

INFLUENCE OF MILITARY ACTIONS ON THE RADIOECOLOGICAL SITUATION AND IMMUNE STATUS OF THE RESIDENTS OF THE DONETSK REGION DURING THE WAR OF UKRAINE WITH THE RF

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Abstract: The purpose of the work was to analyze the ecological-radiation situation and its impact on the state of the immune system in the residents of the Donetsk region during the war of Ukraine with the RF in 2014–2025. It was established that since 2014, as a result of military actions, the infrastructure of the Donetsk region has been destroyed and the radioecological situation, which before the war was in a state of crisis due to the overindustrialization of the region, has been steadily deteriorating. The destruction of chemical, metallurgical, mining, and thermal power industry facilities leads to pollution and the spread of xenobiotics and radionuclides in the environment. The latter come from both destroyed industrial facilities and flooded fields and agricultural lands located in places of natural radioactive emanations that are part of the geological platform of Donbas. In the dynamics of observation from 2014 to 2025, residents of the Donetsk region have been experiencing negative changes in their psycho-emotional state and psychoneuroimmune regulation, which are constantly deepening. Changes in nonspecific resistance cells indicate its tension at the level of adaptation disruption, and the state of the immune system indicates a tendency to the formation of immune deficiency and a decrease in the control of genetic homeostasis.

Keywords: war, Ukraine, ecological and radiation situation, immune system.

1. Introduction

The ecological and radiation situation in the Donetsk region is associated with the peculiarities of the geological platform of Donbas and the impact of pollution caused by the mining, chemical, and metallurgical industries. The geological platform of the Donetsk region is saturated with radioactive emanations, which causes a constant effect on the biota of low-intensity ionizing radiation due to the presence of isotopes ²²⁶Ra, ²³²Th, and ⁴⁰K [1, 2]. Soil, air, and water contamination with radioactive elements constantly occurred during the extraction of minerals and agricultural work. Waste dumps located near the residential area, which were formed as a result of coal mining by mines, and the operation of thermal power plants, cause the appearance of radioactive dust and ionizing γ -radiation, which further complicates the radiation situation in the region [3]. In the Donetsk region, 13,000 radioactive spots were formed as a result of radioactive fallout after the Chernobyl accident, with radiation sometimes up to 1 km²rad. It was established that raw materials and food products were contaminated with radionuclides of Chernobyl origin [4]. In fact, before the military operations, the Donetsk region was constantly under the influence of the combined action of technogenic and natural radiation and a complex of harmful factors: chemical, metallurgical, mining, and mining processing industries [1, 3].

The purpose of the work was to analyze the ecological radiation crisis and its impact on the state of the immune system in the inhabitants of the region against the background of the ecological and radiation situation in the Donetsk region in the pre-war period and in 2014–2025 during the Russian aggression.

