Adv Syst Sci Appl 2022; **04**; 202-211
Published online at http://ijassa.ipu.ru.

The Nature of the Combined Effect of Low Doses of Radiation and Chemical Pollutants in Doses Close to the Maximum Permissible, on the State of Somatic Health of the Population

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Abstract: Technogenic development of the society besides improvement of social and living conditions of people leads to increase of emissions into the environment of industrial wastes, including radioactive wastes. The purpose of this work was to study the influence of low doses of radiation combined with chemical pollutants in doses close to the maximum permissible, on the health of people in comparison with similar health indicators of the population living in an area with similar chemical pollution (with radiological well-being) and in the area with "clean ecology".

The study was conducted on the territory of one region for 3 years: from 2016 to 2018 in three districts: the first district - district with the presence of radiation and chemical pollution, the second district (comparison) - district with natural radiation background and chemical pollution and the third district (comparison) - district of "Environmental Wellbeing".

The state of health of the population, the specified settlements was studied on the basis of analysis of data from the accounting Form № 12 (departmental form of state statistical observation of the Ministry of Health of the Russian Federation on Form 12 "Information on the number of diseases registered in patients residing in the service area of the medical organization" in the Moscow region, for 2016-2018 years).

It was found that both radiation and chemical pollution of the environment in low doses leads to an excessive risk of somatic diseases and MND. When their effects on the human body are summarized, the resulting negative effect on human health is intensified.

In the studied area of the RWDF, natural and climatic features and the nature of anthropogenic influence led to contamination, first of all, of the air and soil, which affected the structure of cancer mortality, risks of development of MNS and the nature of pathology predominantly spread among the population - upper and lower respiratory tract diseases, allergological diseases, which opens new directions for preventive and health-improvement work among the population.

Keywords: low doses of radiation, chemical pollutants, somatic pathology risks.

1. INTRODUCTION

Despite being one of the driving forces for improving social and living conditions, technogenic development has led to an increased environmental pollution, including the production of radioactive waste. Chemical pollutants and radionuclides contaminate soil, air, and water and then can enter the human body through inhalation and ingestion of contaminated food and water. Regular intake of pollutants may result in chronic intoxication and trigger various somatic disorders, such as cancer [1,2,3,4]. The hypothesis we suggested

stated that combination of low dozes of radiation and chemical pollution enhance each other and results in more complications compared with separate exposition of radiation and chemicals.

The objective of the study: to clarify whether the combined effect of low doses of radiation and chemical pollutants (in doses less or close to the maximum allowable) on human health outcomes in compared with similar health indicators of the population living in an area with chemical contamination only (with radiological well-being) and in an area without any contamination ("clean ecology").

2. OBJECTIVES

The objectives of this research were:

1. To assess the in a comparative aspect the radiation background and level of chemical contamination of three territorial formations: settlement 1 (in Sergiev Posad district), settlement 2 (in Voskresensk district) and settlement 3 (in Lotoshinsk district) of Moscow region and their total impact on the health of the population;
2. In a comparative aspect to analyze the state of health of the population, the specified settlements to clarify the degree of influence of low doses of radiation and chemical pollutants in doses close to the maximum allowable, on the state of somatic health of residents.

3. METHODS

The study was conducted on the territory of one region for 3 years: from 2016 to 2018 in three settlements of different districts of the region: the first district - 4 kilometers from the radioactive waste dump (RW) and presence of territorial closeness of industrial enterprises - settlement 1, the second district - with only natural radioactive background and territorial closeness of industrial enterprises - settlement 2, and the third district (according to the environmental well-being assessment one of the most environmentally safe areas - settlement 3). When selecting residential settlements for the study, we relied on the statistical comparability of natural and climatic factors and the population structure in the studied settlements, which could affect the value of the parameters under study. The number of residents in these settlements is presented in Table 1.

