Magnetic Storms and an Emergency Ambulance Call Pattern in Petrozavodsk

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Abstract: - We use geophysical and geochemical data and an impersonalized catalogue of ambulance calls for the period 2015-2017 to study the morbidity of the population in Petrozavodsk, which is located in sub-Arctic area with complex climatic and weather and geomagnetic conditions. Temporal, spatial and other emergency call distributions, reflecting the effects of a variety of factors on morbidity, have been investigated. The effect of geomagnetic activity on the number of ambulance calls with myocardial infarction and stenocardia diagnoses and reducing the number of calls in weekend and holiday were corroborated. Urban soil pollution did not correlate with the distribution of the ambulance call number in residential areas for common diseases. The results reflect the structure of the morbidity of the urban population and are not contradicted to known environmental models.

Key-Words: - Geomagnetic activity, diseases, emergency calls, distributions, spectra, diagnosis.

1 Introduction

The primary goal of the studies of environmental processes and the human response to them is to asses factors affecting human health. This problem is particularly acute for cardiovascular diseases, a major mortality factor in highly developed countries. Disease incidence models could be used to generalize the results obtained differing in geographic position, climate and environment.

The electromagnetic fields of transport, electrical power lines and electrical power plants are known to affect the physical and mental state of people [1]. Scientists remain uncertain as to the effect of geomagnetic variations on human health. The attention given to this problem after the publications of A.L. Chizhevsky [2], [3] is due to the contradictory results of studies.

Magnetic storms, understood as long, vigorous geomagnetic field perturbances, correlated in time with solar flares, are of utmost interest. They are assumed to be provoked by corpuscular radiation, which accompanies flares, perturbs the magnetosphere and ionosphere, triggers the degradation of the solar batteries of satellites, the malfunction of electronic and navigation guiding systems in electrical power lines and power plants and exert a radiation effect on spacemen and air passengers [4]. Most people are assumed to be unaffected by magnetic storms, except for highly sensitive people, who find themselves in extreme situations, and those suffering from heart insufficiency and nervous disorder [5].

A magnetic field can influence the blood circulation, nervous and digestive systems of the organism through blood viscosity, signal travel speed and the resistance of microorganisms [6]-[9]. The cyclic constituents of the field synchronize biological rhythms, while sporadic perturbations disturb them. In some studies, disease incidence was not found to be correlated with magnetic storms [10].

Ambulance call catalogues, which contain data on the location and time of a call, impersonal data on a patient and the disease diagnosed, are used in some studies to analyze the impact of environmental factors on disease incidence [11]-[14]. Publications [10], [15], [16], in which some techniques are described, are noteworthy. The Moscow ambulance call database, covering a long period of time, was used, many medical indices were assessed and various diseases were analyzed in [10]. Weather is assumed to be related to geomagnetic activity in [15], in which the effect of weather on the ischemic disease of the heart in Kaunas, Lithuania, a city with a relatively small population, is discussed. The effect of geomagnetic activity on the ischemic disease of the heart, myocardial infarction and insult was studied in Moscow [16] using a generalized linear model with temperature, pressure, geomagnetic activity and other input parameters.

In the past few decades, disease incidence is commonly correlated with areal pollution. The risk of cardiac diseases is believed to be largely related to air pollutants [17]-[19].

It is relevant to investigate the incidence of population in Arctic and sub Artic areas with difficult climate and weather and geomagnetic conditions [20].

The goal of the present study is to construct and analyze ambulance call distribution in Petrozavodsk, to obtain profiles for groups of diseases and to assess the impact of environmental factors on human diseases.

The City of Petrozavodsk (61°4705″N, 34°20′48″E) is located on the Onega Lake shore (Fig. 1).

Variable weather, elevated humidity, abundant precipitation, strong winds and atmospheric pressure variations are common here. The proximity to high latitudes leads to elevated geomagnetic activity, geomagnetic field pulsations, high ionospheric currents and the expansion of the aurora borealis zone.

