ALGORITHMS, METHODS AND RESULTS OF EVALUATION OF EXPOSITION OF RISK FACTORS

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ON ASSESSING ELECTROMAGNETIC FIELD (300 KMHz – 300MHz) IN A LARGE INDUSTRIAL CITY ON THE BASIS OF 3D MODELING AND INSTRUMENTAL MEASURING

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The article dwells on issues of modeling electromagnetic fields levels (EMF with frequency equal to 300 KMHz - 300 MHz which are created by television and radio broadcasting objects, radiolocation, and mobile communication in a large regional center, in geoinformation system environment. Our task was to estimate EMF levels on areas where apartment blocks were located; to assess energy flows at various floors, to determine zones in a city as per EMF levels; to verify the obtained results with the direct factor measuring. Our calculation included data on 2,011 EMF sources located on a city territory. We allowed for bulk parameters of 31,949 buildings including 17,307 apartment blocks, 3,160 administrative buildings, 307 pre-school children facilities and 105 secondary schools. We performed our calculations in city coordinate system at 109 thousand points. Each calculation created a picture of EMF spread in a plane at a set height which allowed us to determine exposure level at a control point as per "slice" results and to build up a 3D contamination model. Approximately 80% of all the calculated results had EMF parameters within 0.1-10 safety criterion range. We spotted zones with maximum calculated EMF levels at 18-25 meters. Instrumental research proved high factor levels in these zones including those where levels exceeded safety criterion 4-6 times; it makes for certain vigilance in judgments on environmental safety for people who live on the examined territory permanently. The obtained data can be used for foundation of instrumental research points within the frameworks of specific research or social-hygienic monitoring as well as for consequent exposure and health risk assessment. The materials can be used in epidemiologic research for conjugate spatial analysis of energy flows and children and adults mortality.

Key words: *electromagnetic field, health risk factor, spatial modeling.*

Modern technologies based on electromagnetic waves properties are developing quite intensively now and it makes it absolutely necessary to update existing techniques for hygienic assessment of the environment [4, 6, 10]. Base stations of mobile communication, departmental communication (emergency, fire-fighting teams, RF EMERCOM teams etc.), frequency-modulated TV and radio broadcasting, radio relay systems, trace surveillance locators which control situation in the air as well as

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other radiation sources satisfy all the needs of industry and population in constantly increasing scope as they are replacing other processes and devices. Electromagnetic fields levels (EFL) of artificial origin are becoming a significant ecological factor with high biological activity. New technologies are being developed in the sphere of radio- and TV-broadcasting, wireless communication etc. and they are aimed at maximum dense "radio-coverage" of territories where people live permanently. And given the severe competition which exists on the telecommunication services market, we can observe multiple overlapping of electromagnetic fields created by competing companies.

In 1995 the World Health Organization (WHO) officially introduced a concept of "global electromagnetic contamination of the environment" and listed an electromagnetic contamination issue among those being top priority for the mankind. The WHO is implementing the International EMF Project and it highlights the actuality and significance this subject has for the society.

Research on electromagnetic fields levels, including those performed in the context of population exposure to them, has been conducted within a framework of specific scientific projects [1, 7, 12, 15, 16] or complex programs; for example, COST244bis European Scientific program (Bergqvist et al. 2001) [18]. Some authors consider electromagnetic fields to be risk factors for malignant neoplasms evolvement [3, 12], There are some data proving that electromagnetic radiation within radio frequencies range can cause non-carcinogenic risks of population health disorders [11, 13–15,23,24]. We have come across some works containing evidence that certain effects exerted on health still need to be proved [21]. However, all the research in general confirms that it is really vital to study impacts exerted by electromagnetic fields on a human body. In any case, documents issued by the WHO and other international organizations require to adhere to a principle of caution when assessing ionizing radiation objects safety [17, 22, 25–28]. It becomes even more important as some authors believe people in our country tend to underestimate electromagnetic fields danger for health and there is no systemic monitoring of the factor or individual dosage meters for electromagnetic fields measuring.

