December 2019	78	4.2	−9.2	−4.1	0	1.1
	12 December 2019	91	1.7	−7.9	−2	0	1.1
	17 December 2019	87	11.4	−1	4.1	0	1.4
Szczawno-Zdrój	19 January 2019	81	1.9	−9.5	−4.3	0	0.8
	20 January 2019	127	0.2	−11.6	−7.2	0	1
	21 January 2019	150	0.2	−13.6	−8.1	0	0.6
	22 January 2019	157	−0.6	−13.9	−8.7	0	0.8
	23 January 2019	79	−5	−15.6	−9	0	3.8
Duszniki-Zdrój	31 October 2019	87	7.4	−7.5	−1.8	0	0.9
	19 January 2019	81	−0.3	−11	−7.2	0	1.5
	20 January 2019	104	−2	−12.4	−7.9	0	1
	21 January 2019	93	−4.3	−10.5	−7.7	0	0.9
Ustroń	22 January 2019	118	−3.4	−14.5	−9.5	0	0.9
	10 January 2019	79	−0.6	−3.6	−2.7	5.8	1.6
	21 January 2019	150	−5.2	−10.6	−8.4	0	0.8
	22 January 2019	85	−2.5	−11.6	−7.4	0	1.5
Agl. Wroclawska	23 January 2019	87	−5	−12.4	−8.2	0	3.3
	20 January 2019	96	0.9	−8.7	−4.5	0	0.8
	21 January 2019	81	−1.1	−7.1	−4.1	0	1.9
	22 January 2019	101	−4.8	−7.7	−6.2	0	2.5
Konstancin-Jeziorna	17 February 2019	87	14.4	−3	4.3	0	0.8
	18 February 2019	106	14.7	−4	4.1	0	1.4
Uniejów	20 January 2019	82	−0.9	−8.2	−4.1	0	1.9
	22 January 2019	97	−2.7	−8.5	−5.6	0	2.1
Kołobrzeg	31 January 2019	98	1.6	−3.2	−0.6	0	2.3
	23 April 2019	104	20.4	9.2	15.1	0	5.4

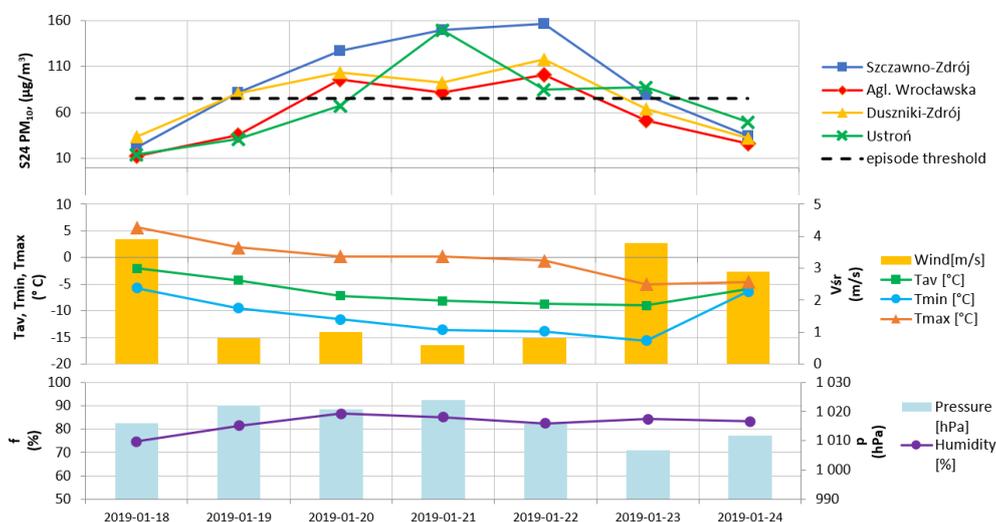
(Source: own elaboration based on data from the SEM [30,47]).