Table 1. Population dynamics in the sites analyzed

Site/year	Number of residents (abs.)		
	2016	2017	2018
Site 1	7157	7135	7114
Site 2	7987	7988	8012
Site 3	16906	16788	16567

The health status of the population of these settlements was studied based on the analysis of data from the accounting Form № 12 (departmental form of state statistical observation of the Ministry of Health of the Russian Federation on Form 12 "Information on the number of diseases registered in patients residing in the service area of a medical organization" for the Moscow region, for 2016-2018), obtained by excerpting. All residents permanently residing in the area were included in the study. The diagnosis was made on the basis of classification proposed in ICD-10. The dynamics of pathology prevalence over the period from 2016 to 2018 were assessed.0 The prevalence of somatic pathology among the entire population of the settlement as a whole was evaluated. Age periodization adopted by WHO among adults and children population was not considered due to the fact that the studied factors equally affected the entire population, in this regard, the health status of the population as a whole

was assessed. This study did not aim to compare the intensity of exposure to different age groups [6,7,8,9].

The questionnaire "Do you have any problems with breathing?" was used to detect latent pulmonary pathology. Interpretation of the results: if an interviewee has a total of 18 points or less, the probability of COPD in the form of chronic bronchitis or pulmonary emphysema (or both) is high.

The air condition in the residential area was assessed on the basis of reports on maximum permissible concentrations of substances (MPC) in the air. MPC levels were determined by levels approved by Resolution of the Chief State Sanitary Doctor of the Russian Federation On Approval of Hygienic Standards GN 2.1.6.3492-17 "Maximum allowable concentrations (MPC) of pollutants in the air of urban and rural settlements" from December 22, 2017 N 165 with amendments as of May 31, 2018, in force for the study period.

Radioactive contamination at all sites was measured and results were interpreted in accordance with the following regulatory documents:

1. SanPiN 2.6.1.2523-09 'Radiation safety standards (NRB-99/2009).'
2. SP 2.6.1.2612-10 'Basic sanitary rules for radiation safety (OSPORB -99/2010).'
3. SanPiN 2.6.1.2800 'Requirements for radiation safety in case the population is exposed to natural ionizing radiation.'

Measurements were performed according to the methods described in the regulatory document MU 2.6.1.2398-08 'Radiation control and sanitary-epidemiological assessment of land plots intended for the construction of houses, buildings, and structures for public and industrial purposes to ensure radiation safety.'

Information on measuring instruments is shown in Table 2.

Table 2. Measuring instruments used to assess radioactive contamination

Instrument	Serial number	Verification certificate	Measuring range	Measurement error
Dosimeter "DKS AT-1123" (Russia)	52711	No. 897 dated 11.02.2020	Between 50 nSv/h to 10 Nsv/h	≤ ± 15%

Statistical results were considered reliable at $p<0.05$. Dependence between the signs was assessed using the paired correlation coefficient (r), its error (mr), and the significance level of differences. Dependence was considered strong if $r> 0.7$, and average if the modulus of the pair correlation value lay within 0.3-0.7. If a correlation value less than 0.3 was found, it was considered to be weak. Calculations were performed in Microsoft Excel 2007 spreadsheets and with the help of the licensed program Statistica 6.1 for Windows.

4. RESULTS

Analysis of the environmental situation of the main area and comparison areas also showed that the most polluted environment was the air environment, in connection with which we evaluated the number of nosological forms, whose relationship with environmental factors has now been established by numerous studies (Table 3).