We should point out that there is very little research on assessing exposure as a measure of contact between this factor and a man when electromagnetic fields are measured. A lot of researchers have noted that it is very complicated to assess this exposure correctly. For example, data on electromagnetic fields levels collected in different countries within COST224bis program network in zones near base stations of mobile communications were within the range from 0.000001 to 48 mW/m2. There was a series of research conducted in Germany, France, and Switzerland, and the data obtained in it also varied greatly: average electromagnetic field level was equal to 0.027-0.09 mW/m2 while its maximum amounted to 3.5 mW/m2 (Vielt et al. 2009, Breckenkamp, 2009) [19, 28]. Some Russian scientists give data on energy flux density from base stations being equal to 0.1 to 5 µW/cm2. Significant dispersion in the results proves it is necessary to search for unified approaches to drawing up observation programs, measuring techniques and reports.

The report issued by Sweden SSM's Scientific Council on Electromagnetic Fields in 2016 contains the most relevant contemporary meta-analysis of research results within "electromagnetic fields - population health" system; it highlights the necessity to improve overall quality and validity of epidemiologic research [19].

The latter is especially vital when it comes to sanitary-hygienic assessments, research, inspections, and examinations conducted in cities. It is due to the fact that as per data given by some authors electromagnetic contamination issue is deteriorated by complicated interaction between electromagnetic fields and city environment objects (waves reflection and diffraction); by air-wires being multi-directional; by fields vertical volatility etc. [8–11]. But it is hygienic assessment which should underlie city planning and developing and high-rise buildings construction including those aimed for permanent residence [2]. It is also vital to improve techniques for analysis and prediction of sanitary and hygienic situation when choosing a place for a new radiation source location (for example, base stations of mobile communication), and when fixing or eliminating limitations imposed on a height of buildings located near transmitting radio-technical objects and when optimizing a system of electromagnetic fields control points [5]. Here it seems optimal to combine calculations and field observations as it allows to simultaneously decrease costs on the latter and to have a tool for scale assessments and situation modeling [2].

So, given the importance which creation of methodological approaches to design of dynamic 3D maps showing electromagnetic contamination on territories has for urban development tasks, social and hygienic monitoring optimization, and consequent hygienic assessment, we set the goal and tasks of the present work [2, 5].

Our research goal was to create a dynamic 3D vector map of electromagnetic fields in a large industrial center integrated with topical spatial information on places where city population lived constantly and to verify it with instrumental techniques.

We set the following tasks: to perform an inventory of basic electromagnetic fields sources which were located on the city territory; to determine their properties; to calculate electromagnetic fields on the whole city territory at 22 different heights from 2 to 75 meters above a source baseline; to give criteria assessment of the obtained results; to divide the city into zones as per electromagnetic fields levels; to verify the obtained results via direct measurements of the factor.

Data and methods Our research object was the territory and population of Perm, a large industrial center located in the Western Urals. Its total area amounts to 720 square kilometers; population is about 1 million people. To get territorial connection, we applied a vector map of the city in Arc GIS geoinformation system (9.3 version, the total square of the calculated rectangle being 1.085 thousand km2).

Primary processing of all collected data was performed with conventional software, i.e. Microsoft Excel, but we also secured consequent possibility to transfer them into other software packages to calculate electromagnetic fields levels.

Our calculations allowed for volume parameters of 31,949 buildings including 17,307 apartment blocks, 3,160 administrative buildings, 307 pre-school children facilities and 105 secondary schools. Data on 2,011 electromagnetic radiation sources were given by Perm Regional Center for Hygiene and Epidemiology. The database contained information on telecommunication objects, which made for the saturation of the environment with electromagnetic energy in various ranges:

30...300 MHz (10...1 m) was due to mobile communication, frequency-modulated radio broadcasting (ultrashort waves), TV broadcasting, and ambulance;

0,3...3 GHz (100... 10 cm) was due to radio relay lines, mobile communication, radiolocation, radio navigation, and NV broadcasting;

3...30 GHz (10...1 cm) was due to radio location, satellite communication, mobile communication, meteorological locators, and radio relay lines;

30...300 GHz (10...1 mm) was due to radiolocation, satellite communication, radio relay lines, and radio navigation.

Base stations of mobile communication emit electromagnetic energy within the range from 463 to 2,200 Hz. We took into account that base stations aerials are usually located 15-100 meters above the ground on already existing buildings (public, administrative, industrial ones and apartment blocks, on smoke pipes of industrial enterprises etc.) or on specially designed masts.