The study of the disease incidence of Karelia's population is commonly based on Goscomstat publications. Local medical statistics is dominated by respiratory, cardiovascular and oncological diseases [21].

2 Materials and Methods

The present study is based on the data obtained by Petrozavodsk Geophyical Laboratory, Tesis Laboratory of X-ray Astronomy at the Physical Istitute, RAS, the impersonified Ambulance Call Catalogue of Petrozavodsk City Hospital over the period 1.01.2015 - 19.12.2017 and geochemical analysis of urban soils.

Geophysical measurements are favoured by the weak artificial impact on Petrozavodsk Observatory located in the forested Botanical Gardens at the city outskirts, reliable security, electricity and a data transmission channel [22].

The horizontal and vertical constituents of the Earth's magnetic field are monitored by GI MTS-1 geophysical facility at a frequency of 50 Hz. The results of measurements are used to form 5- and 10-minute databases.

The deviations of the Earth magnetic field from the standard over a 3-hour interval are described by the planetary index, Kp, varying from 0 to 9. Values of 5 to 9 indicate strong magnetic storms [23]. Kp index is shown in real time at web-sites [24], [25].

The lines in the Ambulance Call Catalogue correspond to calls and the columns to locality, address, age and sex of a patient, the date and time of a call, the disease diagnosed in accordance with International Classification of Diseases (ICD-10). The total number of calls during period is 352641. Only confirmed calls with diseases diagnosed were analyzed. The diagnosis to the patient is made by medical worker, who is part of ambulance team.

The distributions of N-calls for k-events were constructed by calculating the number $f_k(x)$ over the variation range of x-variable using the formula:

$$f_k(x) = f_{k-1}(x) + \delta_k(x) \quad (1)$$

k=1, 2,...,N; $f_0(x)=0$; $\delta_k(x)=1$, if $h<x<h+\Delta h$, and $\delta_k(x)=0$, if $x<h$ or $x>h+\Delta h$, k is a call number and h and Δh are the count and step of a histogram, respectively.

The superposed epoch method was used to construct distribution of the number of the ambulance calls relative to day with an given Kp index.

To process distributions in the MATLAB system, spectral analysis, data approximation and clusterization functions were used [26]. QGIS Package was used for mapping [27].

3 Results

3.1 Cardiovascular disease profile

Annual emergency ambulance calls for patients with major cardiovascular diseases are shown in Table 1.

Over half the calls were made for essential hypertension, about 10% for stenocardia, 9-13% for chronic ischemic disease of the heart and about 8% for insult.

3.2 Time distributions of ambulance calls

Fig.2 shows variations in the Z-constituent of the magnetic field in Petrozavodsk from 18.10 to 25.10 2015 and ambulance call number distribution in October 2015 with the diagnoses of cardiovascular diseases.

The time dependences of the mean daily values of Kp index and the number of ambulance calls by patients with myocardial infarction and their spectra, calculated from the residue after the subtraction of trends, are shown in Fig.3. The trends are presented as the regression dependences by polynomials in the 10th (Fig.3a) and zero (Fig.3c) power. The spectra were calculated using the maximum entropy method [28] with the window width of 40. The variances of dependences approximated (a,c) are 0.44 and 1.27 correspondently. Chi-square distribution with two degrees of freedom and confidence probability of 0.95 makes significant peaks with amplitudes greater than 0.12 (b) and 0.34 (d) [29].

Fig. 1 The maps of Petrozavodsk. The asterisk marks the position of the Petrozavodsk Geophysical Observatory.