Table 3. Average content of chemical pollutants in the air of residential areas of comparison settlements (compared with MPC (%)

No. of the point	Chemical poppution	Allowed concentration in the air according to regulations (mg/m^3)	Settlement 1: actual concentration in the air (mg/m^3)	Settlement 2: actual concentration in the air (mg/m3)1	Settlement 3: actual concentration in the air (mg/m^3)	Hazard classification according to regulations
1	Hexavalent chromium (converted to	0,0015	100	100	76	1

	chromium trioxide) Vanadium (V) oxide Beryllium and its compounds in beryllium equivalent Cobalt	0,002 0,00001 0,001	98 102 98	99 100 97	62 75 63	
2	Bromine Chlorine Carbon disulfide Manganese and its compounds (in terms of manganese dioxide) Nickel oxide (in terms of nickel)	0,040 0,030 0,005 0,001 0,001	104 103 114 100 100	105 99 112 98 101	57 62 76 54 51	2
3	Nitrogen oxide Sulfur dioxide anhydrite (sulfur dioxide)	0,06 0,05	94 105	98 100	77 80	3
4	Carbon oxide	3	112	112	84	4
5	Action summation coefficient		1,03	1,02	0,68	

When several substances with a summation effect are present in the ambient air together, the sum of their concentrations should not exceed one when calculating by the formula:

$$\sum\left(\frac{p1}{MPC1}+\frac{p2}{MPC2}+\frac{p3}{MPC3}+\cdots\frac{p}{MPC}\right)/n \leq 1,$$

where p1, p2, p3....p - actual concentrations of substances in the atmospheric air; MPC1, MPC2, MPC3 ... MPC - maximum permissible concentrations of the same substances, n - number of analyzed substances.

In the case of settlements 1 and 2 the value of the action summation factor is 1.03 and 1.02, respectively. It means that during the long-term stay in the territory of their registration people can form the prerequisites for formation of somatic pathology associated with the mechanisms of impact of these compounds on human physiology, regardless of the fact that their concentrations in the air are practically close to the values of MPC.

Analysis of radiological situation showed that in settlement 1 the level of gamma-radiation was at the upper limit of the norm (did not exceed 0,28-0,30 μSv/h), and in compared settlements did not differ from background values for the studied region (Table 4).

Table 4. Measurement results of the ambient dose equivalent rate of gamma radiation at the points with the maximum readings of the search instrument

No. of the point	Place of measurement	H, μSv/h	Δ, μSv/h	Note

On the territory of the settlement				
1	Site 1	0,30	±0,02	Upper limit of normal
2	Site 2	0,10	±0,02	Normal background
3	Site 3	0,07	±0,004	Normal background

The study of the nature of somatic pathology showed that in settlements 1 and 2 the most frequent pathology is bronchopulmonary pathology. The structure of bronchopulmonary pathology in the studied settlements is presented in Tables 5.1, 5.2.

Table 5.1. Characteristics of the prevalence of upper and lower respiratory tract diseases in the population (Site 1, Site 2)

Parameter	Site 1		Site 2		
	Abs. (cases)	Prevalence among the adult population, %	Abs. (cases)	Prevalence among the adult population, %	Δ with Iudino parameters, %
2016					
J30	1302	18.2	1296	16.2	-2.0
J30.1	1276	17.8	1231	15.4	-2.4
L50	154	2.2	104	1.3	-0.9
L27.2	134	1.87	112	1.4	-0.47
T78.1	138	1.9	101	1.3	-0.5
T 88.7	459	6.4	434	5.4	-1.0
2017					
J30	1305	18.3	1299	16.3	-2.0
J30.1	1279	17.9	1239	15.5	-2.4
L50	154	2.2	109	1.4	-0.8
L27.2	135	1.9	118	1.5	-0.4
T78.1	142	2.0	115	1.4	-0.6
T 88.7	458	6.4	434	5.4	-1.0
2018					
J30	1306	18.4	1332	16.6	-1.8
J30.1	1280	18.0	1249	15.6	-2.4
L50	155	2.2	109	1.4	-0.8
L27.2	137	1.9	119	1.5	-0.4
T78.1	148	2.1	117	1.5	-0.6
T 88.7	461	6.5	438	5.6	-0.9

Note: data is adjusted to population dynamics

Table 5.2. Characteristics of the prevalence of upper and lower respiratory tract disease in the population (Site 3)

