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Research article

Is the occurrence of electromagnetic hypersensitivity related to sensitivity to air pollution and weather factors?

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Abstract: The main research topics in 2020 and 2022 were the relationship between the frequency of electromagnetic hypersensitivity (EHS) and air pollutants, such as suspended dust ($PM_{2.5}$ and PM_{10}), sulphur dioxide (SO_2), and nitrogen dioxide (NO_2), and the relationship between EHS and weather factors or parameters (station-level pressure, relative humidity, duration of sunshine), wind speed, wind gusts, cloud cover, average winter air temperature, and average summer air temperature) that describe the environmental levels of electromagnetic fields from the telecommunications infrastructure. The research was carried out in the form of surveys among residents of selected Polish cities. The strongest qualification criterion for the group of people declaring themselves hyperelectrosensitive allowed us to estimate the maximum incidence of EHS in the Polish population at 1.8% among the 2020 study group and 1.6% in 2022. The results showed no strong correlation between EHS and sensitivity to weather factors or air pollution. The causal relationship between environmental parameters and the number of individuals classified as EHS+ with the highest probability cannot be expected. The results showed that, among people who declare themselves hyperelectrosensitive, there is a significantly higher percentage of those who declare themselves hypersensitive to environmental pollution and weather.

Keywords: electromagnetic field; hyperelectrosensitive; meteoropathy; PM_{10}; $PM_{2.5}$

1. Introduction

The term proposed by the World Health Organization (WHO)—idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF)—encompasses all critical features of this condition: (1) unknown etiology, (2) the lack of objective methods to classify individuals affected by this phenomenon beyond self-identification as being hypersensitive, and (3) an association with environmental factors [1]. Issues related to the second and third aspects characterizing electromagnetic hypersensitivity (EHS) were the subject of this research. In the literature there is a distinction between electosensitivity—the ability to detect electromagnetic fields—and electromagnetic hypersensitivity, which involves the development of health symptoms as a result of exposure to environmental electromagnetic fields [2]. There are two potential explanations for the occurrence of EHS. One hypothesis suggests the existence of unknown biophysical phenomena associated with the interaction between electromagnetic fields (EMFs) and the body—similar to what happens in the animal world [3]—leading to the development of the symptoms reported by sensitive individuals. The second theory proposes that psychophysiological mechanisms underlie EHS [4], where stress related to fear of adverse health effects leads to psychosomatic symptoms, which causes some people to perceive themselves as being sensitive to EMFs emitted by electrical devices.

A survey was conducted first in 2020, and then repeated in 2022 with a larger sample, to estimate the prevalence of EHS in Poland and to establish criteria that would unequivocally and reliably identify people who can be considered hypersensitive to EMF. Several criteria, defined and tested in the form of questions or combinations of questions posed to the respondents, were developed to classify subjects as being sensitive to EMFs. Individuals classified as hypersensitive to EMFs are designated as EHS+. The remaining individuals (who cannot be classified as such) are marked as EHS-. These criteria are described in (Table 1). The question of defining and selecting classification criteria for hypersensitive individuals was discussed in a survey on electromagnetic hypersensitivity from Poland [5]. Out of the 11 proposed criteria in this paper, only eight, marked C1–C8, were ultimately used. The most stringent and, in our opinion, the most reliable of the proposed criteria for EHS+ qualification assumes that the symptoms associated with magnetic fields are unique—different from those of the general public—and are severe enough for the person affected by them to seek help. This is a double criterion (criterion C8). It allowed us to estimate the prevalence of EHS in Poland at a maximum of 1.8% among the 2020 study group and 1.6% in 2022. In this paper, we present the results mainly for the strongest criterion, C8.

Justification for exploring the connection between the prevalence of EHS and air pollution or atmospheric factors can include the similarity between EHS and environmental intolerance to chemical factors (multiple chemical sensitivity) or physical factors such as the weather (meteorosensitivity) [6]. The similarities between EHS and multiple chemical sensitivity lie in the fact that the mechanisms of interaction for both are not fully explained and that hypersensitivity manifests at very low levels of the associated environmental parameter. Symptoms are mostly subjective and nonspecific, varying widely. Regarding symptoms caused by weather factors, there is a qualitative difference between the terms meteorosensitivity and meteoropathy. Meteorosensitive individuals are biologically susceptible to the mental or physical influence of certain weather events. Meteoropaths are individuals in whom changes in the weather will develop or exacerbate an existing specific disease [7]. In our research, we refer to meteorosensitive individuals.