Table 1. Annual emergency ambulance calls for patients with major cardiovascular diseases for the period from 1th January 2015 to 19th December 2017

Diseases	ICD-10 Code	2015 (%)	2016 (%)	2017 (%)
Essential hypertension	I10	13013 (52.8)	12475(51.6)	12530(50.5)
Secondary hypertension	I15	12 (0.05)	10 (0.04)	13 (0.05)
Stenocardia	I20	2554 (10.4)	2183 (9.0)	2102 (8.5)
Sharp myocardial infarction	I21	452 (1.8)	480 (2.0)	498 (2.0)
Repeated myocardial infarction	I22	35 (0.14)	28 (0.12)	30 (0.12)
Chronic ishemic desease of heart	I25	3210 (13.0)	2266 (9.4)	2098 (8.5)
Sharp myocarditis	I40	31 (0.13)	21 (0.09)	17 (0.07)
Cardiomyopathy	I42	77 (0.31)	74 (0.31)	67 (0.27)
Sudden cardiac arrest	I46	17 (0.07)	12 (0.05)	18 (0.07)
Insult	I64	1905 (7.7)	1933 (8.0)	1950 (7.9)
All diseases of cardiogroup	I00-I99	24628 (100)	24182 (100)	24796 (100)

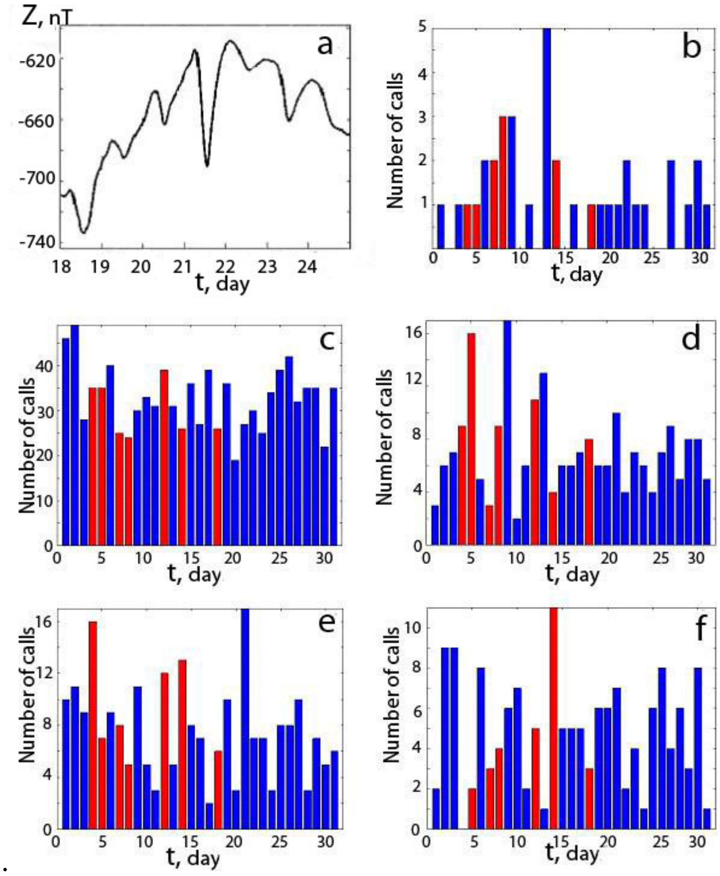

Fig. 2. Variations in Z-component of a magnetic field from 18.10 - 25.10 2015 (à) and emergency ambulance call dynamics in October 2015 for patients with: myocardial infarction (b), essential hypertension (c), stenocardia (d), chronic ischemic disease of the heart (e) and insult (f). - the days with Kp > 4, - the days with Kp<5. The smallest value of Z-constituent of the field (a) is consistent with a magnetic storm on 18 October.