We applied "PC AEMO 4.0" specialized software package as the basis for assessing the existing impacts exerted by electromagnetic fields; this package conforms to Methodical Guidelines 4.3.1167-02 «Determination of energy flux density at places where radio devices functioning within 300 MHz - 300 GHz range are located" and Methodical Guidelines 4.3.1677-03 "Determination of electromagnetic field created by radiating technical TV devices, frequency-modulated radio broadcasting and base stations of land mobile communication".

Calculations were accomplished within the city coordinate grid in 109,000 points. Each calculation formed a picture of electromagnetic field propagation in plane at a set height and it allowed us to detect exposure level in a checkpoint as per "slice" results and create a 3D model of contamination.

We considered hygienic standards set forth by Sanitary-Hygienic Requirements 2.1.8/2.2.4.1383-03 "Hygienic requirements to location and operation of transmitting radio technical objects" and Sanitary-Hygienic Requirements 2.1.8/2.2.4.1190-03 "Hygienic requirements to location and operations of land mobile radio communication devices" as our criteria of allowable electromagnetic fields levels. According to the above mentioned sanitary-hygienic requirements, maximum allowable electromagnetic fields levels amounted to 10 μW/cm2 within 30 MHz - 300 GHz range.

Instrumental research which verified our calculations was performed by Center for Sanitary and Epidemiology LLC, laboratory-testing center located in Moscow (state certificate No. RA.RU.21ЦСО1 issued on January 29, 2016). Energy flux density was measured according to Methodical Guidelines 4.3.1167-02 «Determination of energy flux density at places where radio devices functioning within 300 MHz - 300 GHz range are located" with PZ-41 electromagnetic radiation gauge. 80 measurements were accomplished during a year at different heights on apartment blocks and public places in zones where calculated energy flux density was the greatest.

Basic results. We detected that 2,011 telecommunication sources created environmental load in the regional center; they caused the saturation of the environment with electromagnetic energy within various ranges. We created a database on electromagnetic radiation sources which included:

– 1,666 base stations of mobile communications with transmitters power ranging from 10 to 20 W which were located evenly on the whole city territory and emitted electromagnetic energy within 400 to 3,000 Hz range; they were placed 15-100 meters above the ground on already existing buildings (public, administrative, industrial ones and apartment blocks, on smoke pipes of industrial enterprises etc.) or on specially designed masts;

– 248 radio relay communication line devices which were formed by relay radio stations chains;

– 95 aerials which formed aerial fields of three transmitting radio centers belonging to different state agencies;

– 2 trace surveillance radio locators with transmitters power being equal to 4,100 W functioning at 3,000 MHz frequency, and other radiation sources.

These sources are located unevenly on the city territory. The greatest number of such sources is located on heights in the city center. Practically all sources are located directly in zones where people live or in maximum proximity to such zones.

As per results of all the performed electromagnetic fields calculations at heights ranging from 2 to 70 meters we obtained a considering points array within the calculated parallelepiped boundaries with the results of electromagnetic fields calculation at each separate height. We combined the obtained results with vector layers of buildings allowing for their heights and received a 3D picture of impacts distribution a part of which is given on Figure 1.

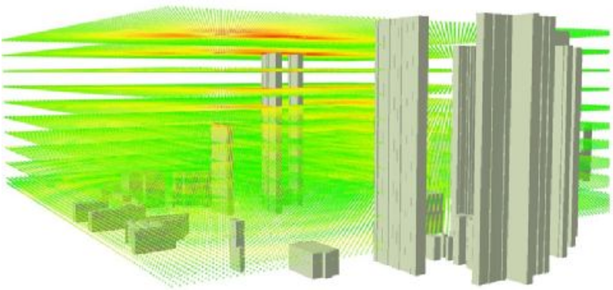

Figure 1. An example of 3D electromagnetic field visualization (heights from 3 to 35 meters above the ground)

Calculations and the consequent mapping of electromagnetic fields on the city territory reveled that their levels didn't exceed maximum permissible ones on the city territory.