There is a possibility that people who are more sensitive than the general population to certain chemical substances, including those observed in polluted air or specific meteorological physical changes, are also more sensitive to EMFs. This connection could be due to the real interactions of these factors with the body or may be related to the psychological makeup of hypersensitive individuals. Individuals more focused on their health status or with depression and anxiety may also fear various environmental factors that could negatively impact their bodies. Consequently, such individuals can simultaneously associate perceived symptoms with different physical and chemical factors. There has been shown to be an admission index for the most common mental disorders according to seasons and climatic factors [8].

Meteorological variables such as barometric pressure, temperature, humidity, cloud cover, atmospheric fronts, wind speed, precipitation, and sunlight [9] affect health and are associated with changes in neurotransmitter levels in the brain [10]. For example, patients with meteoropathy often exhibit elevated levels of adrenocorticotropic hormone (ACTH), which is produced by the pituitary gland and leads to symptoms such as palpitations, anxiety and irritability [11,12].

Another significant issue considered in the 2020 project and repeated in 2022 was examining the relationship between the frequency of EHS and the parameters that describe the environmental levels of EMFs in the telecommunications infrastructure. The hypothesis that the number of people hypersensitive to EMFs is related to their being exposed to it in the environment seems logical and justified. Environmental exposure to EMFs from the telecommunications infrastructure should be linked to the prevalence of EHS, both in the case of real biophysical interactions of EMFs with human bodies and in the case of the second mechanism mentioned above. Higher levels of EMFs in the environment are associated with more frequent observations of telecommunications devices around us, which could lead to increased fear of EMFs and, in turn, psychosomatic symptoms.

Our aim is to explore the relationship between the prevalence of EHS and air pollution, atmospheric factors, and environmental levels of EMFs generated by the telecommunications infrastructure.

2. Materials and methods

The research was carried out using the CATI method (computer-assisted telephone interview). In 2020, a survey was conducted among a group of 2000 individuals. The respondents were selected in such a way as to ensure that the study population accurately reflected the national population in terms of gender, place of residence, and level of education. Investigating the associations between the prevalence of electromagnetic hypersensitivity (EHS) and air pollution, meteorological factors, and environmental exposure to electromagnetic fields (EMF) requires precise information about the place of residence of survey participants. However, the survey conducted at the end of 2020 had different objectives, and the precise identification of the respondents' location of residence was not originally intended. Nevertheless, questions in the survey regarding the population size of the respondent's place of residence allowed for the clear identification of residents from 12 specific cities. For the purposes of this analysis, data from 378 surveys were used. The cities included in the analysis, along with the number of surveys collected in each, were as follows: Białystok (17), Kielce (15), Kraków (50), Lublin (30), Łódź (57), Opole (7), Poznań (40), Rzeszów (19), Tarnów (9), Wałbrzych (21), Warsaw (67), and Wrocław (46).

In 2022, another survey was conducted among a group of 2200 individuals. Respondents were again selected to ensure that the study population accurately reflected Polish society in terms of gender, level of education, and age structure. Therefore, these demographic characteristics of the respondents were not included as factors influencing the self-identification as an EHS individual in the analysis. At the same time, the selection of respondents was limited to their place of residence. Only residents of the twelve cities included in the 2020 survey were invited to participate in the study. Consequently, the study group does not represent a national sample in terms of geographic distribution or degree of urbanization. The number of respondents in each urban center was approximately proportional to the city's population size, with the requirement that no fewer than 100 interviews be conducted in each city. The cities included in the analysis and the number of surveys conducted in each were as follows: Białystok (100), Kielce (100), Kraków (270), Lublin (120), Łódź (230), Opole (100), Poznań (180), Rzeszów (100), Tarnów (100), Wałbrzych (100), Warsaw (600), and Wrocław (200).

