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# **The Electromagnetic-Field Effect of Industrial Origin on the Cardio-Vascular System of Urban Land Inhabitants (Illustrated with an Example of Ivano-Frankivsk City, Ukraine)**

## **1. Introduction**

The health level of people is the key indicator of the optimized social ecological system. Modern society creates and makes the best use of innovative technologies in the field of science and technology that allow satisfying its growing needs. Such a type of social development has to provide a dynamic balance in the system “society – natural environment” – in the social ecological system. The most lability in the context of technocratic society is the balance “society – natural environment” in the urban ecological systems (urbanized social ecological systems). The level increase of comfort of the people in the urban social ecosystems has led to becoming a greater number of factors that can make affects on the balance of the system “society – natural environment” and, consequently, on the people health. Among them the special place takes the influence of the electromagnetic radiation (EMR) on the human body.

To control the influence of electromagnetic fields (EMF) of industrial origin on the human body was developed “The State Sanitary Regulations and Protection regulation of the people from an influence of electromagnetic radiation” approved by the order of The Ministry of Healthcare of Ukraine No. 239 dtd. 8.01.1996. This document is the rules and regulations that protect people from an exposure of electromagnetic fields and includes chapter “The Sanitary Regulations and Protection regulations of the people from an influence of electromagnetic fields forming the radio technical objects” and “The Sanitary and Protection Regulations of the people from electric field exposure, creating facilities of power transmission of industrial frequency”. In accordance with this document “To the electromagnetic sources in the populated area belong the radio, television and radar stations of various profiles that are at work in the radio frequency band, and transmission network, which consists of air high-voltage power line and electrical substations. To the substations may belong: switchgear, electricity transformers, transformers, rectifier units and other facilities and constructions”.

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But, according to this document the maximum permissible limit (MPL) of electromagnetic fields that apply to the frequency range from 30 kHz to 300 GHz, is much lower as such level in Russia and significantly lower as such level in Europe. In addition, a list of radio technical objects (RTO) that radiate electromagnetic energy into the environment, needs to be extended due to the use of digital radio relay stations and base stations of mobile communication. The Regulation of the Board of Ministers of Ukraine No. 808 dtd. 28.08.2013 defines "The list of activities and objects of increased ecological hazard". In the clause 26 of this list are mentioned the radio technical objects, which have increased ecological hazard: radio transmitting stations, radio, TV and radar stations, digital radio relay stations, the base stations of mobile communication.

That is why the regulatory base that governs the maximum permissible limit (MPL) of electromagnetic fields in Ukraine needs to be renewed, and the influence of electromagnetic waves in the radio frequency on the social component of ecological safety of urban social ecological systems has a grate interest of scientific.

## 2. Methods of Ecological and Geographical Researches

For decision of given tasks there was chosen an urban social ecological system of Ivano-Frankivsk city. In urban land of Ivano-Frankivsk city that was chosen as a test area, were defined 122 points at a distance of 200–500 m. The choice of control points of the test area was conducted in accordance with specific of building area including large, crowded places with probably increased electromagnetic fields: educational institutions, health facilities, religious structures, big domestic buildings, bridges over the river Bystrytsa Nadvirnyanska and Bystrytsa Solotvynska, railway station, railway track and bridges across it, big shops, cinemas, bus stops on streets with trolley movement and others.

The urban ecological system in Ivano-Frankivsk city takes an area of 51.36 km<sup>2</sup>, total area of Ivano-Frankivsk city – 83.73 km<sup>2</sup> [12]. The average density of placement of control points on the test area is 2.4 points on 1 km<sup>2</sup>, and in the central part of the city the density of placement of the control points is slightly higher.

At each point of the test area the intensity of the electric field ( $E$ ), the intensity of the magnetic field ( $H$ ) and the intensity of the surface density of energy flow ( $\mu$ ) were measured. For the measurements tester Tenmars RF three-Axis Field Strength Meter TM-195 were used [13]. The facility is used to measure electromagnetic fields of anthropogenic origin in the frequency range from 50 MHz to 3.5 GHz, in particular for measuring the field intensity of high-frequency electromagnetic waves, surface density of energy flow of antennas for mobile communication databases, units for wireless communication (CW, TDMA, GSM, DECT), transmitters, wireless networks LAN (Wi-Fi), the leak detection of microwaves, determination of safety radiation level of mobile phones, the determination of electromagnetic safety of work and domestic establishments. The facility is working with discretization interval – three

measurements in 1 second and allows making measures of immediate, average and maximum measured value. For isotopic measurements of electromagnetic fields the facility is equipped with three-channel sensor. The settings allow for the use of a separate axis X, Y or Z sensor (non-isotopic measurements of electromagnetic field), or all axis in the same time (isotopic measurements of the electromagnetic field).

At each point of the test area was conducted isotopic measurements of EMF at a distance of 1.8 m from the soil surface during 10 minutes, and the facility was placed immovably at a distance not less than 1 m from the experimenter. Also the facility was placed with the sensor towards potential sources of electromagnetic radiation. Received data are presented in the Table 1.

The space around the source of EMF conventionally is divided into the near zone (zone induction) and distant zone (zone of radiation). The near zone covers the space with a radius of about  $1/6$  wave length. In this zone the electromagnetic wave is not formed yet because the intensity of EMF is measured separately with intensification of magnetic and electric field components, negative effect of EMF in this area is mainly caused by the electrical component.

In accordance with the order of the Ministry of Healthcare of Ukraine No. 1040 dtd. 29.11.2013 "About approval of the measurements methodology for levels distribution of electromagnetic fields" including the "The State Sanitary Regulations and Protection Regulations of the people from the influence of electromagnetic radiation", approved by the order of the Ministry of Healthcare of Ukraine No. 239 dtd. 01.08.1996, the maximum permissible limit (MPL) of EMF in the frequency range of 30–300 MHz is 3 V/m and in a frequency range from 300 MHz to 300 GHz – 2.5 mW/cm<sup>2</sup>. For comparison, in the Russian Federation and in Belarus this rate is 10 mV/cm<sup>2</sup>, and in some European countries – 100 mW/cm<sup>2</sup>.

The received data show the maximum permissible limit (MPL) of surface density of energy flow of the electromagnetic field in terms of average values of this factor in the such streets as Evgen Konovalets street – Sichovi Striltsi street – Academician Sakharov street – Vyacheslav Chornovil street (Fig. 1), in terms of the maximum values of this factor in the such streets as Evgen Konovalets street – Sichovi Striltsi street – Academician Sakharov street – Vyacheslav Chornovil street; Zaliznychna street – Mariya Pidhiryanka street – Nezaleyhnosti street; Pylyp Orlyk street (Fig. 2).

The elevation of the maximum permissible limit (MPL) of electric field intensity in terms of average values of this factor are seen in Korolya Danyla street – Evgen Konovalets street – Sichovi Striltsi street – Academician Sakharov street – Vyacheslav Chornovil street – Nezalezhnosti street – Pryvoksalna street (Fig. 3), in terms of the maximum values of this factor Korolya Danyla street – Evgen Konovalets street – Sichovi Striltsi street – Academician Sakharov street – Shevchenko street – Vyacheslav Chornovil street – Nezalezhnosti street – Pryvoksalna street and the intersection Ivasyuka – Vovchynetska street and Ivasyuka – Tysmenytska street (Fig. 4). The maps are created using geographic information system MAP INFO, and the points of test area are marked using the service Google Maps.