The greatest expected electromagnetic field level within the examined range amounted to 15.2 SC (safety criterion) in a zone where the airport radio locator was placed; this locator was for communication between air carriage vehicles and control rooms. It is situated several kilometers away from the city boundaries on Perm district territory. At present there is housing in the area where electromagnetic field levels exceed the existing hygienic standards; so we worked out certain recommendations for the city general design plan.

About 80% of all the considering points were characterized with electromagnetic field parameters lying within 1-10 SC range. Maximum values were within 4-5.5 SC range and were placed at the height of 4-7 floors in various city zones (Figure 2).

As a height grew calculated electromagnetic fields levels increased on the city territory as a whole reaching their peak at 9-18 meters; then they went down gradually but still remained higher than just near the ground.

A square of a territory with 1-10 SC within the calculated rectangle boundaries at 3 meters (first floors) amounted to 5.86 km2; at 12 meters (2-4 floors), 20.9 km2; at 30 meters (9-11 floors), 13,6 km2; at 48 meters, about 14.5 km2.

Approximately 1,000 houses were located in zones where energy flux density amounted to 1-10 SC and where instrumental research was also accomplished; about 145 thousand people live in these houses at present. Quantity of people who permanently live in zones with the greatest calculated electromagnetic contamination (more than 3 SC) amounts to about 15 thousand. Some pre-school children facilities and secondary schools are also located there (Figure 3).

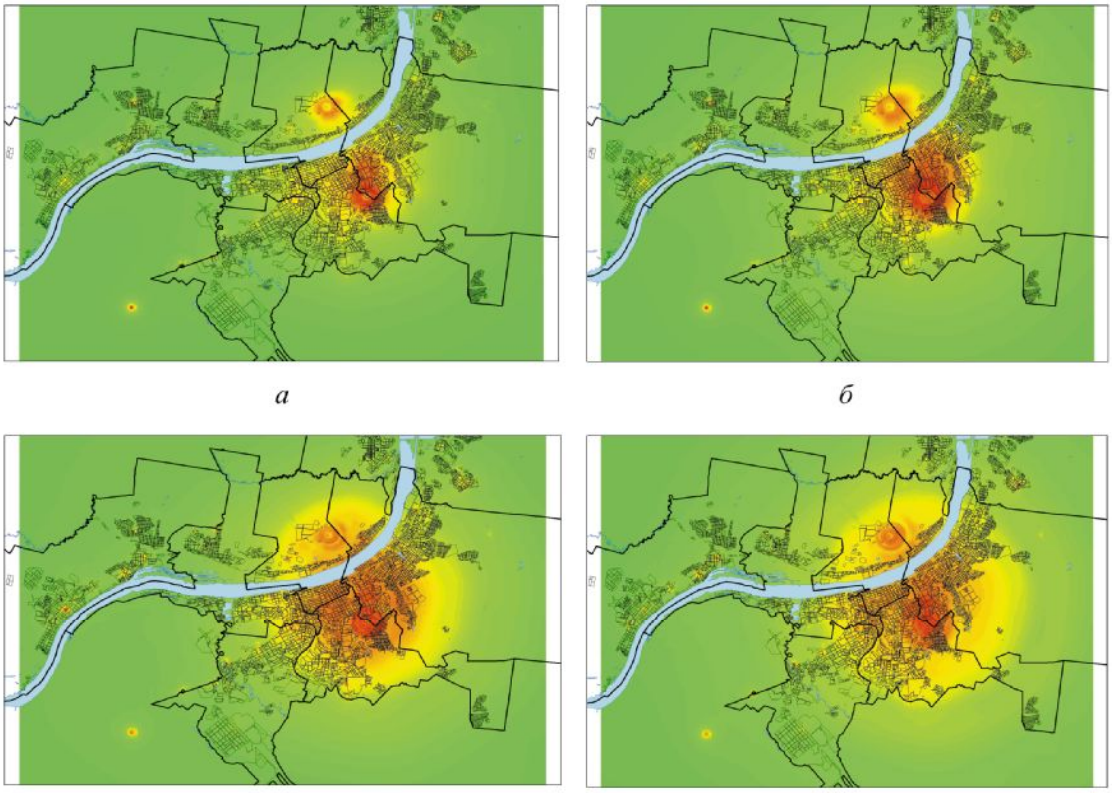

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Figure 2. Electromagnetic field levels on Perm city territory at different heights above the ground: a) 3 m; b) 6 m; c) 18 m d) 30 m