The survey consisted of five questions concerning the respondents' characteristics (gender, age, province of residence, category of place of residence, and education) and 10 questions related to hyperelectrosensitivity, including eight questions about declarations of EMF sensitivity formulated in different ways. The criteria used in the study are presented in (Table 1).

Table 1. Classification criteria C1–C8 used in the survey to identify potentially hyperelectrosensitive individuals (EHS+).

Criteria	Affirmative response to the question/option:
C1	Is your well-being or health affected by the following factors? a) weather, b) air pollution, … e) electromagnetic fields
C2	To which of these factors are you hypersensitive or allergic? … h) magnetic or electric fields
C3	Do you think you are electrosensitive or hypersensitive to electromagnetic fields?
C4	Do you believe that devices emitting electromagnetic fields negatively impact your a) well-being …?
C5	Do you believe that devices emitting electromagnetic fields negatively impact your … b) health …?
C6	Do you think that devices emitting electromagnetic fields negatively impact both your well-being and your health?
C7	Do you experience health symptoms related to the use of electrical devices that, in your opinion, others do not experience?
C8	Do you experience health symptoms related to the use of electrical devices that, in your opinion, others do not experience? If so, were these symptoms severe enough to affect your daily life or did you consult a physician for them?

Criterion C1 was a closed multiple-choice question in which respondents indicated, among other factors, a) weather, b) air pollution, or e) electromagnetic fields as affecting their well-being or health. We aimed to investigate whether respondents who indicated that weather or air pollution affects them also identified themselves as EHS+ individuals with respect to other criteria.

The air pollution data was derived from the analytical results published by the Chief Inspectorate of Environmental Protection (ChIEP) in the Measurement Data Bank [13]. In Poland, measurements are taken for many indicators related to air pollution [14]. For the quantitative analysis, it was decided to consider the measurements of the four factors that have been studied the longest and in the most systematic manner: (1) SO_2, (2) NO_2, (3) $PM_{2.5}$, and (4) PM_{10}. The concentrations of $PM_{2.5}$ and PM_{10}

are averaged over 24-hour periods, while those of SO_2 and NO_2 are measured hourly. ChIEP data summarizing the measurements from 2000 to 2020 were used, but ultimately only data from the period 2011–2020 were analyzed due to incomplete data in previous years. During this period, complete data for the selected environmental factors were available for all cities under analysis.

The potential hypersensitivity to air pollution factors was assumed to result from prolonged exposure to a contaminated environment, together with hypersensitivity to electromagnetic fields. Therefore, the analysis considered the mean, maximum, and minimum values for the concentrations of each factor throughout the analysis period. Additionally, trends in these parameters during the period 2011–2020 were also taken into account. The measure of trends for each parameter was the slope coefficient (a) of a straight line fitted to the data representing the concentration of a selected factor (x) over time: $c_x = at + b$, where c_x denotes the concentration of the selected type of pollution and t denotes the time expressed in years.

The Institute of Communications at the National Research Institute in Warsaw prepared and made available data from simulations of EMF distribution in the areas of the cities selected for analysis. The parameters characterizing the intensity of the electrical component of EMFs in the areas of selected cities came from the Information System on Installations Generating Electromagnetic Radiation (SI2PEM). The EMF distribution was determined using a grid of elements 1 m^2 in size. An aggregated value was determined for each grid point, i.e., the highest value observed in the height range from 0.3 m to 2 m above the ground. The simulation was carried out for base stations operating at maximum power.

For all 12 cities, the following were calculated in the software application R (R Project for Statistical Computing, Free and Open Source Software Licence–General Public Licence: GNU): the average intensity of the EMF electrical component (EMF_Av), the standard deviation (EMF _SD), the median (EMF_Med), and the value of the 10th (EMF_10c) and 90th (EMF_90c) centiles of the distribution of EMF values in the study areas.