Parameter	Site 3		
	Abs. (cases)	Prevalence among the adult population, %	Δ with Iudino parameters, %
2016			
J30	946	5.6	-12.6
J30.1	532	3.1	-14.7
L50	68	0.4	-1.8
L27.2	105	0.6	-1.27
T78.1	96	0.6	-1.3
T 88.7	98	0.6	-5.8
2017			
J30	944	5.6	-12.7
J30.1	523	3.1	-14.8
L50	60	0.4	-1.8
L27.2	100	0.6	-1.3
T78.1	96	0.6	-1.4
T 88.7	95	0.6	-5.8
2018			
J30	930	5.6	-12.8

J30.1	511	3.1	-14.9
L50	49	0.3	-1.9
L27.2	89	0.5	-1.4
T78.1	91	0.5	-1.6
T 88.7	92	0.6	-5.9

Note: data is adjusted to population dynamics

However, as the first international epidemiological study of the spread of chronic respiratory diseases in Russia has shown, the official statistics do not reflect the true picture. The study was conducted by the Global Alliance for Chronic Respiratory Diseases (GARD) under the guidance of the Research Institute of Pulmonology on the initiative of WHO. Thus, for example, according to the official data only 1% of the Russians were diagnosed with COPD, while in the course of the international epidemiological study more than 15% of the Russians included in the examination had COPD symptoms and the experts consider that the real sickness rate is even higher.

In order to increase the objectivity of the data on the prevalence of bronchopulmonary pathology in the study areas, we offered a random sampling of 300 people from each settlement to answer the questionnaire "Do you have problems with breathing?", which was used in the above-mentioned study. In order to objectify the picture, we tried to include in the survey statistically comparable contingents that did not have, according to their medical records, pulmonary pathology. Taking into account the fact that according to the WHO classification periodization of ages covers rather wide time periods, we divided all periods by 10 years (Table 6).

Table 6. Characteristics of people who took part in the survey

Age/sex	18-29	30-39	40-49	50-59	60-69	70-79	Total, %
Site 1							
male	29	27	27	26	25	24	53
female	21	23	23	24	25	26	47
Total	50	50	50	50	50	50	300
Site 2							
male	28	28	27	28	25	23	53
female	22	22	23	22	25	27	47
Total	50	50	50	50	50	50	300
Site 3							
male	30	27	29	27	24	26	55
female	20	23	21	23	26	24	45
Total	50	50	50	50	50	50	300

When processing the results of the questionnaire, in accordance with the requirements of the questionnaire, it was considered that the interviewee had 18 points or less, the probability of developing COPD in the form of chronic bronchitis or pulmonary emphysema (or both) was high. The results obtained during the study are shown in the figure below (Figure 1).