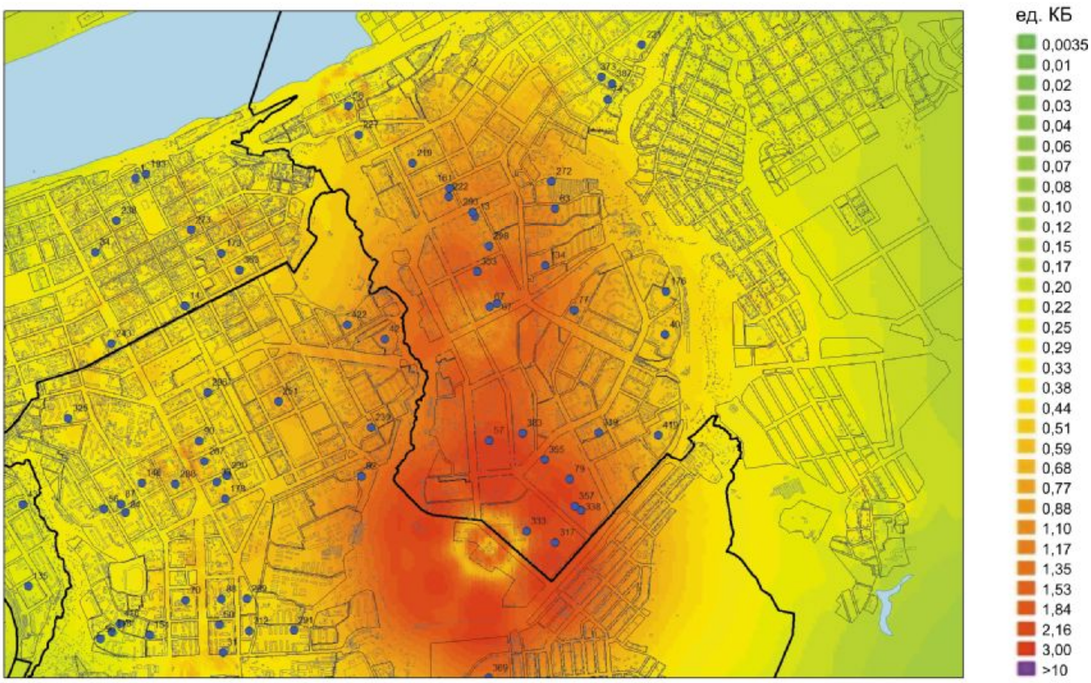

Figure 3. Electromagnetic field levels in the city center and pre-school children facilities located in zones influenced by transmitting radio technical objects (given with dark-blue dots)

Electromagnetic field intensity at different floors of apartment blocks in the central part of Perm in a zone where increased calculated SC values were detected

Parameter	Measuring points				
	Yards	1-2 floors (3-6 m)	3-5 floors (9-15 m)	6-9 floors (18-27 m)	10-14 floors (30-42 m)
Average EFD level, µW/cm2	0,91	0,96	1,58	4,21	1,30
Uncertainty "-" U-	0,45	0,47	0,78	2,07	0,64
Uncertainty "+" U+	0,77	0,82	1,35	3,59	1,11
∑(E/MPL)2	0,04	0,16	0,07	0,13	0,09
SC average	0,20	0,34	0,35	0,87	0,32
Maximum EFD level µW/cm2 sec	1,64	2,56	12,73	**31,29**	4,21
Uncertainty "-" U-	0,81	1,26	6,25	**15,37**	2,07
Uncertainty "+" U+	1,39	2,18	10,85	**26,68**	3,59
∑(E/MPL)2	0,01	0,57	–	**–**	0,25
SC max	0,31	1,05	2,36	**5,80**	1,03

Instrumental research had quite high convergence with the calculated parameters. Electromagnetic fields levels as per data obtained via field observations in "red-orange zone" which was considered to have electromagnetic field ranging from 0.3 to 3.0 SC as per situation modeling via calculation were characterized with average measured energy flux density being equal to 0.52 µW/cm2.

We also fully confirmed that energy flux density changed as per heights. 18-25 meters above a building baseline were "critical" for Perm on the examined area (Table). The highest electromagnetic fields levels were detected exactly at such heights (Table).