In addition to the quantitative data described above, qualitative data published by the ChIEP was also used. The qualitative classification is based on the quantitative measurements and is carried out by the ChIEP every five years. The last summary was published in 2019 and covers the period 2014–2018 [14]. To complement the analysis of chemical factors (air pollution), it was decided to analyze selected weather factors for the same period, corresponding to the qualitative analysis of chemical factors. The data for analysis were obtained from the official database of the Institute of Meteorology and Water Management [15]. Each major city has its own measurement station where the current weather parameters are recorded every hour. From all recorded factors, we decided to select eight parameters for our analysis that are most likely to impact human well-being. For each station, the average values for the given period were calculated and correlated with the survey results. The selected parameters were station-level pressure [hPa], relative humidity [%], duration of sunshine [min/60 min], wind speed [m/s], wind gusts [m/s], cloud cover [oktants] (where 0 = no clouds and 8 = completely overcast), average winter air temperature [°C], and average summer air temperature (June–August) [°C]. The same cities that were selected in the survey were included in the analysis except for Wałbrzych, where there is no research station. For the analysis of sunshine duration, Krakow and Tarnów were excluded due to incomplete data. For the same reason, Tarnów was also excluded from the analysis of wind speed, wind gusts, and cloud cover. In both studies, in 2020 and 2022, the same data sets of physical atmospheric factors (weather) were used.

All parameters mentioned above were subjected to statistical analysis in Statgraphics Centurion 19 (Statgraphics Technologies Inc.). The correlation of all air pollution parameters and those that describe the distribution of EMFs with the number of people with EHS+ for individual cities, determined according to all qualifying criteria for EHS+ (C1–C8), was examined. Spearman's rank method was used. In our research, we took $r_s = \pm 0.6$ as the threshold value for correlation between two quantities. The parameter $|r_s > 0.6|$ indicates a strong and significant relationship.

3. Results

3.1. Development of criteria to identify potentially hyperelectrosensitive patients

Based on the criteria C1–C8 described in (Table 1), we estimated the prevalence of hyperelectrosensitive individuals in Poland in the years 2020 and 2022 (Table 2).

Table 2. Prevalence of EHS+ individuals in Polish cities in 2020 and 2022 according to criteria C1–C8 in 2020.

City	No. of surveys	C1 [%]	C2 [%]	C3 [%]	C4 [%]	C5 [%]	C6 [%]	C7 [%]	C8 [%]
All surveys*	2000	21.4	9.5	9.6	18.2	21.9	14.3	4.4	1.8
All surveys	2200	21.4	8.7	7.7	17.1	23.3	13.9	4.7	1.6

*All surveys collected in the study, not only from residents of major cities. In 2022, all respondents were residents of large cities in Poland.

In the study conducted in 2020, the entire group of 2000 respondents was representative of the Polish population in order to evaluate the precision of the criteria. The collected data suggested that criterion C8 provides information on the prevalence of IEI-EMF individuals in Poland at a level similar to that of neighboring countries (less than 2%) [16].

3.2. Comparison of the prevalence of EHS individuals in Polish cities with air and EMF pollution

The data collected on the prevalence of people with EHS in different Polish cities was then compared with environmental parameters (Tables 3–7). Particulate matter ($PM_{2.5}$ and PM_{10}), sulphur dioxide (SO_2), and nitrogen dioxide (NO_2), as well as electromagnetic field background (EMF), were the environmental factors included in the study. In the statistical analysis of $PM_{2.5}$, PM_{10}, SO_2, and NO_2, the following parameters were included: average/minimum/maximum concentration ($\mu g/m^3$) in 10 years [abbreviations: Av, Min, and Max] and during data collection [abbreviations: AvT, MinT, and MaxT]. For EMF pollution, the data represent the mean [Av], standard deviation [SD], median [Med], and 10th and 90th centiles [10c and 90c] (Table 8). The statistical relation was described by the Sperman's rank test.

Table 3. Correlations between the PM2.5 parameters and the prevalence of EHS+ individuals estimated by the strongest criterion (C8) in 2020 and 2022.