**Table 1.** Value of electrician intensity ( $E$ ), magnetic field ( $H$ ) fields and density of energy flow of electromagnetic field ( $\mu$ ) in the points of test area

No.	Points of measurements		Maximal value				Average value		
	address, location	short description	$E_{max}$ [V/m]	$H_{max}$ [mA/m]	$\mu_{max}$ [mW/cm <sup>2</sup> ]	$E_{aver}$ [V/m]	$H_{aver}$ [mA/m]	$\mu_{aver}$ [mW/cm <sup>2</sup> ]	
1	Mitskevych place, 3	Ivano-Frankivsk Regional Institute of post graduate pedagogical education	3.566	9.435	1.836	3.267	7.826	1.837	
2	Mitskevych place	Monument to Adam Mitskevych	2.462	6.533	1.355	2.056	5.328	0.474	
3	Square behind main building of Ivano-Frankivsk National Medical University	Monument to Ruska Trriytza	2.171	5.762	1.041	2.078	3.869	0.923	
4	Halytska str., 4A	Local History Museum	3.738	9.917	3.337	1.136	8.053	1.785	
5	Sheptytskyy Place	Statue of the Blessed Virgin Mary	1.181	3.152	0.242	0.589	1.483	0.058	
6	Tychyny str., 21	"Pyanyy" markt	2.991	7.922	1.979	2.129	6.077	1.288	
7	Pivnichnyy Bulvar, 4	Magazine "Tourist"	1.537	4.058	0.482	0.843	2.994	0.211	
8	Puluya str., 15	Domestic building	1.909	5.048	0.715	0.232	1.743	0.667	
9	Voyniv Internatsionalistiv Place	Monument to Afghan soldiers	1.324	3.493	0.363	0.845	2.132	0.153	
10	Halytska str., 201	Institute of Natural Sciences of the State Higher Education Institute V. Stefanyk Carpathian National University	0.330	0.860	0.023	0.092	0.353	0.013	
11	Zavodska str.	Stop "Radiozavod"	1.259	3.318	0.265	0.925	2.477	0.216	
12	Horbachevskogo str., 14	Bus station No. 2	0.848	5.977	1.067	0.821	3.122	0.226	
13	Kalush road, 1	Ukrainian Gymnasium No. 1	0.646	3.257	0.564	0.437	1.878	0.312	
14	Fedkovycha str., 91	Regional Hospital	0.588	1.539	0.057	0.345	0.886	0.018	
15	Nechuy Levytskyy str., 6	Nechuy Levytskyy str., 6, Church of the Saint Martyr Demetrius	0.770	2.052	0.196	0.395	1.036	0.174	
16	Khimikiv str., 1	General education school of I-III grades No. 24	0.590	1.573	0.062	0.456	1.317	0.049	

17	Troleybusna str., 7	General education school of I-III grades No. 18	1.745	4.736	0.609	1.112	2.224	0.126
18	Halytska str., 145	Restaurant "Oven"	2.247	5.958	1.065	1.059	2.177	0.242
19	River Bystrytsa Solotvynska	Bridge over the river Bystrytsa Solotvynska on the Halytska str.	2.123	5.314	0.866	1.098	2.989	0.210
20	River Bystrytsa Nadvyrnanska	Bridge over the river Bystrytsa Nadvyrnanska on the Tysmenytska str.	0.472	1.261	0.038	0.223	0.623	0.009
21	Medychna str., 17	Regional clinical ontological dispensary	0.887	2.338	0.154	0.236	0.687	0.020
22	Medychna str., 15	Regional psychoneurological hospital No. 3	0.247	0.638	0.015	0.084	0.345	0.004
23	Konovaltsa str., 433	Hotel "Formula 1"	3.083	8.187	2.244	0.477	1.158	0.040
24	Evhen Konovalets str., 264A	International airport "Ivano-Frankivsk"	0.773	2.034	0.102	0.587	1.656	0.024
25	Blavatskoho str., 3	General education school of I-III grades No. 6	0.335	0.886	0.019	0.140	0.343	0.004
26	Evhen Konovalets str., 229	OJSC "Ivano-Frankivsk Vave Plant"	0.356	1.287	0.052	0.113	0.194	0.015
27	Konovaltsa str., 132	Regional Children's Clinical Hospital	0.930	2.471	0.143	0.292	0.832	0.025
28	Sakharova str., 36A	General education school of I-III grades No. 21	4.731	12.551	4.372	2.055	4.517	0.631
29	Yunosti str., 4	Bus station No. 4	3.177	9.386	3.047	2.263	6.024	1.059
30	Yunosti str., 23	Regional center of State Automobile Inspectorate	0.530	1.434	0.048	0.393	0.845	0.025
31	Yunosti str., 13	Ivano-Frankivsk Regional vocational-boarding school for gifted children from countryside	0.887	2.348	0.141	0.263	0.642	0.012
32	Topolyna str., 6	Ivano-Frankivsk physiototechnical vocational-boarding school	1.052	2.783	0.186	0.843	2.015	0.092
33	Tysmenytska str., 289	Domestic building	0.323	0.850	0.017	0.052	0.144	0.006
34	Tysmenytska str., 287	Magazine "AutoKiss", stop	0.192	2.121	0.134	0.032	0.731	0.014
35	Tysmenytska str.	Petrol filling station "Okko", garden center	1.095	2.906	0.240	0.741	2.093	0.103

Table 1. cont.

No.	Points of measurements		Maximal value				Average value		
	address, location	short description	$E_{\max}$ [V/m]	$H_{\max}$ [mA/m]	$\mu_{\max}$ [mW/cm <sup>2</sup> ]	$E_{\text{aver}}$ [V/m]	$H_{\text{aver}}$ [mA/m]	$\mu_{\text{aver}}$ [mW/cm <sup>2</sup> ]	
36	River Bystrytsa Nadvirnyanska	Bridge over the River Bystrytsa Nadvirnyanska on Evgen Konovalets str.	1.065	2.815	0.187	0.676	1.687	0.063	
37	Nezalezhnosti str., 207	General education school of I-III grades No. 15	0.885	2.124	0.107	0.536	1.357	0.046	
38	Railway line	Bridge over the railway line on Tysmenetska str.	10.523	27.910	17.836	5.288	14.616	5.742	
39	Nezalezhnosti str., 97	Cinema "Kosmos", stop	10.234	27.145	17.146	4.270	15.731	3.618	
40	Nezalezhnosti str., 93 A	Magazine "Pelikan"	9.492	25.230	14.482	2.595	7.376	1.564	
41	Nezalezhnosti str., 40	Hotel "Nadiya"	6.091	16.161	7.556	3.643	8.682	2.288	
42	Nezalezhnosti str., 53	National Painter's Union of Ukraine	5.422	14.397	5.856	4.042	11.860	3.447	
43	Vahylevycha str., 5	Restaurant "Pehas", Pizzeria "Lavazza"	3.468	9.189	2.731	0.861	2.342	0.123	
44	Uhornytska str., 10 A	Restaurant "Lehenda"	0.328	0.847	0.129	0.085	0.226	0.016	
45	Uhornytska str., 16	Domestic building	0.319	0.838	0.019	0.132	0.511	0.003	
46	Ivasyuka str., 76	Christian Church of Seventh-Day Adventists	8.584	22.763	0.013	0.094	2.335	1.253	
47	Hnat Khotkevych str.	Crossing of Hnat Khotkevych and Ivasuka str.	0.677	1.769	0.072	0.391	0.734	0.014	
48	Ivasyuka str., 50A	Kingdom Hall of Jegova's Witnesses	1.104	2.914	0.225	0.548	1.467	0.058	
49	Ivasyuka str., 17	Supermarket "Epicenter"	4.086	10.825	2.993	0.827	2.276	0.094	
50	Stus str.	Food market	0.764	2.026	0.125	0.172	1.483	0.015	
51	Vovchynetska str., 225	Management and Economy Institute "Halych Academie"	2.943	7.795	1.939	1.165	2.976	0.215	
52	Vovchynetska str., 223	Ivano-Frankivsk college for electronic valve	2.407	6.368	1.223	0.991	2.466	0.139	
53	Maksymovych str., 15	Markt "Anatol"	0.945	2.516	0.153	0.361	0.832	0.022	
54	River Bystrytsa Solotvynska	Railway bridge over the River Bystrytsa Solotvynska	1.233	3.264	0.265	0.712	1.953	0.092	
55	Halyska str., 66	Building material store "Keramбуд"	0.593	1.554	0.059	0.192	0.453	0.006	