2. Materials and methods

The study used cognitive, bibliosemantic methods, psycho-emotional state research, and immunological studies. The psycho-emotional state was determined in 671 conditionally healthy individuals, aged 18–65 years, from the contingent of displaced persons from areas not controlled by Ukraine (UZOP) and residents permanently residing in the territory controlled by Ukraine (UZOR) in the period 2017–2019 and 2022–2025. The presence and degree of anxiety (An), depression (Dep), post-traumatic stress (PTS), and functional state (FS) were determined in the studied individuals. The questionnaire and assessment of the obtained results regarding the psycho-emotional state were carried out on the basis of a test developed by the Kyiv-Mohyla Academy based on the inclusion of anxiety and depression indicators (HADS) according to the Hospital Scale in its own modification [5]. The state of the immune system was determined using level I immunological methods. Additionally, cytomorphological methods were used to study the state of neutrophils and lymphocytes [6, 7]. The following indicators of nonspecific resistance were investigated, such as the content of rod-shaped (Rsh) and segmented (SN) neutrophils (N), eosinophils (E), and monocytes (M). To assess the state of the immune system (IS), the content of lymphocytes (L) and natural killer cells (NK) was determined. We studied the frequency of detection of cytomorphologically altered neutrophils in their total pool: disintegrated cells (CR), the number of cells with ruptures of the cytoplasmic membrane and swelling of the nucleus (SN), fragmented (FN), hypo (HpsN) and hyper segmented (HrsN) nuclei, cells with villous chromatin (Vchr), and cells with toxigenic cytoplasmic granularity (TCG). When studying cytomorphological changes in lymphocytes, the number of Botkin-Gumprecht disintegrations, the content of aberrant lymphocytes (ABL), spindle-shaped lymphocytes (SpshL), lymphocytes in the form of a mirror with a handle (MHL), young forms of lymphocytes (YnFL), elongated (EngL), cells with a bean-shaped nucleus (BShN), large granular lymphocytes (LGL), plasma cells (PL), broad-plasma lymphocytes (SPL), and scalloped lymphocytes (FL). And also degraded and pathological lymphocytes: cells with a dry leaf nucleus (SL), villous lymphocytes (VOL), and Ridder lymphocytes (RL) were determined. When analyzing cytomorphological changes in neutrophils and lymphocytes, their number per 100 cells of a particular pool was taken into account. The results obtained were expressed in percentages (%). Data analysis and statistical processing were performed in the statistical program Statistica 12.0 (3BA94C4ED07A). When comparing mean values in normally distributed populations, the Student's t-test was calculated. Differences between the control and experimental groups were considered statistically significant at $p < 0.05$.

3. Results and conclusion

Since 2014, the infrastructure of Donbas has been destroyed as a result of military operations: chemical and metallurgical industry facilities have been damaged, forests and gardens are burning, agricultural lands are being destroyed, and rivers, natural and artificial reservoirs, and the Sea of Azov are being polluted [8, 9]. Flooding of mines and adjacent territories led to contamination of groundwater and surface waters with iron, chlorides, sulfates, other mineral salts, and heavy metals, as well as radionuclides. The operation of water treatment and drainage facilities

has been disrupted and stopped, and municipal sewage and water supply networks have been damaged [9–11]. Explosions and shelling in areas of natural radiation led to the release of radionuclides into the soil, water, and air. Since 2014, an increase in the level of γ -radiation has been recorded. In parallel, heavy metal pollution is increasing. Only during 2017–2018, an excess of the content of such elements as mercury, vanadium, cadmium, and non-radioactive strontium by 1.1–1.3 times was detected in the region. In most cases, the content of heavy metals in soil samples taken in places of military operations exceeds the background value by 1.2–12 times. Residents of the Donetsk region, as well as residents of other territories contaminated with radionuclides, immunosuppression, and an increased frequency of endocrine pathology, were observed [12–15]. It has been established that the population of Ukraine, especially the residents of the Donetsk region, both displaced persons from uncontrolled territories and residents living in territories controlled by Ukraine, have signs of explosive trauma [16]. Existence in conditions of war and resettlement, sometimes multiple, from areas of hostilities, as well as a large flow of information about destruction and deaths, causes constant fear for one's life and future. Being in conditions of constant stress overloads the psyche and nervous system, causes emotional fatigue, and is reflected in the deepening of disorders of psychoneuroimmune regulation [17].

In the conditionally healthy population of the Donetsk region, negative changes in psycho-emotional state are observed, which are constantly deepening from 2014 to 2025.

Figure 1 shows data on negative changes in indicators of anxiety, depression, post-traumatic stress, and functional ability among the contingent of displaced persons and residents, compared with the norm. As can be seen from the data presented, in the period 2017–2019, the indicators of the psycho-emotional state on average did not differ from the norm, with the exception of the post-traumatic state, which was higher, but not significantly, in the persons of the contingent of the UZOP. In the period 2024–2025, such indicators as depression, functional state, and especially post-traumatic stress significantly increase, compared with the norm and the previous period of the study.