**Figure 4.** Illustrations of conditions prevailing on the selected day of the episode: (a) Europe synoptic map (source: [47]), (b) vertical potential air temperature profiles in Legionowo (source: own study based on data published [48]).

A few days before the episode occurred, along the northern edge of the West European high-pressure area, the following low-pressure areas flowed from the Atlantic through Scandinavia to the Baltic Sea and further to Russia. On the first day of the episode, the current low-pressure area settled on SE from the White Sea over northern Russia. From this area, a cold front came to Russia through Lithuania, Poland, Czechia, and Lower Austria. Following the front, a slightly cooler mass flowed over Scandinavia, Germany, Poland, and the countries to the south, settling and creating a high-pressure system. In addition, a high-pressure area wedge from western Europe developed from the west. In the plains of central Poland and the lake districts, from Denmark and northern Germany, moist air flowed under the inversion layer and formed characteristic patches of stratus clouds (Stratocumulus). The anticyclonic system retained over Poland until 22 January, when the low-pressure area began to enter from the Baltic Sea. On 19–22 January, the increase in pressure at the ground created conditions for settlement inversion at altitudes of 1.5–2.5 km, preventing vertical movements and the exchange of pollutants in the atmosphere. On 19 and 20 January, saddle-type atmospheric circulation occurred over Poland. After 23 January, as the low-pressure area was flowing over Poland, the inversion layer became thinner and thinner.

Figure 5 presents the courses of daily average PM<sub>10</sub> concentrations in three selected spas and Wrocław Agglomeration from the day before the episode to the day after it ended. The meteorological data come from the synoptic station in Jelenia Góra. The average air temperature dropped from 0 °C on the first day of the episode to nearly −10 °C on 23 January, followed by temperature increase. Atmospheric pressure increased until 22 January; from 23 January, a decrease in atmospheric pressure was observed, which was synonymous with the inflow of the low-pressure system over Poland. Along with the decrease in temperature and the increase in atmospheric pressure, the conditions of thermal inversion arose, which favored the increase in concentrations of pollutants in the atmosphere’s ground layer. The average wind speed was around 1 m/s. Due to the change in meteorological conditions and the retreat of the inverse layer, PM<sub>10</sub> concentrations decreased.



**Figure 5.** PM<sub>10</sub> 24-h concentration at selected measuring stations and meteorological parameters in Jelenia Góra (Source: own study based on SEM data, [30,47]).

The exchange of air mass in the atmosphere above the inversion limit is inhibited, and below the inversion zone, the impurities move gradually downwards. This causes a dangerous increase in the concentration of certain pollutants at the ground surface level, and this is particularly evident in mountainous regions, where there are additionally difficult conditions for the dispersion of pollutants. At night, the so called local air circulation appears, during which, the local wind increases. Cold air from the mountains, which is heavier than warm air, flows down the slopes towards the valleys, where the temperature drops sharply. This promotes the formation of inverse layers in valleys and,

by limiting vertical air exchange, pollution accumulation. This phenomenon is important for the air quality status of mountain and foothill spas.

## 7. Actions to Prevent the Air Pollution-Related Health Hazards in Health Resorts

### 7.1. General Remarks

As indicated in the analyses presented in the paper, as well as other studies [10,49], air pollution with particulate matter is a problem in many Polish health resorts. Even in 2019, a year characterized by generally favorable meteorological conditions in relation to air quality, there were PM<sub>10</sub> high concentrations episodes, and in some spas, the situation was worse than in large urban agglomerations. It is necessary to provide appropriate conditions for residents and patients of these spas, who, due to their diseases, are often particularly sensitive to increased PM<sub>10</sub> levels, even during short episodes. Therefore, various types of administrative and organizational activities are undertaken at the national, regional, and local levels, e.g., legislative changes, financial support programs, development works, management and control measures, as well as information and educational measures. Their purpose is to reduce emissions of pollutants, as well as health exposure of residents, also when the episodes occur.