56	Naberezhna str., 2	Domestic building	0.333	0.874	0.019	0.064	0.173	0.002
57	Naberezhna str., 24	Domestic building	0.475	1.234	0.038	0.071	0.193	0.001
58	Karpatska str., 15	Main building of Ivano-Frankivsk Oil and Gas National University	1.691	4.473	0.571	0.333	0.874	0.026
59	Beregova str., 30	Novopostolska Church	2.173	5.765	0.958	0.344	0.925	0.027
60	Petryury str., 10	Petryury str.,10. OJSC "Ivano-Frankivsk meat processing plant	1.442	3.813	0.389	0.794	2.595	0.189
61	Chornovola str., 130	Automobile circle	1.177	3.176	0.249	0.467	1.467	0.066
62	Dovzhenko str., 2	Christmas Church	1.022	2.732	0.196	0.855	2.226	0.129
63	Dovzhenko str., 26	Domestic building	0.921	2.623	0.183	0.622	1.521	0.093
64	T.H. Shevchenko's Park	Park lake	1.123	2.932	0.202	0.531	1.392	0.035
65	Hetmana Mazepy str., 90	Educational complex "General education vocational school No. 23 of V. Stefanyk Carpathian National University "	0.723	1.865	0.084	0.356	0.774	0.014
66	Sichovi Striltsi str., 29	Translation bureau	12.651	33.572	25.283	3.264	9.375	17.165
67	Chornovola str., 2	Hotel "Stanislaviv"	8.446	22.393	1.221	3.123	8.647	8.736
68	Shevchenko str., 57	Main building of the State High Educational Institute "V. Stefanyk Carpathian National University"	4.384	11.623	4.215	1.298	8.258	1.863
69	Chornovola str., 103	Domestic building	0.830	2.221	0.013	0.364	0.984	0.007
70	Shevchenko str., 98	Domestic building	1.210	3.212	0.252	0.456	0.916	0.026
71	Shevchenko str., 32	Crossing of Shevchenko and Hordynskyy str.	3.754	9.935	3.158	1.088	2.669	0.213
72	Shevchenko str., 2	Crossing of Shevchenko and Sichovi Striltsi str.	1.058	2.797	0.197	0.964	2.544	0.163
73	P. Orlyk str., 7	Crossing of P. Orlyk and Volodymyr Velykyy str.	9.318	24.723	14.275	4.263	10.185	3.938
74	Belvederska str., 14	Coffee "Halka"	6.185	16.416	7.339	3.028	7.919	1.804
75	Belvederska str., 40	Domestic Building	2.324	6.165	1.129	1.031	2.872	0.169
76	Belvederska str., 39	Crossing of Belvederska and Korolya Danyla str.	0.784	2.068	0.103	0.253	0.675	0.013

Table 1. cont.

No.	Points of measurements		Maximal value				Average value		
	address, location	short description	$E_{\max}$ [V/m]	$H_{\max}$ [mA/m]	$\mu_{\max}$ [mW/cm <sup>2</sup> ]	$E_{\text{aver}}$ [V/m]	$H_{\text{aver}}$ [mA/m]	$\mu_{\text{aver}}$ [mW/cm <sup>2</sup> ]	
77	Korolya Danyla str., 18	Crossing of Korolya Danyla and Volodymyr Velyky str.	2.258	5.977	1.064	0.615	1.644	0.065	
78	Korolya Danyla str., 4	Crossing of Korolya Danyla and Hetman Mayepy str.	0.946	2.485	0.149	0.426	1.167	0.034	
79	Vichevy Maydan	Fountain	4.625	12.274	4.485	1.434	3.775	0.410	
80	Valova str., 10	Domestic building	2.206	5.844	1.018	0.844	2.345	0.113	
81	I. Franko str., 33	Ivano-Frankivsk Natural and Mathematical Lyceum	1.312	3.483	0.292	0.632	1.763	0.078	
82	Pavlyk str., 5	Domestic Building	1.963	5.212	0.776	0.513	1.385	0.044	
83	Harkushi str., 37	Crossing of Harkushi and B. Lepkoho str.	2.373	6.294	1.221	0.751	2.123	0.096	
84	Railway line	Foot bridge over the railway lines, railway station	4.676	12.387	5.333	2.717	7.778	1.245	
85	Khotkevycha str.	Crossing of H. Khotkevych and Remisnycha str.	0.853	2.244	0.129	0.423	1.134	0.034	
86	Myru str., 33	Crossing of Myru and Selyanska str.	1.357	3.596	0.339	0.765	2.156	0.098	
87	Vovchynetska str., 92	Roman Catholic Church	0.665	1.746	0.076	0.238	0.668	0.011	
88	Vovchynetska str., 54	Church of Saint Joseph the Betrothed	0.856	2.257	0.127	0.443	1.154	0.033	
89	Vovchynetska str.	Under the railway bridge	0.974	2.585	0.223	0.187	0.987	0.096	
90	Pryvoksalna str., 1	Ivano-Frankivsk railway station	2.816	7.467	1.760	1.122	2.613	0.166	
91	Nezalezhnosti str., 43	Pizzeria "Lavazza"	2.483	7.124	2.307	0.642	2.084	0.107	
92	Mykolajchuka str., 2	Supermarket "Arsen"	4.085	10.826	2.994	0.824	2.275	0.094	
93	Hetmana Mazepy str., 165	Ivano-Frankivsc base medical college	0.878	2.377	0.152	0.583	1.414	0.088	
94	Hetmana Mazepy str., 162	Bus station No. 3	0.824	2.225	0.143	0.645	1.486	0.093	
95	24 Serpnyya str., 13	General education school of I-III grades No. 25	0.823	1.884	0.103	0.157	1.326	0.015	
96	Ivano-Frankivsk city lake	Lovers island	0.534	0.925	0.056	0.245	0.676	0.009	