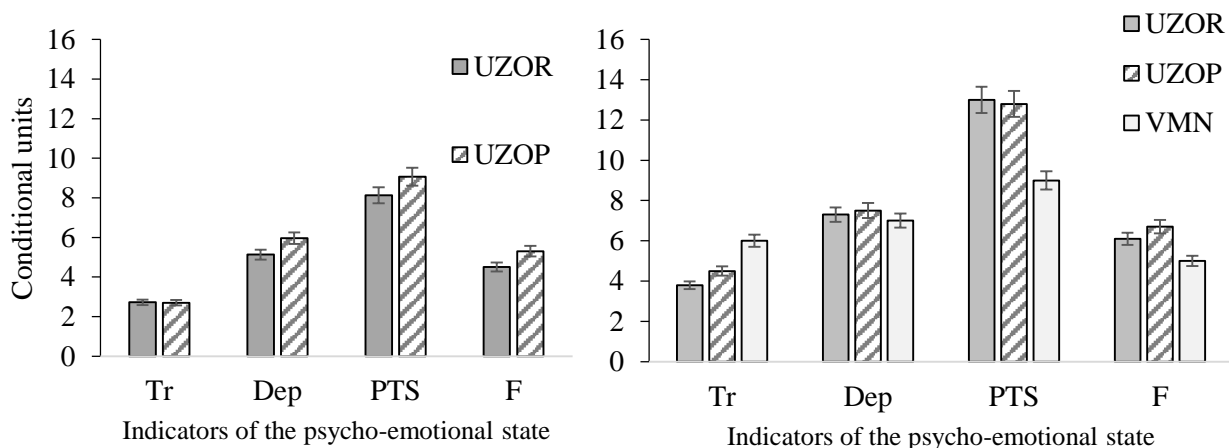


Fig. 1. Indicators of the psycho-emotional state of conditionally healthy residents (UZOR) and displaced persons (UZOP) of the Donetsk region in comparison with the upper limit of the norm: anxiety (Tr), depression (Dep), post-traumatic stress (PTS), functional state (F) VMN- upper limits of the norm for the period 2017–2019 yy. (A) and 2024–2025 yy. (B)

Data on the dynamics of the content of leukocytes and cells that provide nonspecific resistance: neutrophils, eosinophils, and monocytes and the functioning of the immune system in

the peripheral blood of conditionally healthy residents of the Donetsk region during the observation period (1992–2024) are shown in Figures 2–4. The results of the study showed that the reduced levels of leukocytes and leukogram elements in residents of the Donetsk region who did not participate in the liquidation of the Chernobyl accident and did not work in the mines from 1992 to 2012 gradually recovered from the period of the Chernobyl accident (1986) to the regional norm [10, 13, 14].

A constant content of leukocytes and leukogram elements, with the exception of monocytes, the content of which gradually increased within normal limits (0–0.6 G in 1), was recorded for 10 years, including 2012. After the beginning of the Russian aggression in 2014, changes were detected in the content of leukocytes and leukogram elements when compared with the indicators of the pre-war period and in the dynamics of military operations from 2017 to 2024. Thus, a tendency to increase the content of leukocytes to the upper limit of the norm was established. Changes in the content of leukocytes occurred mainly due to cells that provide nonspecific resistance: neutrophils, especially rod-shaped ones, eosinophils, and monocytes. The content of the latter increased significantly ($P < 0.05$) from 2012 to 2017 and had a tendency to increase during the active phase of the war with the Russian Federation in 2024. Unlike cells that provide nonspecific resistance, the content of L practically did not change in the dynamics of the study from 1992 to 2024 and corresponded to the average norm (AN). At the same time, the content of natural killer cells (NK) was within the regional norm from 1992 to 2017, and in 2024 it significantly decreased ($P < 0.05$).