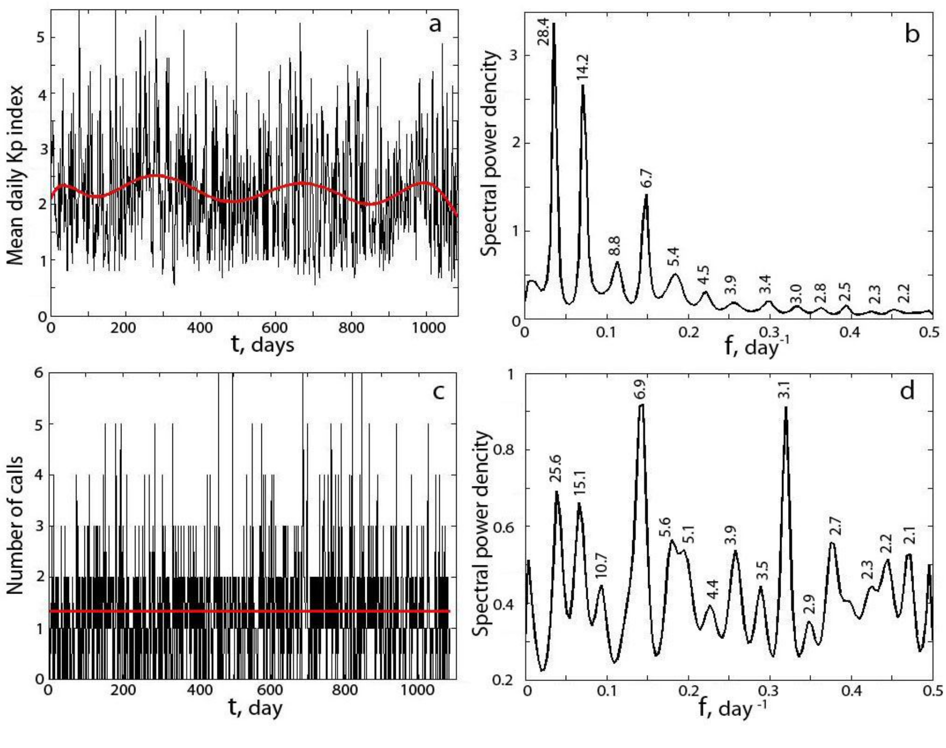

Fig. 3. Time dependences of daily Kp index values (a) and the number of emergency ambulance calls for patients with myocardial infarction (c) and their trends (-) and spectra (b, d), respectively.

Trend (Fig.3a) shows seasonal variations. The variation spectrum of Kp index (Fig.3b) displays a 28.4 daily cycle similar to the sun's 27-day rotation period, a two-week cycle (14.2 days), a week cycle (6.7 days) and other cycles. No seasonal factors for myocardial infarction (Fig.3c) were revealed, possibly due to insufficiently number of calls. The spectrum (Fig.3d) is dominated by week, 25.6, 15 and 3-day cycles.

Seasonal factors for other cardiovascular diseases affect call frequency for hypertension, stenocardia and ischemic disease of the heart.

A 25.6-day cycle, close to a geomagnetic activity period, is expressed in hypertension spectra, a weaker cycle in stenocardia and insult spectra and no cycle in the spectrum for ischemic disease of the heart. Most spectra display peaks similar to week, half-week and 3-, 4- and 6-day periods.

3.3 Daily ambulance calls dynamics. A weekend effect.

Fig.4 shows the dynamics of ambulance calls for patients with myocardial infarction on week-days, at weekends and on holidays, the age distribution of patients with this diagnosis, similar ambulance call distributions for patients with essential hypertension, stenocardia, ischemic disease of the heart and insult.

Male calls 816 predominate over female calls 569. The Student test shows that both distributions reduced to the number of males calls with the probability of 0.95 have the same mean values. On week-days, the maximum number of calls is made at 10-11, 14-15 and 19-20. Most patients with myocardial infarction are 55, 63, 76-83 years old.

The ambulance call distribution histograms at weekends and on holidays (346 days), corresponding to 738 work days, show at least a three-fold decline in the number of calls for patients with the diseases of the cardiovascular system.