Air quality in the analyzed health resorts depends on several factors, of which the most important are the methods of obtaining heating energy in the municipal and household sector. The problem concerns the quality of fuels and the quality of installations in which fuels are burned [50], including the use of inefficient boilers or solid fuel heating devices. To a lesser extent, air quality is shaped as a result of fuel combustion processes in internal combustion engines. On the other hand, emissions from industrial sources, especially local ones, are usually of the lowest importance, since health resorts are not legally predisposed to locating industrial activities.

The activities undertaken in Polish health resorts are, in part, consistent with measures aimed at improving and maintaining a good level of air quality in localities in other European countries. A good example is Germany, where the responsibility to meet air quality levels enables local and regional authorities to set up air quality plans containing various measures for emission control and air quality improvement [51]. When limit values of air quality are exceeded, cities must propose corresponding clean air plans and action plans to reduce the air pollution level and to protect public health. One control measure, which has drawn a lot of attention and been proposed in the action plans, is the introduction of low emission zones (LEZ). According to the regulations of LEZ at different stages (red, yellow, or green), only vehicles that fulfil certain emission standards and have the corresponding sticker are allowed to enter the zone [52]. In Poland, this type of solution is being discussed. However, the greatest effort is made to reduce the emission of pollutants from the municipal and housing sector due to its large impact and the specificity of a large share of solid fuels in the structure of fuels used for heating in Poland.

### 7.2. Actions at the National Level

The Polish national “Clean Air” program is dedicated to all residents of the country, including health resorts, to improve the process of reducing municipal and household emissions. This government priority program has been operating since 2018 and will last until 2029. The program, which aims to improve energy efficiency and reduce or eliminate the emission of PM<sub>10</sub> and other pollutants released into the atmosphere, is addressed to individuals.

The persistently high level of air pollution and the need for air protection in Poland, including health resorts, has resulted in further initiatives to co-finance the thermomodernization actions. From 1 January 2019, a thermomodernization discount applies, i.e., the option to deduct from the tax base the calculation of expenditure on building materials, equipment, and services related to the implementation of the thermomodernization project in a detached residential building. Another is the Thermomodernization and Renovation Fund operating at Bank Gospodarstwa Krajowego. The purpose of the fund is financial assistance for investors implementing thermomodernization and

renovation projects as well as payment of compensation to owners of residential buildings in which accommodation units were provided [53].

### 7.3. Regional Self-Government “Anti-Smog” Resolutions

To improve air quality, spa municipalities are also taking measures to reduce emissions of pollutants to the environment, in particular elimination of coal heat sources due to the excessive emission of PM<sub>10</sub>, PM<sub>2.5</sub>, and B(a)P. Corrective actions were formulated in the air protection programs prepared by voivodeship self-governments [54,55]. Development of the above programs for the zones and areas with exceedances was imposed by the provisions of Ambient Air Quality Directive transposed to the national legal system. This directive ordered recommendations to be made so that the period in which air pollution exceeds the permissible values was as short as possible [56]. However, the ecological effects of the activities carried out by municipal governments were relatively low, reaching several percent per year. The same obligations specified in the Directive apply to all European Union Member States [26]. In many Member States, responsibility for developing and implementing air quality plans has been devolved by national authorities to local governments.

In view of the persistent level of emissions, subsequent voivodeship self-governments adopted resolutions on the introduction of restrictions and bans on the operation of installations in which fuel combustion occurs (Table 8). The “anti-smog” resolutions as acts of local law specify obligations for residents as users of installations. Thus, they are a tool for more effective implementation of the objectives set out in the air protection programs. In the case of two voivodeships (Dolnośląskie and Pomorskie), dedicated resolutions concern restrictions and prohibitions for health resorts.

**Table 8.** Resolutions applicable to the analyzed health resorts regarding the introduction of restrictions and bans on the operation of fuel-burning installations (Source: own study based on [57–64]).