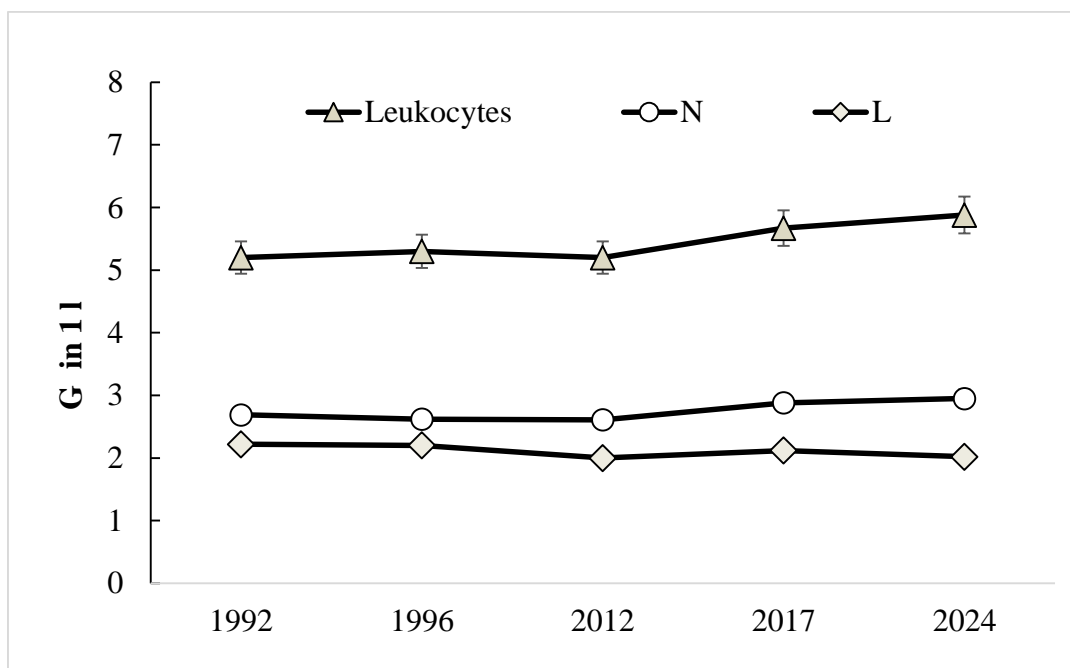


Fig. 2. Dynamics of leukocytes, neutrophils (N), and lymphocytes (L) content in residents of Donetsk region 3 from 1992 to 2024.

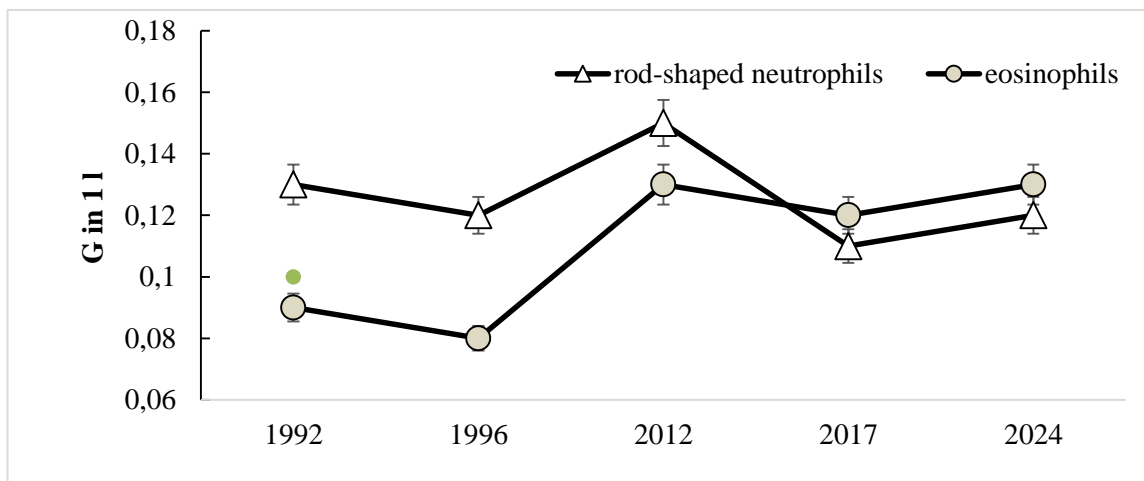


Fig. 3. Dynamics of the content of rod-shaped neutrophils and eosinophils in residents of the Donetsk region 3 from 1992 to 2024.