97	H. Khotkevych str., 56	General education school of I-III grades No. 19	7.883	20.024	0.013	0.086	2.037	1.006
98	Naberezhna str., 6	Domestic building	0.305	0.815	0.019	0.054	0.155	0.002
99	Naberezhna str., 16A	General education school of I-III grades No. 7	0.425	1.186	0.036	0.075	0.187	0.002
100	Chornovola str., 47	Ivano-Frankivsk Regional maternity hospital	3.823	10.623	3.812	1.026	7.567	1.466
101	Chornovola str., 63A	Church of the nativity of the Blessed Virgin	3.636	8.450	3.619	0.984	6.830	1.266
102	Depovska str., 97	Hotel "Stanislavskyy Dvir"	2.803	4.244	0.239	2.538	2.127	0.433
103	Shukhevychiv str., 35	Ivano-Frankivsk Gymnasium No. 2	0.876	1.547	0.320	0.877	1.168	0.088
104	Hoholya str., 10	Ivano-Frankivsk Gymnasium No. 3	6.220	12.620	0.013	0.076	1.887	0.803
105	Dovha str., 37	Specialized general education school of I-III grades No. 1 with enhanced education in English	1.221	3.872	0.424	0.865	2.477	0.199
106	Doroshenko str., 29	General education school of II-III grades No. 2	3.202	6.803	1.245	0.683	4.244	0.869
107	Franka str., 14	General education school of I-III grades No. 3	1.229	3.128	0.298	0.785	1.866	0.088
108	Pivdennyi Boulvar, 24	General education school of I-III grades No. 4	7.280	18.609	8.845	4.434	8.125	2.625
109	I. Franko str., 19	Specialized general education school of I-III grades No. 5 with enhanced education in German	1.125	3.246	0.287	0.824	1.956	0.094
110	Hrushevskoho str., 16	General education school of I-III grades No. 7	2.344	5.433	1.256	2.012	4.873	0.425
111	Vovchynetska str., 196B	General education school of I-III grades No. 10	0.670	1.680	0.076	0.328	0.748	0.012
112	B. Lepkyy str., 9	Ivano-Frankivsk Specialized general education school of I-III grades No. 11 with enhanced education in English	5.542	12.042	5.543	3.227	7.128	1.890

Table 1. cont.

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	address, location	short description	$E_{\max}$ [V/m]	$H_{\max}$ [mA/m]	$\mu_{\max}$ [mW/cm <sup>2</sup> ]	$E_{\text{aver}}$ [V/m]	$H_{\text{aver}}$ [mA/m]	$\mu_{\text{aver}}$ [mW/cm <sup>2</sup> ]	
113	Nationalnoyi Hvardiyi str., 13	General education school of I–III grades No. 12	0.365	1.350	0.066	0.127	0.267	0.016	
114	Halytska str., 65	General education school of I–III grades No. 13	1.284	3.125	0.325	0.782	2.134	0.137	
115	Vovchynetska str., 103	General education school of I–III grades No. 16	0.569	1.683	0.067	0.188	0.567	0.014	
116	Вул. Будівельників, 24	General education school of I–III grades No. 22	0.769	1.887	0.118	0.125	1.366	0.012	
117	Chornovola str., 130	General education school of I–III grades No. 28	1.049	2.850	0.210	0.781	2.113	0.117	
118	Dnistrovska str., 28	Dnistrovska str., 28. Ivano-Frankivsk Institut for Management of Ternopil Academy of National Economy	1.801	4.922	0.613	1.245	2.487	0.133	
119	S. Bandery str., 79	Ivano-Frankivsk S. Granat financial and business cooperative college	0.676	1.445	0.082	0.123	0.213	0.016	
120	Yunosti str., 11	Ivano-Frankivsk State Agricultural College	0.785	2.146	0.136	0.245	0.586	0.015	
121	Halytska str., 45	Ivano-Frankivsk College of Statistics of State Academy of Statistics, Accounting and Audit	1.303	3.184	0.337	0.835	2.309	0.149	
122	Evhen Konovalets str., 140	Ivano-Frankivsk State Technology and Business College	2.870	3.241	0.348	0.932	2.643	0.188	

So, in the urban social ecological system in Ivano-Frankivsk city is seen the elevation of maximum permissible limit for surface density of electromagnetic field power  $\mu$  in terms of average values of this factor by 7 points of test area and is from 2.62 mW/cm<sup>2</sup> to 17.16 mW/cm<sup>2</sup>, and in terms of the maximum values of this factor – by 22 points of test area, is from 2.73 mW/cm<sup>2</sup> to 25.28 mW/cm<sup>2</sup> (maximum permissible limit is 2.5 mW/cm<sup>2</sup>). The average value  $\mu_{\text{aver}}$  in Ivano-Frankivsk city, is calculated taking into account the parameters  $\mu_{\text{aver}}$  by all 122 points of test area and is 0.65 mW/cm<sup>2</sup>, and the average value  $\mu_{\text{max}}$ , calculated taking into account the parameters  $\mu_{\text{max}}$  by all 122 points of test area, and is 1.73 mW/cm<sup>2</sup>. The elevation of maximum permissible limit of electrical field intensity  $E$  in terms of average values of this factor is seen by 11 points of the test area, and is from 3.03 V/m to 5.29 V/m, and in terms of the maximum values of this factor – by 29 points of the test area is from 3.08 V/m to 12.65 V/m (maximum permissible limit is 3 V/m). The average value of  $E_{\text{aver}}$  in Ivano-Frankivsk city, calculated taking into account the parameters  $E_{\text{aver}}$  by all 122 points of the test area, is 0.97 V/m and the average value  $E_{\text{max}}$ , calculated taking into account the parameters  $E_{\text{max}}$  by all 122 points of test area is 2.31 V/m.

### 3. Methods of Medico-Ecological Researches

Medical research shows that the most sensitive to the influence of EMF of industrial origin in the human body are the nervous, cardiovascular, endocrine, reproductive systems and the eyes, and EMF can also cause a significant influence on the metabolic rate [1, 2, 4, 6], encourage such syndrome as a medical phenomenon as a result of acute and chronic exposure of EMF of radio frequency range of nonlethal intensity equal to or above 10 mW/cm<sup>2</sup>. To the symptoms belong reactions of the central nervous system and clinical signs of autonomic systems that are appear in changes in mood manipulations and behavior. Clinical signs are cardiovascular, gastrointestinal or endocrine nature [8]. Regulation of the heart functions in the human body is made through the local and central mechanisms. To the local regulation mechanisms apply myogenous, nervous and humoral, that are presented in the heart.

The myogenic regulatory mechanisms:

- 1) preloads – the more ventricle of heart is extended with running blood, the greater is his contraction power;
- 2) afterloads – increasing of contraction power of the left ventricle by increasing the diastolic pressure in the aorta;
- 3) rate of heart contraction – by increasing of the heart rate is growing up the power contraction.

The local nervous regulation mechanism of the heart functions is provided by the cardiac conduction system (sino-atrial node, intermodal atrial tracks, atrioventricular node, bundle of His branch block and its legs, Purkinje fibers), that is capable of impulsive rhythmic membrane depolarization, which leads to the generation of the action potential and reduction of cardiac muscle.

The local humoral regulation of the heart functions consists in the heart synthesis of biologically active substances (natriuretic hormone, catecholamines, etc.), that are able to influence the contractile activity of the myocardium.

The central regulation mechanisms of the heart functions are provided by a nice branch of the nervous system (increases the power contraction of myocardium, increases heart rate, getting up speed of conduction of excitement by the leading heart system, increases the excitability of the heart) and parasympathic nervous system (reduces the power contraction of myocardium, reduces heart rate, reduces speed of conduction of excitement by the leading heart system, reduces the excitability of the heart). So, the regulation of the heart functions is determined by the cooperation of intracardiac and extracardiac mechanisms [10]. The human cardiovascular system is characterized by adaptive meteo-tropic reactions. And the best adaptive reactions are typical for young people at the age of 18–25. By the medical investigations analysis of heart rate variability in young people it was found that the most resistant to various types of weather are young women, and the minor stress of adaptation mechanisms of the cardiovascular system appears by the II type of weather (atmosphere pressure change from 3.75 to 5.5 mmHg a day, changing the average daily temperature at 5–10°C, relative humidity at 60–85%, low cyclonic activity) [3, 5].