Criterion	C8					
Parameter / Year	$PM_{2.5}$_Av	$PM_{2.5}$_Min	$PM_{2.5}$_Max	$PM_{2.5}$_AvT	$PM_{2.5}$_MinT	$PM_{2.5}$_MaxT
2020	0.138	−0.095	0.275	−0.395	−0.083	−0.129
2022	0.116	0.355	−0.519	−0.323	−0.652	0.016

Statistically significant results ($|r_s > 0.6|$) are bolded. Abbreviations: average/minimum/maximum concentration (μg/m^3) in 10 years [Av/Min/Max] and during the survey [AvT/MinT/MaxT].

Table 4. Correlations between the PM_{10} parameters and the prevalence of EHS+ individuals estimated by the strongest criterion (C8) in 2020 and 2022.

Criterion	C8					
Parameter / Year	PM_{10}_Av	PM_{10}_Min	PM_{10}_Max	PM_{10}_AvT	PM_{10}_MinT	PM_{10}_MaxT
2020	0.119	−0.469	−0.037	−0.037	0.376	0.239
2022	0.124	−0.335	−0.36	0.131	−0.007	0.572

Statistically significant results were obtained for $|r_s > 0.6|$. Abbreviations: average/minimum/maximum concentration (μg/m^3) in 10 years [Av/Min/Max] and during the survey [AvT/MinT/MaxT].

Table 5. Correlations between the SO_2 parameters and the prevalence of EHS+ individuals estimated by the strongest criterion (C8) in 2020 and 2022.

Criterion	C8					
Parameter / Year	SO_2_Av	SO_2_Min	SO_2_Max	SO_2_AvT	SO_2_MinT	SO_2_MaxT
2020	0.312	−0.005	0.321	−0.367	−0.33	0.477
2022	−0.074	−0.034	−0.007	0.018	−0.501	0.314

Statistically significant results were obtained for $|r_s > 0.6|$. Abbreviations: average/minimum/maximum concentration (μg/m^3) in 10 years [Av/Min/Max] and during the survey [AvT/MinT/MaxT].

Table 6. Correlations between the NO_2 parameters and the prevalence of EHS+ individuals estimated by the strongest criterion (C8) in 2020 and 2022.

Criterion	C8					
Parameter / Year	NO_2_Av	NO_2_Min	NO_2_Max	NO_2_AvT	NO_2_MinT	NO_2_MaxT
2020	0.229	−0.363	−0.046	0.367	0.597	0.018
2022	0.226	0.121	0.039	0.342	0.12	0.004

Statistically significant results ($|r_s > 0.6|$) are bolded. Abbreviations: average/minimum/maximum concentration (µg/m^3) in 10 years [Av/Min/Max] and during the survey [AvT/MinT/MaxT].

Table 7. Correlation coefficients using the Spearman rank method ($|r_s| > 0.6$) for the relationship between the number of hypersensitive people classified according to the strongest criterion (C8) and the 5-year air quality (2014–2018).

Criterion	C8	
Parameter / Year	$PM_{2.5}$	NO_2
2020	0	0.083
2022	0.284	0.404

A detailed summary of the classification of the areas analyzed in air pollution classes in the 5−year evaluation and a description of the preparation method can be found in (Tatoń, 2022). The description of the criteria can be found in (Table 1).

Table 8. Correlations between the EMF parameters and the prevalence of EHS+ individuals estimated by the strongest criterion (C8) in 2020 and 2022.

Criterion	C8				
Parameter / Year	EMF_Av	EMF_SD	EMF_Med	EMF_10c	EMF_90c
2020	−0.069	0.083	−0.203	−0.005	0.018
2022	0.539	0.428	0.468	0.392	0.481

Abbreviations: average [Av], standard deviation [SD], median [Med], and 10th and 90th centiles [10c, 90c].

3.3. Comparison of individuals with EHS in Polish cities with weather factors

The average values of the meteorological factors were calculated in 2020 and 2022 and were correlated with the survey results (Table 9).

Table 9. Correlations between the number of hypersensitive individuals classified according to the strongest criterion (C8) in 2020 and 2022 and the parameters that describe the weather factors.