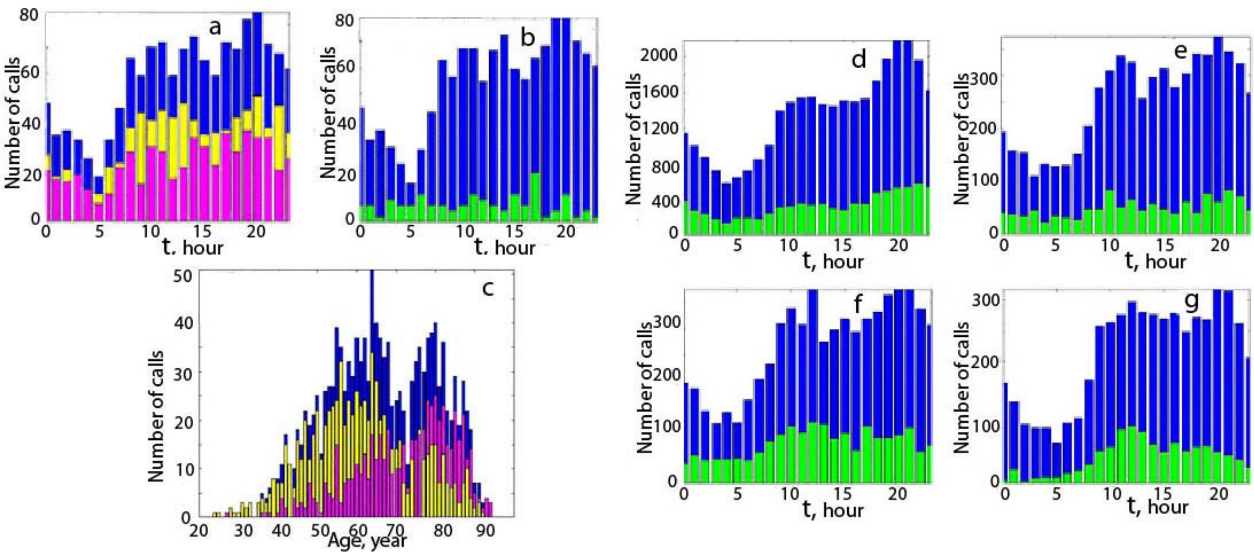

Fig. 4. Distribution showing daily emergency ambulance call dynamics for patients with myocardial infarction (à), dynamics distribution of calls with this diagnosis on work-days, at weekends and on holidays (b), age distribution of patients with myocardial infarction (c), call dynamics distribution similar to (b), for patients with essential hypertension (d), stenocardia (e), ischemic disease of the heart (f) and insult (g). In charts (a, c) - all calls, - male and -female calls. In charts (b, d – g) - the calls on working days, - the calls on weekends and holidays.

3.4 The effect of geomagnetic activity on the number of ambulance calls

The coefficient of correlation of the time values of the geomagnetic activity index, Kp (Fig.3a), and the number of ambulance calls for patients with myocardial infarction (Fig. 3c) is 0.04. Check-up of its validity with $p<0.05$ showed that the above values are not correlated [10]. To study more about the relationship between the geomagnetic activity pattern and disease incidence, cluster analysis was carried out. A «k-mean» algorithm in the daily values of Kp index has revealed five clusters (Fig. 5a).

The distributions of the number of ambulance calls relative to the shift of the event day were obtained for each cluster and cardiac disease using the superposed epoch method.

For myocardial infarction and stenocardia, the distributions (Fig.5 b, c), corresponding to 321 events of the largest cluster, display an increase in the number of calls on days shortly before, during and after magnetic storms.

3.5 Spatial distributions of ambulance calls numbers

The spatial distributions of ambulance call numbers were constructed for a group of cardiovascular diseases, schizophrenia, epilepsy, vegeto-vascular dystonia, tumours, bronchial asthma and other socially essential diseases. To measure the effect of soil pollution on disease incidence, these distributions were considered with a data of geochemical analysis of urban soil samples [30].