Offered estimation method for environmental effects on the cardiovascular system, which is a sensitive indicator of violations of human physiological processes. The corresponding data were measured by the thermometer Omron M2 Basic. Into the base of the invention was taken the task to find a way which allows for identifying and investigating the impact of anthropogenic electromagnetic fields on the cardiovascular system of the people. The method is based on the observation of the human heart, which is within the territory of increased effect of EMF and for data comparison within the territory of the controlled area where the impact of EMF does not exceed the norm. For conducting observations as a rate of arterial pressure  $\phi$  is convenient to use the share, which is reached by lower (diastolic) pressure  $D$  in relation to the upper (systolic)  $S$ :  $\phi = D/S$  [7]. For the medical and environmental research at selected points of test area of urban area of Ivano-Frankivsk city (Tab. 1) at one time with intensity measurements of electric field ( $E$ ), magnetic field ( $H$ ) and the surface density of energy flow ( $\mu$ ) conducted measurements of heart rate ( $HR$ ), systolic arterial pressure ( $S$ ) and diastolic arterial pressure ( $D$ ). To determine the value of  $S$  and  $D$  and heart rate were involved young people at the age of 20–22, students of State higher education institution V. Stefanyk Carpathian National University. The indicators were determined separately for men and women at each point of the test area. The measurements were conducted five times at an intervals of 10 minutes separately by five men and five women. The determination conducted under meteorological conditions of type II. At each point of the test area was determined the arithmetic average value for  $S$  and  $D$  and heart rate separately for men and women. Based on the determined average values  $S$  and  $D$  at each point of the test area separately for men and women was determined the value of arterial pressure  $\phi$ . The research results are presented in Table 2.

**Table 2.** Average value of systolic arterial pressure (S), diastolic arterial pressure (D), values of arterial pressure ( $\varphi$ ) and heart rates (HR) in the points of test area

No.	address, location	short description	Men at the age of 20-22				Women at the age of 20-22			
			S [mmHg]	D [mmHg]	$\varphi$ [D/S]	HR [beats/min]	S [mmHg]	D [mmHg]	$\varphi$ [D/S]	HR [beats/min]
1	Mitskevych place, 3	Ivano-Frankivsk Regional Institute of post graduate pedagogical education	128.10	83.80	0.65	89.30	126.56	75.34	0.60	67.15
2	Mitskevych place	Monument to Adam Mitskevych	120.80	81.40	0.67	80.00	119.11	75.55	0.63	60.26
3	Square behind main building of Ivano-Frankivsk National Medical University	Monument to Ruska Trnytsa	130.60	80.60	0.62	93.60	129.03	72.87	0.56	70.39
4	Halytska str., 4A	Local History Museum	125.60	78.60	0.63	90.60	124.09	70.12	0.57	6.01
5	Sheptytskyy Place	Statue of the Blessed Virgin Mary	123.50	83.30	0.67	80.50	122.02	71.04	0.58	69.54
6	Tychyny str., 21	"Pyanyj" markt	127.60	84.00	0.66	91.40	126.07	86.13	0.68	67.34
7	Pivnichnyy Bulvar, 4	Magazine "Tourist"	130.40	85.00	0.65	87.80	128.84	78.25	0.61	66.24
8	Puluya str., 15	Domestic building	130.30	80.40	0.62	80.00	128.74	77.12	0.60	61.16
9	Voyiniv Internatsionalistiv Place	Monument to Afghan soldiers	125.20	79.80	0.64	91.20	123.80	70.03	0.57	68.42
10	Halytska str., 201	Institute of Natural Sciences of the State Higher Education Institute V. Stefanyk Carpathian National University	124.10	83.20	0.67	80.60	122.61	76.04	0.62	60.61
11	Zavodska str.	Stop "Radiozavod"	123.00	81.40	0.66	90.60	119.52	74.00	0.62	68.13
12	Horbachevskogo str., 14	Bus station No. 2	124.80	84.40	0.68	92.40	123.20	77.48	0.63	69.48
13	Kalush road,1	Ukrainian Gymnasium No. 1	131.70	80.60	0.61	81.20	130.12	71.78	0.55	61.06
14	Fedkovycha str., 91	Regional Hospital	116.80	81.40	0.70	87.80	115.40	71.09	0.62	65.87

Table 2. cont.

Points of test area		Men at the age of 20–22				Women at the age of 20–22				
No.	address, location	short description	S [mmHg]	D [mmHg]	$\phi$ [D/S]	HR [beats/ min]	S [mmHg]	D [mmHg]	$\phi$ [D/S]	HR [beats/ min]
15	Nechuy Levytskyy str., 6	Nechuy Levytskyy str., 6. Church of the Saint Martyr Demetrius	121.60	80.20	0.66	89.80	120.14	70.87	0.59	66.48
16	Khimikiv str., 1	General education school of I–III grades No. 24	118.20	82.40	0.70	87.00	115.78	77.01	0.67	65.34
17	Trolleybusna str., 7	General education school of I–III grades No. 18	119.00	80.20	0.67	87.00	116.24	73.57	0.63	65.68
18	Halytska str., 145	Restaurant “Oven”	115.40	84.60	0.73	86.80	114.02	75.12	0.66	65.27
19	River Bystrytsa Solotvynska	Bridge over the river Bystrytsa Solotvynska on the Halytska str.	116.40	77.60	0.67	87.60	115.00	70.05	0.61	65.88
20	River Bystrytsa Nadvirnanska	Bridge over the river Bystrytsa Nadvirnanska on the Tysmenytska str.	122.60	77.80	0.63	97.60	121.13	70.12	0.58	73.42
21	Medychna str., 17	Regional clinical ontological dispensary	119.20	73.20	0.61	85.40	117.77	69.12	0.59	64.22
22	Medychna str., 15	Regional psychoneurological hospital No. 3	119.00	73.00	0.61	91.80	112.57	66.18	0.59	68.00
23	Konovaltsa str., 433	Hotel “Formula 1”	114.80	73.60	0.64	91.60	113.42	61.98	0.55	67.05
24	Evhen Konovalts str., 264 A	International airport “Ivano-Frankivsk”	113.40	72.40	0.64	89.80	112.04	70.04	0.63	68.02
25	Blavatskoho str., 3	General education school of I–III grades No. 6	115.80	70.40	0.61	88.60	114.41	62.88	0.55	66.87
26	Evhen Konovalts str., 229	OJSC “Ivano-Frankivsk Vave Plant”	113.00	73.60	0.65	79.40	111.64	70.01	0.63	60.01
27	Konovaltsa str., 132	Regional Children’s Clinical Hospital	109.20	72.40	0.66	81.40	107.89	63.89	0.59	62.13