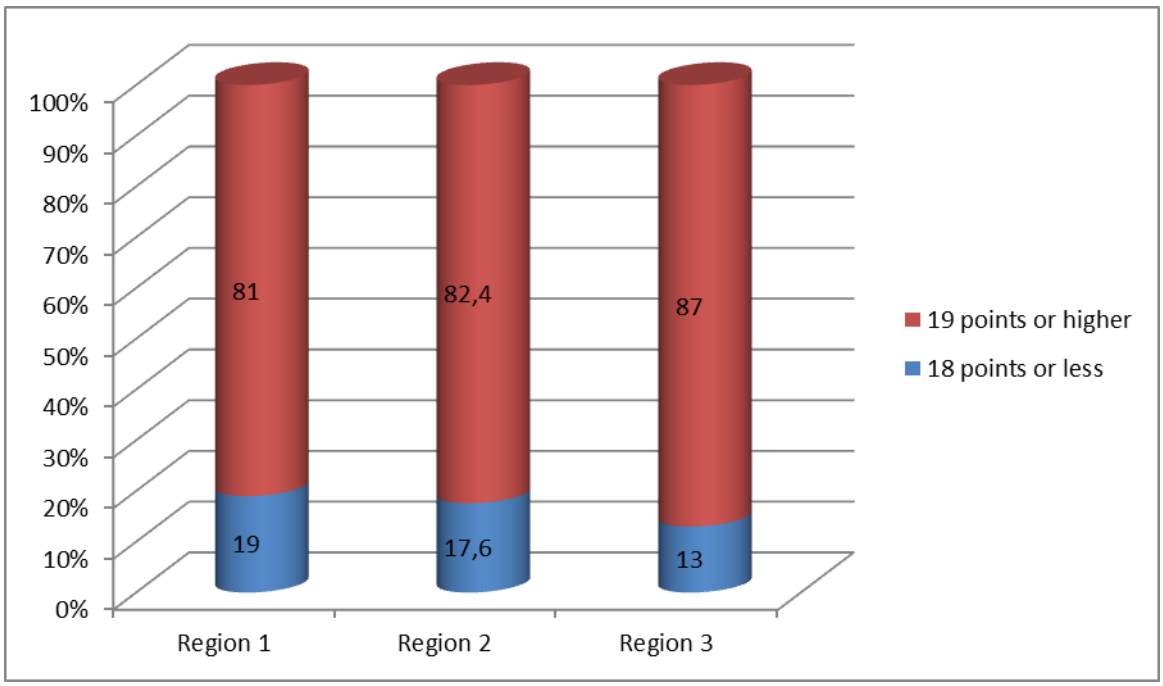

Figure 1. Latent bronchopulmonary pathology identified in the questionnaire

As can be seen from the presented diagram, the greatest difference in the amount of latent pathology is between Settlement 3, where environmental factors are most favorable, and Settlement 1 (by +42.9 %), where there is pronounced toxic-chemical and radiation pollution.

In order to find out whether there is a connection between the qualitative composition of the air/soil of the zone of residential development within the radius of the impact of RAW by the leading environmental factors, including sensitizing factors, and various nosological forms of respiratory disease, we conducted a correlation analysis with calculation of the values of pair linear correlation and the square of the correlation relation. The most significant indicators are presented in Table 7.

Table 7. Chemical pollutants that demonstrated significant squared correlation coefficients (n2xy) for respiratory pathology among the population and levels of pollutants in the environment (soil, air)

No.	Chemical pollutant	Hazard class	Effect on the organism (distribution by type at inhaling) *	η2xy
1	Caesium	Group 2	R	0.91
	Strontium	Group 2	R	0.91
	Polonium	Group 2	I/R	0.91
2	Chromium	Class 1	S	0.78
	Chlorine	Class 2	R	0.87
	Sulfur (carbon disulfide)	Class 2	I	0.78
	Manganese	Class 2	I	0.78
	Cobalt	Class 2	D	0.91
3	Nickel	Class 1	I	0.68
4	Bromine	Class 1	R	0.78
	Beryllium	Class 1	S	0.78
	Vanadium	Class 2	I/R	0.78
5	Manganese dioxide	Class 2	R	0.68
- type 'S'–chemical pollutants slowly soluble in human lungs; type 'I'–chemical pollutants soluble at an intermediate rate; type 'R'–rapidly soluble chemical pollutants				

The second group of disorders closely related to environmental pollution is allergic diseases. We observed a significant difference between sites in the prevalence of allergic rhinitis (J30), pollinosis (J30.1), urticaria (L50), unspecified adverse effect of drug or medicament (T88.7), dermatitis due to ingested food (L27.2), and other adverse food reactions (T78.1). The prevalence of allergic diseases is shown in Table 6.

Figure 2 demonstrates relative prevalence of allergic diseases in sites 2 and 3 compared to site 1 (its prevalence is considered as 100%). It allows us to evaluate the effect of increased levels of radiation and chemical pollution on human health.