Due to the fact that instrumental research was purposely performed on areas where electromagnetic fields levels were potentially the highest, it revealed a number of cases when they exceeded the safety criterion. It was higher than 1.0 in 9 out of 80 samples; excess multiplicity was almost 6 times. Maximum level of energy flux density (31.29 µW/cm2) allowing for "+" U+ uncertainty (26.68 µW/cm2), which amounted to 5.8 SC, was detected at about 18 meters above the ground. 2.35 SC was detected in the same apartment block at the top 5th floor during the next measuring with maximum energy flux density being 12.73 µW/cm2, allowing for "+" U+ uncertainty, 10.85 µW/cm2. Further violations of hygienic standards prove it is necessary to perform systemic monitoring of electromagnetic fields level, to assess population health risks, and to give grounds for consequent solutions aimed at their minimization.

Conclusions:

Overall, the performed research allowed us to conclude that the total assessment of the situation on the basis of calculations within a geoinformation system medium was quite relevant. Creation of a maximum full and correct database on sources of electromagnetic contamination in a city is the primary condition for a qualitative assessment; it is also necessary to geocode these sources with the use of a territory vector map.

Our research revealed that the highest electromagnetic contamination levels on the examined territory of a regional center evolved at 18-25 meters above the ground and it was due to peculiarities of radiating and receiving air wires location.

We detected that electromagnetic field levels were 4-6 times higher than maximum permissible ones in zones with the highest calculated energy flux density at 18-25 meters above the ground; it makes it quite difficult to assume such environment is safe for people who permanently live on the examined territory.

The obtained data are to be applied in giving grounds for field observation points within specialized research framework or social-hygienic monitoring as well as in consequent assessment of exposure and health risks. These materials can be used within epidemiologic research for conjugate spatial analysis of energy flux density and adults and children morbidity with diseases which are proved or considered to be associated with electromagnetic radiation (leukemia, meningioma, hemopathy etc.).

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APPLICATION OF REGRESSION ANALYSIS AND CLASSIFICATION TREES IN CALCULATING ADDITIONAL POPULATION RISK OF ISCHEMIC HEART DISEASE

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Our research goal was to perform a comparative analysis of regression analysis application and tree classification application in calculating additional population risk on the example of ischemic heart diseases (IHD). Our research object was a random population sample comprising both male and female population aged 25-64 in Kemerovo region (1,628 people) within ESSE-RF multi-centered epidemiologic research. We considered the following IHD risk factors: lipid metabolism parameters, arterial hypertension, lifestyle factors, psychoemotional peculiarities, and social parameters. IHD occurrence was assessed as per sum of 3 epidemiologic criteria: on the basis of ECG changes coding as per Minnesota code, Rose questionnaire, and cardiac infarction in case history. We calculated additional population IHD risk determined by risk factors as per unified original algorithms, but with various statistic analysis techniques: logistic regression analysis and classification trees.

We built up mathematic models for IHD probability as per risk factors, with predictive significance equal to 83.8% for logistic regression analysis and to 71.9% for classification trees. The applied statistical analysis techniques show different contributions made by risk factors into IHD prevalence which results from absence of correlation between them.

IBD risk additional to population one and determined by risk factors as per both statistical analysis techniques in sex-age groups changed from negative values in age groups younger than 45 to positive values in older people. Increase in additional IHD risk in aged groups as per both techniques was practically linear with slight deviations. Difference in additional population risk calculated as per two statistical analysis techniques was insignificant and as a rule it didn't exceed 1.5%. Consequently, both techniques give similar results and can be equally used in calculating IHD population risk.

Key words: *regression analysis, risk factor, ischemic heart disease, population risk, predictive models, statistical analysis techniques.*

Cardiovascular diseases etiology is determined by a lot of factors and it makes it necessary to consider probability of their evolvement and unfavorable outcomes with integral risk assessment models. Such models should include several basic factors. In most cases one respondent can have a combination of two and even more risk factors and a forecast for development and clinical course of cardiovascular diseases is much worse when several, even moderately apparent, risk factors are combined [8, 9,12,]. In particular, PROCAM research revealed that a combination of two or more factors of cardiovascular system disorders risks led to significant in-

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