28	Sakharova str., 36 A	General education school of I-III grades No. 21	119.40	75.60	0.63	84.40	117.97	67.94	0.58	64.39
29	Yunosti str., 4	Bus station No. 4	119.00	76.00	0.64	99.20	119.47	69.90	0.59	74.60
30	Yunosti str., 23	Regional center of State Automobile Inspectorate	117.00	77.60	0.66	97.00	115.60	70.88	0.61	73.88
31	Yunosti str., 13	Ivano-Frankivsk Regional vocational-boarding school for gifted children from countryside	134.10	82.70	0.62	92.60	132.49	85.77	0.65	69.64
32	Topolyna str., 6	Ivano-Frankivsk physico-technical vocational-boarding school	127.40	85.20	0.67	84.40	125.67	77.16	0.61	63.52
33	Tysmenytska str., 289	Domestic building	129.20	79.40	0.61	79.40	127.65	72.16	0.57	59.71
34	Tysmenytska str., 287	Magazine "AutoKiss", stop	130.40	82.20	0.63	66.80	128.64	79.36	0.62	50.23
35	Tysmenytska str.	Petrol filling station "Okko", garden center	128.40	81.40	0.63	76.80	126.86	73.12	0.58	57.75
36	River Bystrytsya Nadvirnyanska	Bridge over the River Bystrytsya Nadvirnyanska on Evgen Konovalets str.	131.40	79.80	0.61	75.00	129.82	72.18	0.56	56.40
37	Nezalezhnosti str., 207	General education school of I-III grades No. 15	126.40	77.60	0.61	69.20	124.88	65.13	0.52	53.34
38	Railway line	Bridge over the railway line on Tysmenetska str.	125.80	77.00	0.61	69.00	124.29	58.92	0.47	51.89
39	Nezalezhnosti str., 97	Cinema "Kosmos", stop	123.00	84.00	0.68	91.90	121.36	75.12	0.62	68.05
40	Nezalezhnosti str., 93 A	Magazine "Pelikan"	128.40	81.80	0.64	77.60	124.86	72.56	0.58	58.36
41	Nezalezhnosti str., 40	Hotel "Nadiya"	129.40	75.20	0.58	74.60	127.85	78.34	0.61	56.20
42	Nezalezhnosti str., 53	National Painter's Union of Ukraine	126.40	75.40	0.60	76.40	124.88	69.36	0.56	57.34
43	Vahylevycha str., 5	Restaurant "Pehas", Pizzeria "Lavazza"	129.40	77.00	0.60	72.60	127.15	54.88	0.43	54.80
44	Uhornytska str., 10 A	Restaurant "Lehenda"	116.40	74.40	0.64	106.40	115.00	64.15	0.56	82.21
45	Uhornytska str., 16	Domestic building	123.00	79.40	0.65	102.80	121.17	70.89	0.59	77.32

Table 2. cont.

No.	Points of test area		Men at the age of 20–22				Women at the age of 20–22			
	address, location	short description	S [mmHg]	D [mmHg]	$\varphi$ [D/S]	HR [beats/min]	S [mmHg]	D [mmHg]	$\varphi$ [D/S]	HR [beats/min]
46	Ivasyuka str., 76	Christian Church of Seventh-Day Adventists	125.40	77.60	0.62	98.00	121.90	70.01	0.57	73.70
47	Hnat Khotkevych str.	Crossing of Hnat Khotkevych and Ivasuka str.	119.80	80.00	0.67	90.60	118.36	73.12	0.62	67.22
48	Ivasyuka str., 50 A	Kingdom Hall of Jegova's Witnesses	123.60	81.00	0.66	97.00	122.12	68.18	0.56	72.87
49	Ivasyuka str., 17	Supermarket "Epicenter"	124.60	82.20	0.66	98.00	123.10	71.12	0.58	72.82
50	Stus str.	Food market	127.40	84.60	0.66	92.80	124.87	77.16	0.62	68.24
51	Vovchynetska str., 225	Management and Economy Institute "Halych Academie"	127.20	84.20	0.66	94.40	125.67	76.00	0.60	70.34
52	Vovchynetska str., 223	Ivano-Frankivsk college for electronic valve	131.60	85.20	0.65	96.20	130.08	78.21	0.60	72.34
53	Maksymovych str., 15	Markt "Anatol"	124.40	81.00	0.65	94.60	122.91	72.06	0.59	71.28
54	River Bystrytsa Solotvynska	Railway bridge over the River Bystrytsa Solotvynska	123.40	80.60	0.65	91.20	121.92	73.18	0.60	68.58
55	Halyska str., 66	Building material store "Kerambud"	130.40	83.80	0.64	89.80	127.84	77.10	0.60	67.53
56	Naberezhna str., 2	Domestic building	125.60	83.40	0.66	78.00	124.09	76.16	0.61	58.79
57	Naberezhna str., 24	Domestic building	124.80	83.40	0.67	77.00	123.67	72.89	0.59	57.90
58	Karpatska str., 15	Main building of Ivano-Frankivsk Oil and Gas National University	124.40	84.20	0.68	87.40	122.91	75.12	0.61	65.72
59	Beregova str., 30	Novopostolska Church	124.20	85.00	0.68	86.40	122.71	77.83	0.63	64.97
60	Petryur str., 10	Petryur str., 10. OJSC Ivano-Frankivsk meat processing plant	120.00	79.20	0.66	90.80	115.56	71.12	0.62	68.28
61	Chornovola str., 130	Automobile circle	118.60	72.00	0.61	86.20	117.18	68.34	0.58	64.82



62	Dovzhenko str., 2	Christmas Church	116.20	72.20	0.62	83.40	114.81	62.40	0.54	62.80
63	Dovzhenko str., 26	Domestic building	122.40	77.00	0.63	87.60	120.93	59.08	0.49	66.18
64	T.H. Shevchenko's Park	Park lake	127.00	86.30	0.68	92.80	125.48	79.22	0.63	69.79
65	Hetmana Mazepy str., 90	Educational complex General education vocational school No. 23 of V. Stefanyk Carpathian National University	124.40	76.20	0.61	85.20	122.13	70.03	0.57	64.08
66	Sichovi Striltsi str., 29	Translation bureau	119.00	70.00	0.59	69.00	117.57	64.16	0.55	52.36
67	Chornovola str., 2	Hotel "Stanislaviv"	119.20	70.40	0.59	69.80	117.77	67.82	0.58	52.50
68	Shevchenko str., 57	Main building of the State High Educational Institute V. Stefanyk Carpathian National University	120.10	72.40	0.60	73.00,	118.66	70.01	0.59	54.90
69	Chornovola str., 103	Domestic building	125.40	84.20	0.67	92.20	124.87	78.10	0.63	68.33
70	Shevchenko str., 98	Domestic building	117.70	75.40	0.64	92.00	116.29	66.80	0.57	69.18
71	Shevchenko str., 32	Crossing of Shevchenko and Hordynskyy str.	128.60	76.20	0.59	71.40	125.06	69.18	0.55	53.69
72	Shevchenko str., 2	Crossing of Shevchenko and Sichovi Striltsi str.	124.00	82.20	0.66	90.20	122.43	73.00	0.60	67.66
73	P. Orlyk str., 7	Crossing of P.Orlyk and Volodymyr Velykyy str.	118.40	70.20	0.59	67.20	116.98	62.76	0.54	50.53
74	Belvederska str., 14	Caffee "Halka"	120.80	70.20	0.58	71.80	118.35	61.99	0.52	53.90
75	Belvederska str., 40	Domestic Building	125.00	77.00	0.62	70.20	121.50	64.18	0.53	52.79
76	Belvederska str., 39	Crossing of Belvederska and Korolya Danyla str.	126.00	78.20	0.62	90.20	124.49	70.18	0.56	66.89
77	Korolya Danyla str., 18	Crossing of Korolya Danyla and Volodymyr Velykyy str.	126.00	78.20	0.62	72.00	122.36	74.14	0.61	54.16
78	Korolya Danyla str., 4	Crossing of Korolya Danyla and Hetman Mayepyy str.	124.00	77.00	0.62	91.20	122.18	70.00	0.57	67.12
79	Vichevyy Maydan	Fountain	119.10	72.20	0.61	71.00	118.67	64.98	0.55	53.40

Table 2. cont.