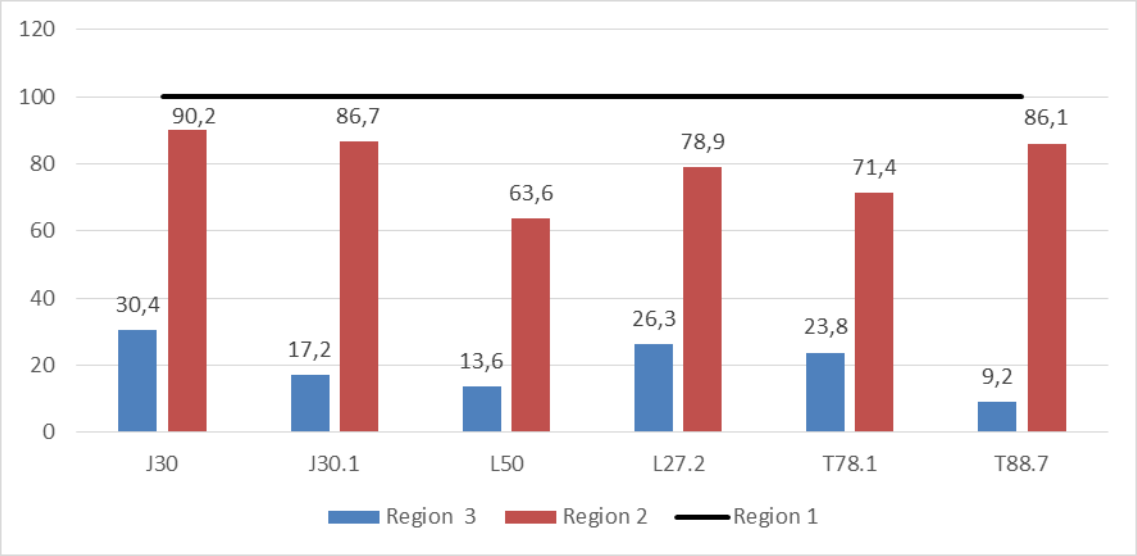

Figure 2. Ratio of allergic pathology among residents of the studied residential settlements (as of 2018)

Analysis of the mortality structure from malignant neoplasms (MN) in the included settlements showed some differences from the general statistical pattern (Figure 4). Thus, in Settlement 1 there was an increase in the number of persons with cancer of the respiratory organs, as well as organic lesions of lymphatic and hematopoietic tissue compared to the average statistical data for the Moscow region by 7.0% and 1.5% respectively, the number of deaths from colorectal cancer and stomach cancer was also increased by 2.9%.

In Settlement 2, the structure of mortality from cancers was close to that of the study region, except for mortality from respiratory cancers (Figure 3).

At the same time, it was noted that MCH mortality in Settlement 1 increased by 1.9% in 2018 compared to 2016, in Settlement 2 by 1.6%, and in Settlement 3 increased by only 0.2%.