To assess the degree of soil pollution, the environmental hazard index (EHI), calculated as a sum of the weighted average values of the coefficients of concentrations of such pollutants as As, Pb, Zn, Cd, Co, Cu, V and W, was used. Fig. 6 shows maps of Petrozavodsk indicating the distributions of the number of calls for patients with bronchial asthma and the environmental hazard index.

The correlation coefficients of spatial ambulance call distributions for patients with the above diseases and the environmental hazard index are shown in Table 2.

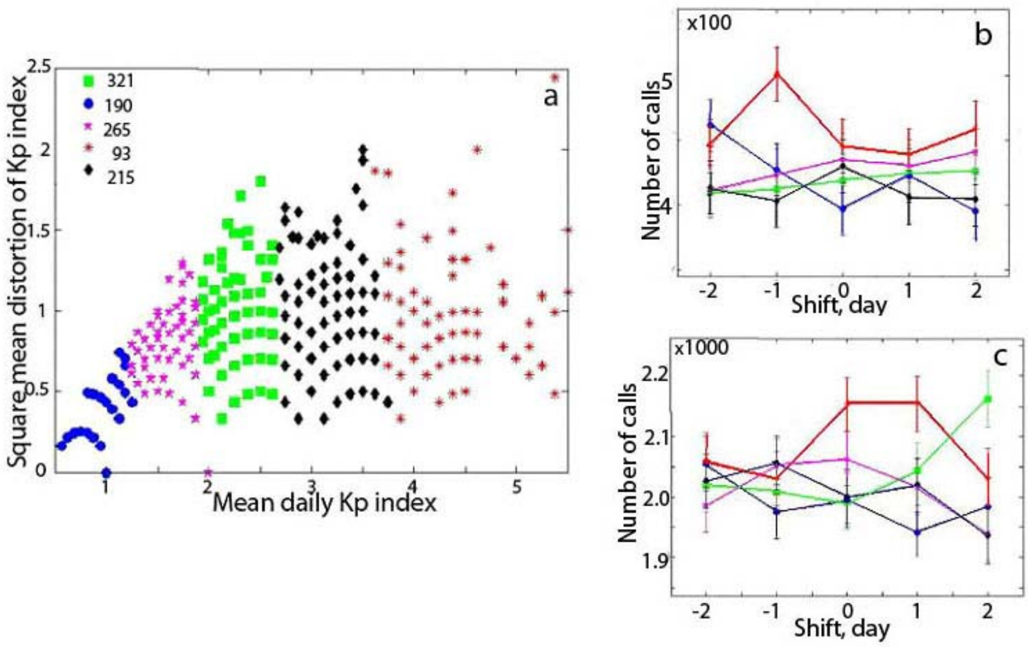

Fig. 5. Cluster analysis of daily Kp index values (a) and the distribution of the number of ambulance calls relative to a shift from the cluster element day for patients with myocardial infarction (b) and stenocardia (c).