No.	address, location	short description	Men at the age of 20–22				Women at the age of 20–22			
			S [mmHg]	D [mmHg]	$\phi$ [D/S]	HR [beats/ min]	S [mmHg]	D [mmHg]	$\phi$ [D/S]	HR [beats/ min]
80	Valova str., 10	Domestic building	124.00	76.20	0.61	72.00	122.51	71.56	0.58	53.88
81	I. Franko str., 33	Ivano-Frankivsk Natural and Mathematical Lyceum	125.40	80.40	0.64	77.80	123.90	71.77	0.58	59.37
82	Pavlyk str., 5	Domestic Building	127.40	86.80	0.68	109.30	125.12	79.68	0.64	83.19
83	Harkushi str., 37	Crossing of Harkushi and B. Lepkoho str.	125.80	76.40	0.61	71.00	124.29	70.12	0.56	54.20
84	Railway line	Foot bridge over the railway lines, railway station	118.40	70.20	0.59	73.00	116.98	60.88	0.52	55.01
85	Khotkevycha str.	Crossing of H. Khotkevych and Remisnycha str.	126.00	74.20	0.59	92.40	122.49	71.22	0.58	67.52
86	Myru str., 33	Crossing of Mury and Selyanska str.	119.00	76.20	0.64	89.20	117.00	69.85	0.60	67.08
87	Vovchynetska str., 92	Roman Catholic Church	127.00	77.80	0.61	92.60	125.18	77.36	0.62	66.25
88	Vovchynetska str., 54	Church of Saint Joseph the Betrothed	125.00	76.00	0.61	91.00	123.50	68.88	0.56	67.75
89	Vovchynetska str.	Under the railway bridge	123.20	76.80	0.62	90.20	121.72	70.24	0.58	67.13
90	Pryvoksalna str., 1	Ivano-Frankivsk railway station	128.10	82.00	0.64	90.20	126.34	77.88	0.62	67.23
91	Nezalezhnosti str., 43	Pizzeria "Lavazza"	128.20	78.20	0.61	74.00	126.66	71.52	0.56	54.00
92	Mykolaychulka str., 2	Supermarket "Arsen"	122.40	81.60	0.67	98.80	120.93	65.84	0.54	74.30
93	Hetmana Mazepy str., 165	Ivano-Frankivsc base medical college	120.60	75.00	0.62	86.60	119.15	65.98	0.55	65.12
94	Hetmana Mazepy str., 162	Bus station No. 3	121.00	76.00	0.63	88.20	117.38	66.83	0.57	65.37
95	24 Serpnyaya str., 13	General education school of I–III grades No. 25	125.80	76.70	0.61	84.40	124.29	70.58	0.57	63.41
96	Ivano-Frankivsk city lake	Lovers island	122.80	80.20	0.65	87.00	121.33	71.01	0.59	65.55
97	H. Khotkevych str., 56	General education school of I–III grades No. 19	124.20	78.00	0.63	98.00	122.71	70.88	0.58	74.80

98	Naberezhna str., 6	Domestic building	124.00	82.00	0.66	76.00	122.16	74.36	0.61	56.49
99	Naberezhna str., 16A	General education school of I-III grades No. 17	122.80	82.40	0.67	78.00	119.33	76.03	0.64	58.43
100	Chornovola str., 47	Ivano-Frankivsk Regional maternity hospital	120.00	72.00	0.60	72.00	118.26	67.20	0.57	54.14
101	Chornovola str., 63A	Churche of the nativity of the Blessed Virgin	119.00	70.00	0.59	75.00	117.00	60.87	0.52	55.29
102	Depovska str., 97	Hotel "Stanislavskyy Dvir"	124.00	72.00	0.58	90.40	121.57	63.00	0.52	68.05
103	Shukhevychiv str., 35	Ivano-Frankivsk Gymnasium No. 2	124.60	78.00	0.63	87.00	123.10	71.03	0.58	66.81
104	Hoholya str., 10	Ivano-Frankivsk Gymnasium No. 3	122.00	76.00	0.62	90.00	120.54	68.77	0.57	67.92
105	Dovha str., 37	Specialized general education school of I-III grades No. 1 with enhanced education in English	128.20	82.40	0.64	86.80	126.66	78.12	0.62	66.34
106	Doroshenko str., 29	General education school of II-III grades No. 2	120.20	71.80	0.60	77.40	118.76	64.51	0.54	58.20
107	Franka str., 14	General education school of I-III grades No. 3	122.60	80.20	0.65	88.00	121.13	72.55	0.60	66.18
108	Pivdennyi Boulevar, 24	General education school of I-III grades No. 4	118.60	70.20	0.59	68.20	117.00	64.20	0.55	51.30
109	I. Franko str., 19	Specialized general education school of I-III grades No. 5 with enhanced education in German	121.40	78.20	0.64	86.00	119.54	69.08	0.58	64.67
110	Hrushevskoho str., 16	General education school of I-III grades No. 7	128.60	76.40	0.59	92.20	127.06	71.12	0.56	69.24
111	Vovchynetska str., 196B	General education school of I-III grades No. 10	124.20	76.80	0.62	90.20	122.71	70.01	0.57	68.34
112	B. Lepky str., 9	Ivano-Frankivsk Specialized general education school of I-III grades No. 11 with enhanced education in English	124.60	74.20	0.60	75.20	122.17	67.13	0.55	56.67

Points of test area		Men at the age of 20–22				Women at the age of 20–22				
No.	address, location	short description	S [mmHg]	D [mmHg]	$\phi$ [D/S]	HR [beats/ min]	S [mmHg]	D [mmHg]	$\phi$ [D/S]	HR [beats/ min]
113	Nationalnoyi Hvardiyi str., 13	General education school of I–III grades No. 12	114.00	74.20	0.65	80.20	112.63	68.24	0.61	60.55
114	Halytska str., 65	General education school of I–III grades No. 13	121.20	77.40	0.64	88.60	118.75	68.25	0.57	66.63
115	Vovchynetska str., 103	General education school of I–III grades No. 16	126.20	77.60	0.61	90.40	124.69	69.15	0.55	67.98
116	Вул. Будівельників, 24	General education school of I–III grades No. 22	124.60	82.40	0.66	90.20	124.30	74.98	0.60	67.54
117	Chornovola str., 130	General education school of I–III grades No. 28	118.00	72.40	0.61	82.40	116.58	72.08	0.62	61.96
118	Dnistrovska str., 28	Dnistrovska str., 28. Ivano-Frankivsk Institut for Management of Ternopil Academy of National Economy	121.00	80.20	0.66	88.20	119.42	69.17	0.58	66.13
119	S. Bandery str., 79	Ivano-Frankivsk S. Granat financial and business cooperative college	115.20	78.40	0.68	80.20	113.82	72.06	0.63	60.32
120	Yunosti str., 11	Ivano-Frankivsk State Agricultural College	120.00	80.20	0.67	91.00	108.36	70.00	0.65	68.43
121	Halytska str., 45	Ivano-Frankivsk College of Statistics of State Academy of Statistics, Accounting and Audit	119.00	78.20	0.66	90.00	115.23	70.98	0.62	67.68
122	Evhen Konovalets str., 140	Ivano-Frankivsk State Technology and Business College	119.60	80.00	0.67	78.20	119.16	73.32	0.62	58.83

### 4. Methods of Statistical Research

For the obtained data reproduced correlation coefficients were calculated using spreadsheet Microsoft Excel (CORREL functioned) for indicators  $S, D, \phi$  and heart rate (Tab. 2) and indicators  $E_{max}, H_{max}, \mu_{max}, E_{aver}, H_{aver}, \mu_{aver}$  (Tab. 1) separately for men and women. The results of the relevant calculations are represented in the Tables 3 and 4.