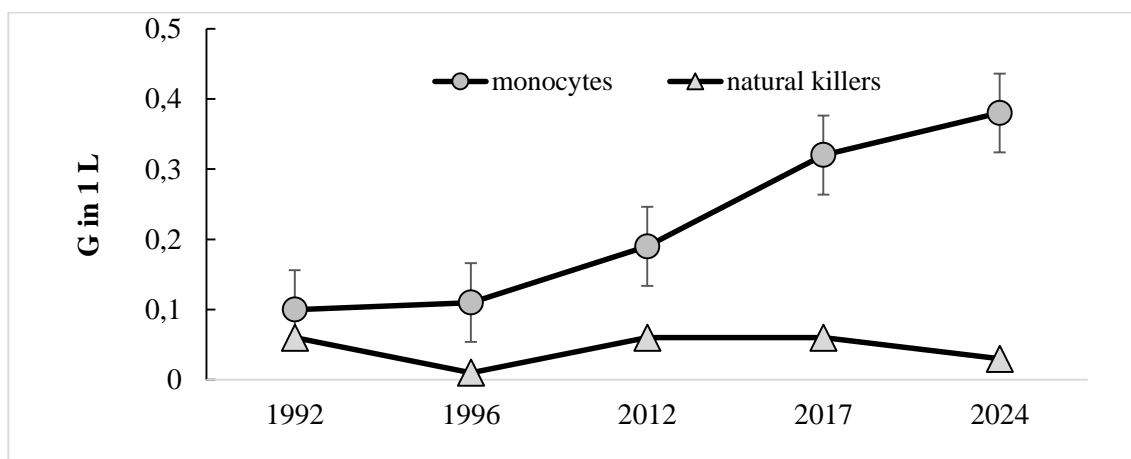


Fig. 4. Dynamics of the content of monocytes and natural killers in residents of the Donetsk region 3 from 1992 to 2024.

Figure 5 shows data on cytomorphological changes in cells that provide nonspecific resistance in dynamics from 1992 to 2022.

Cytomorphological changes, such as cell disintegration, nuclear swelling, villous nuclear chromatin, toxigenic granularity of neutrophil cytoplasm, nuclear fragmentation, and nuclear hypersegmentation, were recorded in 100% of the examined contingent at all reference points of the study. But their content in the neutrophil pool differed.

As can be seen from the data presented in Figure 5, the content of SN cells, the appearance of which indicates an increase in lipid peroxidation processes, doubled from 2017 to 2024 ($P < 0.05$). The average content of Vchr cells, the presence of which in the neutrophil pool documents the presence of initiated and incomplete cell division, more than doubled during the study period from 2017 to 2024 ($P < 0.05$). The presence of Vchr cells in the neutrophil pool also indicated a decrease in the function of lymphocytes in removing such cells, i.e., a partial loss of the function of controlling genetic homeostasis by lymphocytes. The content of young hypo segmented cells in the neutrophil pool practically did not change from 1992 to 2012 and had a

slight tendency to increase during the ATO/JCO period and significantly increased before the start of the war in 2024 ($P < 0.05$). The content of old hypersegmented cells (HrSN) in the neutrophil pool had no significant differences from 1992 to 2012 and increased more than 10 times in 2024 ($P < 0.05$). The content of TCG cells in the neutrophil pool, the content of which indicates the presence of endogenous intoxication, increased significantly in 2017 compared to 2012, and in 2024 it was three times higher than the indicators of 2017 and the norm ($P < 0.05$). The content of degraded cells with fragmented nuclei (FN) was stable from 1992 to 2012 and more than doubled since 2017 ($P < 0.05$). The frequency of cell decays (CR) tended to increase in 2017 compared to the pre-war period and significantly increased by almost 2.5 times ($P < 0.05$) in 2024 compared to the indicators of 2012. That is, on the one hand, since 2017, the processes of aging and cell decay have significantly accelerated, and on the other hand, the myelocytic germ of hematopoiesis has been activated, which is reflected in the increased release of young neutrophils with hyposegmented nuclei into the peripheral blood. These processes occur against the background of significantly increased toxic-inflammatory processes.