Voivode-Ship	Health Resort	Resolution	Fuel Prohibitions	Applicable Restrictions/Approvals for New Installations
Dolnośląskie	Cieplice Śląskie-Zdrój	Resolution No. XLI/1406/17 of the Parliament of Dolnośląskie Voivodeship of 30 November 2017, regarding the introduction of restrictions and bans on the operation of fuel-burning installations in the area of health resorts in Dolnośląskie Voivodeship	As of 1 July 2018—a ban on the use of brown coal and fuel produced using this coal, coal sludge and flotoconcentrates, as well as mixtures produced using it; hard coal in fine form (fine coal) with grain size less than 3 mm; solid biomass (wood) with an operating humidity above 20%	Approved for use—gaseous fuels: high-ethane or nitrogen-rich natural gas, propane-butane, agricultural biogas; light heating oil; solid biomass for recreational fireplaces; boilers meeting the eco-design requirements in zone “C” of spa protection in areas without the possibility of connecting to the heating or gas network (from 1 July 2028).
	Szczawno-Zdrój			
	Duszniki-Zdrój			
Śląskie	Ustroń	Resolution No. V/36/1/2017 of Śląskie Voivodeship Assembly of 7 April 2017.	As of 1 September 2019—a ban on the use of brown coal; silt and fleet and mixtures thereof, hard coal with 0–3 mm grain content above 15%; biomass with moisture content over 20%	As of 1 September 2017—solid fuels (coal, wood) in boilers of the 5th grade or meeting the eco-design requirements (EU Directive).
Podkarpackie	Rymanów-Zdrój	Resolution No. LII/869/18 of the Podkarpackie Council of 23 April 2018.	As of 1 July 2018—a ban on the use of brown coal; sludge and flotoconcentrates and mixtures produced with their use; fuels with less than 5 mm grain size and more than 12% ash content; biomass with moisture content over 20%	As of 1 June 2018 to 31 December 2019—solid fuels (coal, wood) in 5th grade boilers. As of 1 January 2020—solid fuels (coal, wood) in boilers meeting the eco-design requirements

Table 8. Cont.

Voivode-Ship	Health Resort	Resolution	Fuel Prohibitions	Applicable Restrictions/Approvals for New Installations
Kujawsko-Pomorskie	Ciechocinek	Resolution No. VIII/136/19 of the Council of Kujawsko-Pomorskie Voivodeship of 24 June 2019.	As of 1 September 2019—a ban on the use of carbon flotation concentrates and mixtures produced with their use; hard coal with a grain size below 3 mm above 15%; solid biomass with moisture content over 20%	As of 1 September 2019—solid fuels (coal, wood) in 5th grade boilers or meeting eco-design requirements
Łódzkie	Uniejów	Resolution XLIV/548/17 of the Council of Łódzkie Voivodeship of 24 October 2017.	It is forbidden to use: hard coal with a grain size of 0–3 mm above 15% and fuels with a calorific value of less than 24 MJ/kg and ash content above 12%; brown coal; sludge and coal flotoconcentrates as well as mixtures produced with their use; biomass with humidity above 20%	As of 1 January 2023—No use of non-class solid fuel boilers (from 1 January 2020—for installations installed in buildings connected to the heating network)
Mazowieckie	Konstancin-Jeziorna	Resolution No. 162/17 of the Masovian Regional Assembly of 24 October 2017.	As of 1 July 2018—a ban on the use of sludge and coal flotation concentrates as well as mixtures produced with their use; brown coal; hard coal with grain size 0–3 mm; wood with a moisture content above 20%.	As of 1 July 2018—it is possible to use solid fuels in new boilers that meet the eco-design requirements.
Pomorskie	Sopot	Resolution No. 236/XIX/20 of Pomorskie Regional Assembly of 24 February 2020, regarding the introduction of restrictions and bans on the operation of installations in which fuels are burning in the area of the Municipality of Sopot	-	The use of LPG gaseous fuel is permitted; light heating oil; solid biomass with moisture content below 20% for specific installations (from 2024)
Zachodniopomorskie	Kołobrzeg	Resolution No. XXX/540/18 of the Council of Zachodniopomorskie Voivodeship of 26 September 2018.	As of 1 May 2019, a ban on the use of unsorted fuels, i.e., solid fuels: hard coal, briquettes and pellets containing at least 85% coal, solid and brown coal for combustion, coal sludge and flotoconcentrates, a mixture of fuels containing less than 85% coal	As of 1 May 2019—solid fuels (coal, wood) in 5th grade boilers or meeting eco-design requirements