**Table 3.** The index of correlation between the value  $S, D, \phi, HR$  and  $E_{max}, H_{max}, \mu_{max}, E_{aver}, H_{aver}, \mu_{aver}$  in the points of test area, the men at the age of 20–22

Parameters	$S$ [mmHg]	$D$ [mmHg]	$\phi$ [D/S]	$HR$ [beats/min]
$E_{max}$ [V/m]	-0.0068	-0.3018	-0.3487	-0.3249
$H_{max}$ [mA/m]	0.0058	-0.2813	-0.3351	-0.3260
$\mu_{max}$ [mW/cm <sup>2</sup> ]	-0.0242	-0.2524	-0.2778	-0.3824
$E_{aver}$ [V/m]	-0.0023	-0.2951	-0.3418	-0.3767
$H_{aver}$ [mA/m]	0.0014	-0.2868	-0.3375	-0.3778
$\mu_{aver}$ [mW/cm <sup>2</sup> ]	-0.0820	-0.3261	-0.3186	-0.3458

**Table 4.** The index of correlation between the value  $S, D, \phi, HR$  and  $E_{max}, H_{max}, \mu_{max}, E_{aver}, H_{aver}, \mu_{aver}$  in the points of test area in the points of test area, women at the age of 20–22

Parameters	$S$ [mmHg]	$D$ [mmHg]	$\phi$ [D/S]	$HR$ [beats/min]
$E_{max}$ [V/m]	0.0033	-0.2811	-0.3254	-0.2922
$H_{max}$ [mA/m]	0.0151	-0.2622	-0.3111	-0.2951
$\mu_{max}$ [mW/cm <sup>2</sup> ]	-0.0128	-0.2631	-0.2946	-0.3315
$E_{aver}$ [V/m]	0.0185	-0.2449	-0.2925	-0.3101
$H_{aver}$ [mA/m]	0.0248	-0.2247	-0.2744	-0.4133
$\mu_{aver}$ [mW/cm <sup>2</sup> ]	-0.0624	-0.2236	-0.22033	-0.3075

The index of correlation  $r$  can take the value in the interval from  $-1$  to  $+1$ , it means  $-1 \leq r \leq 1$ . The correlation relationship can be positive (direct) and negative (inverse). If  $r > 0$ , then it talks about positive correlation or direct connection between values when with increasing of one value increases on the average value of the others. If  $r < 0$ , the correlation is negative and it is inverse relationship between values. This means that during the growth of the second value will on the average decrease [9].

According to the data of correlation analysis is seen moderate negative correlation relationship between heart rate in men and women and measures  $E_{max}, H_{max}, \mu_{max}, E_{aver}, H_{aver}, \mu_{aver}$ . Moreover, the maximum relationship is observed between heart rate in men and  $\mu_{max}$  and heart rate in women and  $H_{aver}$ .

The indexes of the correlation as a measure of relation between random values are also random values, and have stochastic nature. The index of correlation as sample characteristics, is tested for significance due to Student criterion  $t$ . The real value  $t$  of the statistics  $t_{exp}$  is compared with the table value  $t$ -distribution with  $n + m - 2$  degrees of freedom, and by the given significant level  $p < 0.05$ . If,  $|t_{exp}| > t_{tabl}$ , it can be concluded that the index of the correlation is positiv (significant), and the relationship between the dependent variable and all independent factors is significant [11].

For the obtained data was calculated paired Student  $t$  criterion with one sided distribution using spreadsheet Microsoft Excel (TTEST function) for the values  $S$ ;  $D$ ;  $\varphi$  and heart rate (Tab. 3) and the values  $E_{max}$ ,  $H_{max}$ ,  $\mu_{max}$ ,  $E_{aver}$ ,  $H_{aver}$ ,  $\mu_{aver}$  (Tab. 2) separately for men and women. The results of the relevant calculations are represented in Tables 5 and 6.

**Table 5.** Paired  $t$ -Student criterion with one sided distribution ( $t_{exp}$ ), men at the age of 20–22

Parameters	S [mmHg]	D [mmHg]	$\varphi$ [D/S]	HR [beats/min]
$E_{max}$ [V/m]	3.271	4.745	8.425	1.263
$H_{max}$ [mA/m]	3.938	4.183	6.270	1.898
$\mu_{max}$ [mW/cm <sup>2</sup> ]	7.321	9.407	0.001	3.074
$E_{aver}$ [V/m]	2.843	1.208	0.001	7.891
$H_{aver}$ [mA/m]	5.385	4.369	8.143	2.220
$\mu_{aver}$ [mW/cm <sup>2</sup> ]	4.093	2.585	0.464	5.364

**Table 6.** Paired  $t$ -Student criterion with one sided distribution ( $t_{exp}$ ), women at the age of 20–22

Parameters	S [mmHg]	D [mmHg]	$\varphi$ [D/S]	HR [beats/min]
$E_{max}$ [V/m]	2.218	2.979	2.634	1.182
$H_{max}$ [mA/m]	5.483	7.237	3.926	2.292
$\mu_{max}$ [mW/cm <sup>2</sup> ]	2.176	4.343	0.001	1.447
$E_{aver}$ [V/m]	3.401	2.907	7.574	2.540
$H_{aver}$ [mA/m]	1.299	1.267	2.977	2.175
$\mu_{aver}$ [mW/cm <sup>2</sup> ]	2.550	3.896	0.349	1.982

The number of degrees of freedom  $f$  for all calculations is as follows  $(122 + 122) - 2 = 242$ . In the table we find the value Student  $t$ -test (at  $p = 0.05$ ) – 1.960 ( $t_{tabl}$ ).

The positive (significant) index of correlation is when  $|t_{exp}| > t_{tabl}$ .

## 5. Conclusions

The conducted research and calculations suggest that the value of the human arterial pressure and heart rate in general correlate with indicators of the electromagnetic field of the urban social ecological system in Ivano-Frankivsk city. In particular:

- There is a statistically significant negative index correlation between the values of heart rate [beats/min.] and  $E_{\text{aver}}$  [V/m],  $H_{\text{aver}}$  [mA/m],  $\mu_{\text{aver}}$  [mW/cm<sup>2</sup>] for men and women at the age of 20–22 showing an inverse relationship between these values at moderate correlation ratio between them.
- There is a statistically significant negative index of correlation between arterial pressure  $\phi$  and  $E_{\text{max}}$  [V/m],  $H_{\text{max}}$  [mA/m] for men and women the age of 20–22 showing an inverse relationship between these values at moderate correlation ratio between them.
- The moderate correlation ratio and negative index of correlation in men at the age of 20–22 and the lower correlation ratio and negative index of correlation in women at the age of 20–22 are statistically significant for indicators of diastolic arterial pressure  $D$  [mmHg] and  $E_{\text{max}}$  [V/m].
- For the parameters of systolic arterial pressure  $S$  [mmHg] and electromagnetic field indicators of urban social ecological system in Ivano-Frankivsk city significant correlation relationships were not found.

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