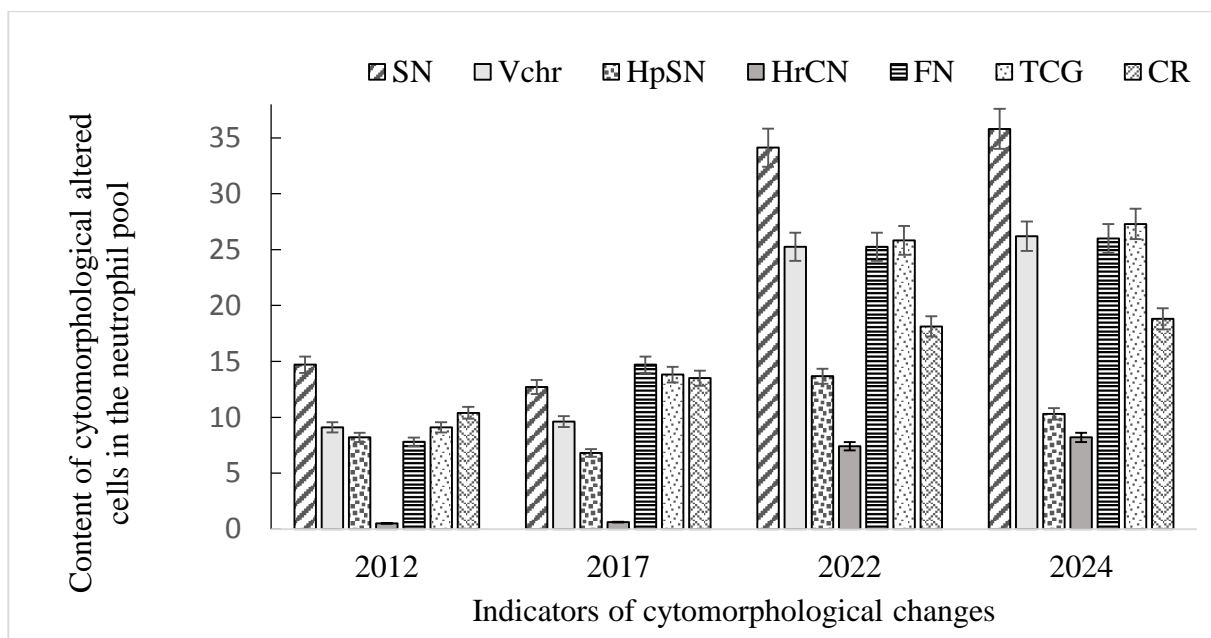


Fig. 5. Dynamics of the content of cytomorphological altered cells in the neutrophil pool of cells with nuclear swelling (SN), chromatin villainess (Vchr), fragmented (FN), hypo (HpSN), and hypersegmented (HrSN) nuclei, with toxigenic cytoplasmic granularity (TCG) and cells in a state of disintegration (CR) for the period 2012–2024.

Figure 6 shows data on cytomorphological changes in the lymphocyte pool. As can be seen from the data presented, the content of immature T-lymphocyte populations in the pool: SpSpL and MHL was stable and corresponded to the norm for the region from 1992 to 2017, and in the dynamics of the study from 2017 to 2024, it significantly increased by more than 6 and 8 times, respectively. The content of young lymphocytes (YnFL), which was stable in 1992–2017, increased threefold in 2024 and significantly exceeded the previous indicators and the norm ($P < 0.05$). At the same time, the content of natural killer precursors – BshN - gradually increased within the normal range from 1992 to 2017 inclusive, and in 2024 it significantly decreased ($P < 0.05$), compared with the indicators of 1992–2012 and the norm. The constant content of natural killer analogues – LGL - had a tendency to decrease in 2024, compared with the results of