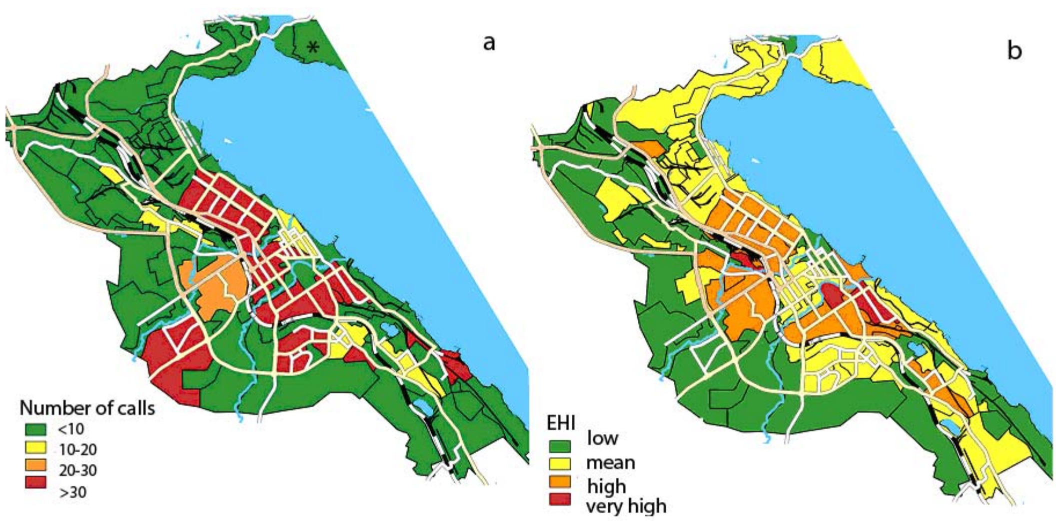

Fig. 6. Distribution of emergency ambulance calls for patients with brochial asthma in Petrozavodsk (a) and environmental hazard index distribution (b).

Table 2. Matrix of the correlation coefficients of emergency ambulance calls for patients with some diseases and the environmental hazard index, EHI.

	I10	I21	I20	I25	I64	F10	F20	G90	G40	J	J45	C	EHI
I10	1												
I21	.94	1											
I20	.98	.96	1										
I25	.99	.94	.99	1									
I64	.96	.96	.99	.98	1								
F10	.54	.61	.53	.55	.62	1							
F20	.62	.62	.67	.63	.67	.44	1						
G90	.99	.93	.98	.98	.97	.54	.64	1					
G40	.97	.94	.99	.97	.97	.59	.67	.98	1				
J	.98	.92	.97	.98	.97	.55	.62	.98	.96	1			
J45	.94	.85	.90	.92	.89	.49	.64	.94	.92	.92	1		
C	.95	.90	.93	.96	.94	.61	.55	.94	.93	.95	.88	1	
EHI	.24	.21	.25	.24	.23	.10	.16	.26	.26	.22	.26	.23	1

4 Discussion

The cardiac disease profile (Table 1) shows that the annual numbers of ambulance calls for patients with these diseases in the period studied are at the same level. The maximum number of ambulance calls for patients with the above diseases (Fig.2 b–f) does not necessarily occur on magnetic storm days. Near 3- and 6-day cycles (Fig.3d) could be associated with thyroid gland hormone activity. The cycles close to 4 days may be corresponded to activity of glucocorticoid hormones catalyzing metabolic processes [31] Cyrcadian cycles are thought to be common or are interpreted as the unwillingness of people to be sent to hospital at weekends [10]. In the case of myocardial infarction the latter factor does not work, immediate assistance is needed. Nevertheless a week-long peak in the time dependence spectrum of calls is observed (Fig.3d).

Gender differences between ambulance patients (Fig. 4a, c), the presence of maxima and minima in age call distributions are characteristic of myocardial infarction [32]. A decline in the number of ambulance calls for patients aged 72-75 and 85 years indicates a decline in population, a drop in birth rate during the 1930s hunger and the Great Fatherland War.

The weekend effect could be interpreted with regard for the properties of cortisol, a stress hormone [33]. At normal concentration in the blood, cortisol controls mineral and water metabolism, splits up fats, inhibits cholesterol production and synthesizes insulin and glycogen. Upon stress, the discharge of the hormone into the blood provokes its supply to the heart and muscles, making the organism respond immediately to hazard which provokes disease. Relaxation after production activities decreases the cortisol level and the number of ambulance calls for patients with cardiovascular diseases at weekends. Peaks in the distributions of daily ambulance call dynamics are ssumed to be due to air pollution from motor vehicles at rush hours: at 9-10, 13-14, 18-19 and a near-one hour delay in the growth of disease and an ambulance call. For a small city, irregular traffic at weekends and on holidays becomes a problem at rush hours on week-days. The engines of cars, working in a low revolution mode, standing in traffic jams emit maximum amounts of carbon monoxide, nitrogen and lead oxides, benzaperene, other harmful substances and dust.