#### 7.4. Local Actions in Spa Municipalities

Low-emission economy plans (PGN), which are strategic documents covering territorial areas of municipalities, are also important in reducing pollutant emissions. The activities contained therein are to contribute, among others, to improving air quality in places where exceedances of limit values occurred and air protection programs or short-term measures are implemented [65]. All of the analyzed health resorts have implemented PGN (by assumption covering the years 2015–2020 with a perspective until 2030).

The actions to improve the air quality in spa resorts are usually associated with investments involving the elimination of solid fuel-fired heat sources and the installation of another eco-friendly heating source, which, in turn, requires specific financial outlays. Health resorts, under low-stack emission reduction programs (PONE), adopted resolutions dedicated to residents, changing the way of heating.

Here are examples of activities carried out at the local level in the analyzed spas.

- Sopot: Since 1996, local authorities have progressively implemented a low-stack emission reduction program. The municipal financial initiative significantly contributed to the process of decommissioning coal furnaces. The number of individual coal hearths has been limited from around 8000 existing in 1995, to approx. 300 coal furnaces in 2019 [66]. At the same time, all local coal-fired boilers were closed (as of 30 September 2019). Despite financial incentives, and in the absence of legal tools, not all residents decided to exchange coal heat sources [67]. Implementing subsidy programs, the Sopot health resort municipality benefited from the resources of the Voivodship Fund for Environmental Protection and Water Management (WFOŚiGW) in Gdańsk and the budget of the Sopot City Municipality (among others, for the project entitled: “Modernization of heat sources in residential premises in Sopot”) [67] as well as the Regional Operational Program of Pomorskie Voivodship for 2014–2020 (RPO WP) for the project “Comprehensive energy modernization of public buildings in Sopot” [68]. For a more effective reduction of air emissions, the municipal authorities of Sopot introduced free public transport for students, as well as discounts for residents of council flats who are changing their heating systems and subsidies for window replacement. At the same time, the municipality conducts inspections regarding the type of fuel burned [67].
- Kołobrzeg: The authorities of the spa municipality grant targeted subsidies from their resources, under the adopted resolution on determining the rules for granting specific subsidies from the budget of Kołobrzeg Municipality for investment projects in the field of replacing heating sources for air protection [69]. Under the ROP for Zachodniopomorskie Voivodeship, two programs received funding: low-stack emission, i.e., replacement of coke boilers and pulverized coal-fired boilers, and thermomodernization of the residential buildings [70].
- Ustroń: Residents of the health resort exchange coal-fired heat sources as part of the resolution adopted by the City Council in 2015 on granting a targeted subsidy for co-financing the costs of investments for air protection, involving the replacement of heat sources in residential buildings in the city of Ustroń and resolutions adopted in subsequent years [71]. Additionally, since 2019, the City of Ustroń in cooperation with the Ministry of Technology and Entrepreneurship has been implementing a project: “Integrated support system for policies and programs to reduce low-stack emissions”. The main goal of the project is, among others, to create a prototype system of inventory of low-stack emission sources with a database of heating devices and tools for analyzing these data [72]. In addition to inspection of heat sources, this program includes tests regarding the impact of air pollution on younger residents, including spirometry tests at schools for children aged 10–13 [73].
- Rymanów-Zdrój: The municipality supports fitting of solar installations: sets of solar collectors, photovoltaic installations, ground and air heat pumps, and boilers for biomass for interested residents as part of co-financing obtained from the ROP for Podkarpackie Voivodeship. Since 2019, the Rymanów municipality, in partnership with others, has been implementing a project called “Support of distributed energy among the residents of Lesko, Jaśliska and Rymanów municipalities” in the scope of replacing traditional central heating boilers with class 5 boilers fired with biomass (pellets). Another project which contributes to the improvement of air quality in the Rymanów-Zdrój spa is “Thermomodernization of public buildings in Rymanów municipality”, co-financed from the European Regional Development Fund under Priority Axis III. Clean energy, Activities 3.2. Energy modernization of buildings of the Regional Operational Program for Podkarpackie Voivodeship for 2014–2020 [74].
- Ciechocinek: To take care of the air condition in their area, the authorities grant specific subsidies from the Municipality’s budget for co-financing the costs of the investment eliminating the so called low-stack emissions. At the same time, applications for the installation of gas heating are rewarded, as well as applications submitted by the residents of the “A” and “B” spa zones. The co-financing is consistent with the subsidy obtained from the Voivodeship Fund for Environmental Protection