Year	Atmospheric pressure at station level [hPa]	Relative humidity [%]	Sunshine duration [min/60 min]	Wind speed [m/s]	Wind gusts [ms]	Cloud cover [octants]	Temp. in winter [°C]	Temp. in summer [°C]
2020	–0.295	0.208	–0.109	0.186	0.283	0.022	–0.353	–0.081
2022	0.265	0.110	–0.126	–0.079	–0.041	0.237	–0.174	–0.429

The coefficients that may indicate statistical significance and suggest causal relationships between the variables were $|r_s| > 0.6$.

Similar to the comparison of parameters that describe environmental pollution, weather factors appeared to correlate only in some cases with data on the occurrence of EHS in people in Poland.

3.4. Comparison of the negative influence of environmental pollution on the well-being in EHS- and EHS+ individuals

Table 10. Percentage of respondents who claim that environmental pollution or weather influences their health and well-being.

EHS criteria	Percentage among EHS+ [%]	Percentage among EHS- [%]	Percentage among EHS+ [%]	Percentage among EHS- [%]
	2020 Air pollution		2020 Weather factors	
C1	89.7	60.2	82.9	65.9
C2	85.8	65.8	85.3	68.4
C3	80.6	67.1	81.2	68.7
C4	82.1	64.4	83.2	67.3
C5	84.0	63.6	81.5	66.8
C6	84.6	62.8	82.9	65.6
C7	83.0	68.0	88.6	70.1
C8	86.8	79.6	94.7	83.7
	2022 Air pollution		2022 Weather factors	
C1	92.4	69.2	78.6	67.2
C2	88.0	74.3	79.4	68.1
C3	87.6	74.6	81.9	65.2
C4	85.4	73.9	79.1	65.1
C5	86.3	72.2	83.0	64.5
C6	87.9	72.2	77.9	68.4
C7	85.6	76.0	94.4	69.1
C8	91.7	82.4	81.1	63.5

In addition to questions about hyperelectrosensitivity, the respondents were asked if they consider environmental pollution (Table 1, C1(b)) or weather (Table 1, C1(a)) to be a factor that negatively influences their health and well-being. The results presented in (Table 10) show that in the EHS+ group, there was a statistically significantly higher percentage of people who claim hypersensitivity to environmental pollution and weather.

The results show a higher prevalence of EHS+ individuals who consider environmental pollution or weather to be a factor that negatively influences their health and well-being, which can suggest the presence of a multifactorial hypersensitivity phenomenon in the Polish population.

4. Discussion

The Spearman's rank correlation analysis examining associations between factors that describe air pollution and the frequency of EHS showed that causal relationships between these variables can be considered and studied. Increasing the sample sizes in the cities selected for analysis in 2022 improved the data quality, which in turn enhanced the statistical significance and strength of the observed correlations.

The questions in the survey were intended to determine what percentage of the population self-identifies as EHS+. Electromagnetic hypersensitivity is a broad phenomenon. EHS+ symptoms may be experienced both in the presence of everyday household devices, which primarily emit low-frequency electromagnetic fields, as well as in the vicinity of telecommunication equipment that emits high-frequency fields, such as base stations [17]. We aimed to identify an objective parameter that would reflect the actual exposure of residents in selected cities to electromagnetic fields; therefore, we chose to use environmental measurements of fields originating from base stations. We analyzed the correlation between the prevalence of self-reported electromagnetic hypersensitivity and actual environmental exposure to electromagnetic fields. However, no such correlation was observed for the strongest criterion (C8). This analysis also served as a complement to studies on the influence of environmental factors such as weather and air pollution.

In 2020, for the strongest criterion (C8), a parameter for NO_2 was (0.597) and was very close to statistical significance (0.6), which is consistent with the state of knowledge about NO_2, SO_2, and O_3 having a significant negative impact on subjective well-being [18]. The results would be consistent with research conducted in the cities with the highest levels of pollution, Shanghai and Beijing, showing that only SO_2 and NO_2 have negative impacts on life satisfaction, while PM pollutants do not affect the life satisfaction of Shanghai residents [19].