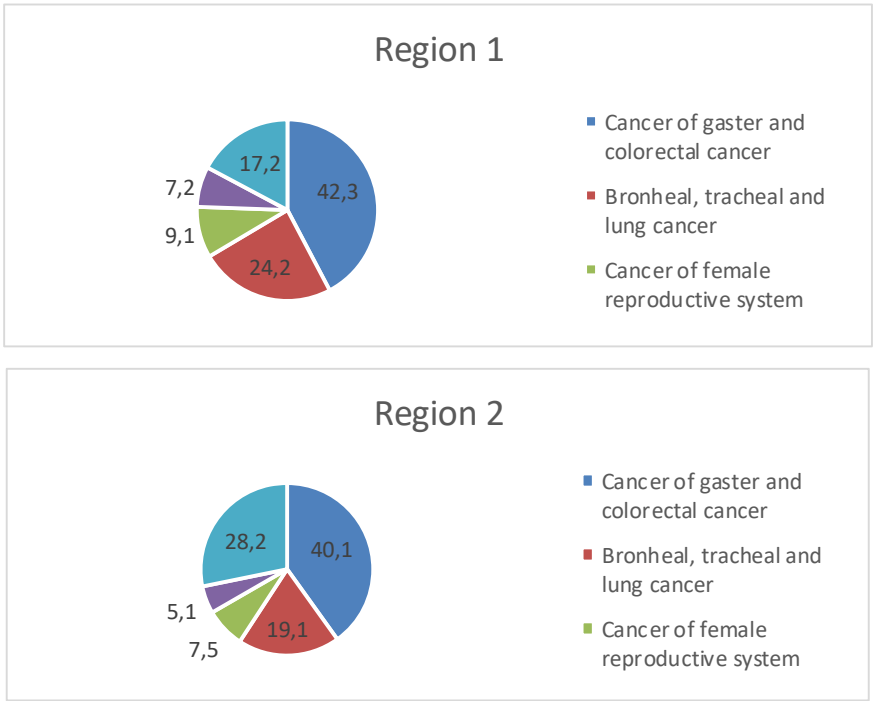

Figure 4. Structure of mortality from STDs from 2016 to 2018:
a - Settlement 1, b - Settlement 2

5. DISCUSSION OF THE OBTAINED RESULTS

As can be seen from the data obtained, the combined effect of low doses of radiation and chemical pollutants in doses close to the maximum allowable, can have a negative impact on the somatic health of the population.

What is this related to? Most studies to date have been based on a study of the effects of high doses of radiation on the human body, due to the need to consider the presence of nuclear weapons in the world, and the high likelihood of technogenic accidents. Until recently, when mentioning low doses of radiation, only its stimulating effect - hormesis - was considered. However, recent studies have shown that low-dose irradiation also induces numerous structural modifications in cells, resulting in changes in their functional activity, and thus may lead to the development of pathology. And small doses of radiation can kill the cell just as well as large ones, if the question is not about a single exposure, but a long-term exposure. What is the reason? Weak irradiation acts indirectly, triggering the mechanisms of genomic regulation. It can provoke apoptosis - programmed cell death. High doses of radiation simply cause death by directly damaging the DNA molecule, while low doses do so through gene expression and the appearance of proteins that will trigger the mechanism of programmed cell death.

The data obtained do not contradict the fundamental science, since any living organism can give different responses and they will not necessarily obey the linear "dose-effect" relation. This is due to the fact that a reparation (repair) reaction does not always occur to small doses. This is due to the fact that human evolution took place in conditions of natural background radiation, which resulted in the body not recognizing low doses of radiation as a hazard, not mobilizing, not trying to adapt, "not defending".

The second important factor of negative impact on the human body is chemical factors. This is due to the development of both industrial and domestic and agricultural pollutants. The simultaneous impact of factors of chemical and radiological nature, even in low concentrations, as it was in settlement 1, or only chemical pollutants (settlement 2), leads to a significant increase in somatic diseases among the population. At the same time, the important fact remains that regardless of the nature of the factors acting on the person, the synergism is maximized when they are affected simultaneously. At the same time, experimental studies have shown that a decrease in the radiation dose (low doses) requires a proportional decrease in the concentration of the other agents in order to maintain maximum synergistic effect. This is precisely the condition that arises when low doses of radiation and concentrations of chemical agents close to the MAC are combined. The result is a decrease in the health indicators of the population even if the sanitary-hygienic standards are observed.

6. CONCLUSION

1. At summation even small doses of radiation and chemical pollution of environment (not exceeding maximum permissible norms) their resultant negative influence on human health increases.

2. The synergistic effect of low doses of radiation and chemical contamination of the environment (not exceeding maximum permissible norms) can lead to the development of excessive risk of somatic diseases and MND, which opens new directions for preventive and health-improving work among the population.

ACKNOWLEDGEMENTS

The research was supported by the Moscow Department of Rospotrebnadzor and Medical University REAVIZ, Moscow, Russia.

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