and Water Management in Toruń [75]. Ciechocinek health resort is a town supplied with gas for 90%, so the change from coal to gas heating is appropriate.

- Konstancin-Jeziorna: The local government of the city continues the program of co-financing the replacement of old coal-fired boilers with new ecological ones. Previously, heating co-financing programs implemented by WFOŚiGW in Warsaw were available to residents. In previous years, the heating change was also carried out as part of two programs. The first one was “Limiting air emissions by modernizing individual boilers”, including replacement of boilers or coal hearths with gas, oil or biomass-fired furnaces, replacement of gas, oil or biomass-fired heaters with a source with higher heat production efficiency than before (excluding the installation of a coal-fired furnace and eco-pea coal). Another one, called “Limitation emissions of pollutants into the air through the purchase and installation of solar collectors, the purchase and installation of photovoltaic installations, the purchase and installation of heat pumps”, was also targeted at private residents who do not run a business at the place of the task being carried out [76].
- Szczawno-Zdrój: Reduction of emissions from coal heat sources took place, among others, from the “Kawka” Program, in connection with the adoption of a resolution on co-financing in 2015. In 2015–2018, 228 coal heat sources were eliminated [77].
- Cieplice Śląskie: The elimination of the sources of air pollutant emissions was supported by financial resources from the “Kawka” program. Since 2017, the change to low-emission heating has been based on the resolution of Jelenia Góra City Council on determining the rules and procedures for granting specific subsidies from the municipality’s budget to co-finance the costs of investment tasks related to reducing low-stack emissions in the city of Jelenia Góra [78]. Corrective actions are also carried out at this resort within the framework of the ROP project for Dolnośląskie Voivodeship: “Reduction of pollutant emissions through modernization of heat sources in Jeleniogórska Agglomeration”, “Priority axis 3 Low-emission economy, Action 3.3 Energy efficiency in public buildings and the housing sector, Sub-action 3.3.3 Energy efficiency in public buildings and the residential sector, Modernization of heating systems and renewable energy sources—projects to eliminate chimney emissions” [79].
- Duszniki-Zdrój: To improve air quality, the authorities of the health resort joined the project “Kłodzko Land—Clean Air” [80]. Besides, Duszniki Zdrój, similarly to the health resort of Uniejów, participates in the government program “Clean Air”, which grants the residents funds for replacement of unclassified boilers and house insulation.

### 7.5. Information on Air Quality

Another type of action aimed at limiting the exposure to air pollution and protecting human health, including that of spa patients, is to provide reliable and appropriate information on the current and forecasted situation regarding air pollution and related threats. This task is carried out on a national scale by the Chief Inspectorate for Environmental Protection, which provides, among others, the results of measurements from stations operating within the SEM on the Air Quality Portal [30]. The portal also presents short-term forecasts of the concentration of selected pollutants for Poland and its voivodeships, based on the results of modeling performed routinely by the Institute of Environmental Protection—National Research Institute.