Since the only air pollution factor that showed high correlations with statistical significance in the 2020 study was PM_{10} concentration, and only for the weaker criteria C1–C7, the results are not presented in this work. They were, however, motivation for us to repeat the research in 2022, where we expected a given correlation to occur for a strong criterion. This correlation led to the working thesis that the only environmental factor directly related to the frequency of smog (that is, the societal perception of the threat) correlates with the frequency of individuals perceiving themselves as being sensitive to EMFs. Such a visible and readily available air pollution indicator as dense fog raises public awareness of environmental contamination more than factors without such visible effects. This link could explain the higher correlations between PM_{10} and EHS+ and, if proven, would suggest a psychological mechanism underlying EHS. This was consistent with the results obtained for weather factors for the weak criteria, which are not shown in this article because only cloud cover, an observable factor, correlated with sensitivity to EMF. This would speak more to a psychological explanation. Research shows that four affective temperaments (depressive, cyclothymic, irritable, and anxious) positively correlated with meteoropathy among women (although the correlation coefficients were small to medium). The medium correlations between cyclothymic or anxious temperaments and meteoropathy were disclosed [20]. The age of the subjects also has an impact on the association between personality and meteoropathy. Studies on the role of the Big Five personality traits [21] (openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism) in the intensity of meteoropathy in two age groups—younger (18–30 years) and older adults (60+)—have shown an association between personality and meteoropathy only in the group of young adults. Among this group, only one personality trait was significant in relation to meteoropathy: neuroticism. Studies on weather sensitivity suggest that the tendency to report seasonal changes in affective disorder symptoms coincide with neuroticism [22].

The hypothesis about smog cannot be confirmed by the results of the study in 2022. Only one parameter (for the strong criterion, C8) describing suspended particulate concentrations showed a Spearman coefficient exceeding 0.6 and statistical significance for the correlations between the variables: the trend of the minimum value of $PM_{2.5}$ concentration. The coefficient was negative, indicating that as the minimum observed $PM_{2.5}$ concentration decreases over time, the number of individuals identifying as EHS+ increases. This observation cannot be logically explained beyond a chance correlation, thus not indicating a real causal relationship.

It seems that only positive Spearman coefficients could indicate a real connection between the frequency of EHS occurrence and the parameters under analysis, thus suggesting a physical mechanism of the impact of EMF on humans. Higher concentrations and higher field intensities should increase the number of individuals sensitive to EMFs. Negative Spearman coefficients can only be explained by a greater perception of a threat in a less-polluted environment, leading to a larger number of sensitive individuals. This, in turn, supports the hypothesis of psychological mechanisms underlying EHS rather than the real impact of EMFs on the human body. Research on the nocebo effect of subjective well-being under influence of EMF indicated that IEI-EMF consistently reported significantly lower levels of well-being when they believed that the base station, which emits EMFs, was ‘on’ compared to ‘off’ [4].

5. Conclusions

It is essential to emphasize the significant difference between the effects of air pollution and EMFs on health. The negative impact of the latter at levels that are considered safe is only postulated, while the negative impact of the former on our bodies is real and confirmed.

The strongest criterion (C8) for the group of people who perceive themselves as being hyperelectrosensitive allowed us to estimate the maximum incidence of EHS as 1.8% in the 2020 study and 1.6% in 2022.

It should also be noted that statistically significant correlations between the parameters describing air pollution, weather factors and EMF levels in the environment, and the frequency of EHS were not found for the strongest EHS+ classification criterion (C8) (except for the previously mentioned negative case of the $PM_{2.5}$ minimum value trend). In other words, a causal relationship between environmental parameters and the number of individuals classified as EHS+ with the highest probability cannot be expected. If such a relationship existed, it could be considered a real connection between EMF sensitivity and air pollution levels.

In the EHS+ group, there is a statistically significant higher percentage of people who define themselves as hypersensitive to environmental pollution and weather. Sensitivity to EMF is based on individual perceptions of threats to life and health from various environmental factors such as EMFs, air pollution, and weather factors.

Use of generative-AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

The authors declare no conflict of interest.

Author contributions

D.K. and G.T. conceived of the presented idea. D.K. and G.T. developed the theory and performed the computations. G.T. carried out the study experiments. D.K. and G.K. wrote the manuscript. All authors discussed the results and contributed to the final manuscript and its revised versions.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

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