Another interpretation of the weekend effect is connected with a work [34]. The week cyclicity is understood as the result of the effect of various industries on the magnetosphere and lithosphere. Industrial activity suppresses regular magnetic variations and decreases seismic activity on work-days. The daily dynamics peaks of ambulance calls indicate the growth of electric power consumption at certain hours on work-days. Changes in the cluster structure and properties of water could provide a mechanism for the transfer of electromagnetic effects to man [35]. Such mechanisms also are considered to be Schuman resonances and geomagnetic Pc1 variations having biotropic frequencies [36], [37] and change of natural oscillations of the atmosphere and associated variations of temperature and pressure under the action of geomagnetic perturbations [38].

Fig.5 reflects the non-linear pattern of relationship between time changes in Kp index and the number of ambulance calls for patients with cardiovascular diseases. The correlation coefficient is not a suitable tool for describing non-linear relationship. Only some diseases are sensitive to strong magnetic field perturbations that are not abundant. From this standpoint, we should be cautious when applying linear models of diseases which are geomagnetically active at the input. This result, together with evidence for the influence of magnetic fields on the sedimentation rate of erythrocytes and thrombus formation [39], indicate that the human organism is adaptable to common geomagnetic field variations.

Analysis of the spatial distributions of ambulance call numbers for a group of cardiovascular diseases in city districts has shown that the maximum number of calls for patients with essential hypertension (over 10 calls per 100 people) was in districts with poor living conditions dominated by elderly population. Calls for patients with stenocardia prevail at the outskirts, in the old parts of the city. The number of calls for patients with myocardial infarction is elevated in areas close to presently operating plants, indicating poor air quality there. Ischemic disease of the heart is common (over 20 calls per 1000 people) in the city centre and in estates with a high percentage of young dwellers. Verification of correlation coefficients (Table 2) with $p < 0.05$ for 52 living zones of Petrozavodsk has shown that they are below the threshold value of 0.27. Thus, the metal pollution of the soils does not affect the number of calls for patients with the above diagnoses.

5 Conclusion

The above method for data processing was used to obtain various ambulance call distributions and to measure the effect of environmental factors on them. Ambulance call distributions for individual diagnoses are combined to form a dynamic pattern showing the disease incidence of the city population.

Time distribution trends show the influence of seasonal factors on the frequency of ambulance calls, while residue spectra indicate disease cyclicity.

The age distributions of ambulance calls characterize population demography and the disease sensitivity of age groups.

The spatial distributions of ambulance calls reveal a relationship between the disease incidence and their living conditions.

The decrease of the number of calls for patients with cardiac diseases at weekends seems to be due to a decline in the cortisol (stress hormone) level in the blood and the decreased effect of human activities on the lithosphere and magnetosphere. The ambulance call distribution peaks in the daily dynamics of work-days could be related to the influence of motor car gases on cardiac diseases and the growth of electrical power consumption at certain time on work-days.

Geomagnetic activity is not correlated with the number of ambulance calls for patients with cardiac diseases due to a non-linear relationship between them, as well as the adaptation of the human organism to common Earth's magnetic field perturbations and a small portion of geomagnetic variations with a high daily Kp index.

The absence of correlation between the number of ambulance calls from living zones for patients with the above diseases and environmental hazard index distribution indicates the low level of heavy metal pollution of the urban soils.

Acknowledgements

Researches were conducted during performance of the state task of Institute of geology of the Karelian research center of RAS. The authors wish to thank Chief Physician at the Petrozavodsk Hospital Alexey Ilyich Kheifets. B.Z. Belashev thanks RFBR research project No. 19-05-00481\19.

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