For the health resort areas, implementing more accurate information systems that are linked to the medical context and take into account the specificity of a given spa and the nature of the health conditions of its residents should be considered. Specific information should be provided to residents, local administrations, patients, and the medical staff. The local analytical and information system could include the following elements:

- Detailed and continuously updated database, where an inventory of pollution emission sources located in a given area and its surroundings and directly affecting the health resort are documented.

- Air monitoring data analysis system based on measurements obtained as part of the SEM network, possibly supplemented with additional local measurements, while maintaining an appropriate level of quality; measurements of indoor air quality in therapeutic facilities and accommodation of patients could be included.
- A local system for analyzing the scenarios of planned and undertaken actions and their effects in relation to the air quality in the spa, including the potential for episodes of high pollution concentrations.
- A system of short-term, high-resolution local air quality forecasts, taking into account local emission sources, pollution inflow, boundary conditions provided by the national forecasting system, topographic conditions, and land development; information provided by this system (including identification of anticipated occurrences of episodes) should be associated with information on health effects and medical information specific to the particular spa. Appropriate recommendations and scenarios for actions should be developed with the participation of specialists in the field of impact of pollution on health and local medical personnel. Dedicated information delivered well in advance to medical services, and spa services could, for example, allow for appropriate activity planning, limiting the adverse effects of pollution on health.

## 8. Summary

We presented the analyses of air quality in 10 selected health resorts in the scope of the PM<sub>10</sub> concentrations variability based on measurements from SEM. According to the analyses, the so called low-stack emission and meteorological or topographic conditions which, e.g., reduce the possibility of pollution dispersion, especially in mountain valley spas, significantly affect higher pollutant concentrations.

The analyses of the average annual and daily concentrations of particulate matter in 2015–2019 proved that the best air quality conditions are in health resorts located in the north of Poland, while the least favorable conditions are in the south and partly in the central part of Poland. It was also found that these cities have taken the most actions to protect the air, especially in the spa of Sopot. At the same time, the most stringent requirements for the measures to improve air quality were adopted at the health resorts of Lower Silesia.

The best conditions for ambient air quality, especially in the winter season, were in years with high temperatures (as in 2019), which is directly related to the lower emission of pollutants resulting from the combustion of solid fuels in furnaces and boilers. Thus, emissions from the household sector, i.e., “low-stack emissions”, directly translate into the quality of air in the analyzed spas. Due to the emission of particulate matter pollution in health resorts, both from local sources and incoming from neighboring sources, as well as topographic conditions, often unfavorable in terms of dispersion of pollution, there are situations (including episodes) in which air quality is comparable to or even worse than in large urban agglomerations.

Air quality, along with the deposits of natural medicinal resources and spa facilities, is one of the most important factors shaping the therapeutic values and predispositions of a given spa. Proper management of air quality in health resorts can be an important condition contributing to the effective treatment of patients from groups particularly sensitive to air pollution. It is worth underlining the importance of reliable information on the state of air, which, when properly used, should be an integral part of air quality management. The information system on the current and forecast concentrations of pollutants has a particularly important medical dimension in the spa treatment system.

It is necessary to supervise the implementation of anti-smog resolutions, including the development of financial support for changing the heating system in terms of replacing coal furnaces with low-emission heating. Actions taken so far in recent years to improve air quality have brought some effects, which is visible in the changes in concentration levels. However, it should be borne in mind that these changes largely result from the meteorological conditions prevailing in a given year. More research and analysis are needed as new regulations enter into force and action is taken in practice,

as well as new measurement data (multi-year measurement series) and reliable mathematical modeling results become available. This will allow for the correct estimation of trends and determination of the effectiveness of air quality management measures.

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