previous studies, but remained within the normal range. In the B-lymphocyte population in 2024, a tendency was recorded to increase the pools of plasma cells PL and broad plasma cells SPL, the indicators of which remained within the normal range, and a probable increase in the pool of scalloped lymphocytes FL ($P < 0.05$), compared with the norm and data from previous studies. The content of pathological lymphocytes with a deformed membrane in the form of a dry sheet SL and Ridder lymphocytes RL fluctuated during 1992–2017 from low to high values within the normal range, and in 2024 it significantly and reliably increased ($P < 0.05$), compared with the data of previous studies, and went beyond the upper limits of the norm. The results obtained showed that 10 years after the beginning of the Russian invasion of Ukraine, in the lymphocyte pool of conditionally healthy individuals of the Donetsk region, the content of immature low-functioning T-lymphocytes significantly increases, the content of NK and their precursors decreases, and the content of B-lymphocytes also increases, creating an imbalance in the populations of T- and B-lymphocytes and disrupting the homeokinesis of the organism. This is manifested by a probable and significant increase in the lymphocyte pool of pathological cells in the form of SL and RL and indicates not only stress but also a violation of adaptation at the level of the T-link of the IS. At this time, the T-link insufficiency is probably still compensated by the B-link of the IS and the tense functioning of the non-specific resistance at the level of the disorder, which was established by us in previous studies. [11, 13, 14].

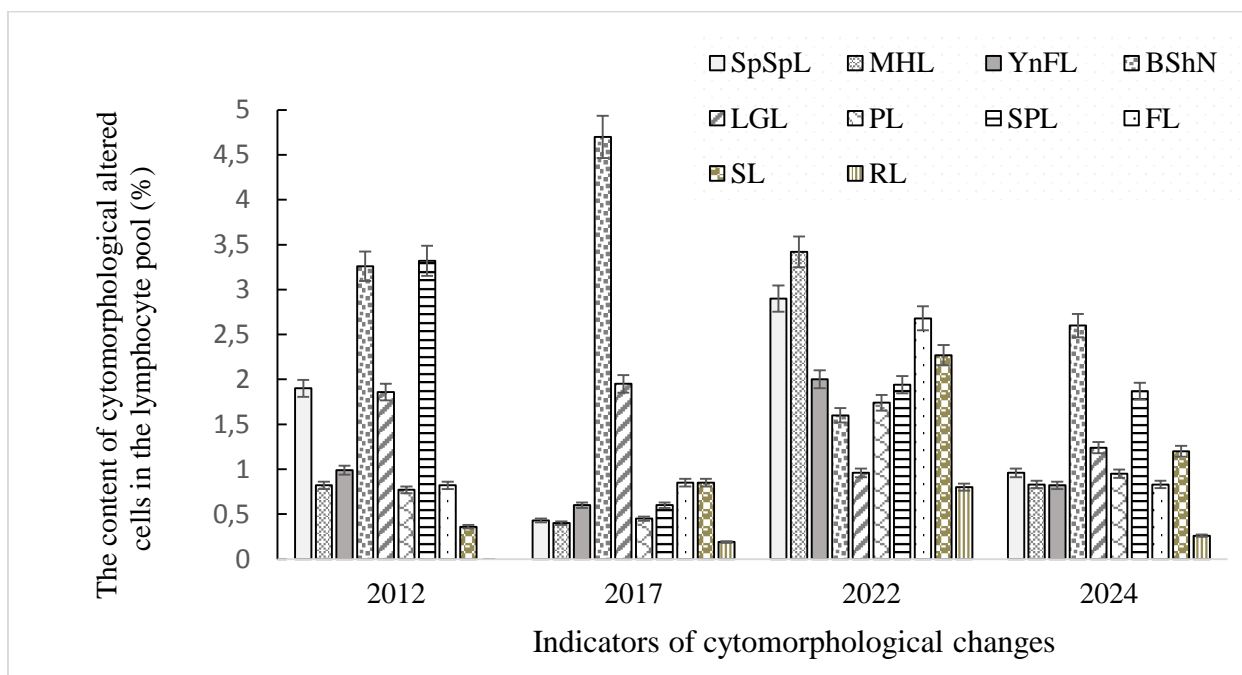


Fig. 6. Dynamics of the content of cytomorphological altered cells in the lymphocyte pool of neutrophils: spindle-shaped lymphocytes (SpSpL), mirror-shaped lymphocytes with a handle (MHL), young forms of lymphocytes (YnFL), cells with a bean-shaped nucleus (BShN), large granular lymphocytes (LGL), plasma cells (PL), broad-plasma lymphocytes (SPL), scalloped lymphocytes (FL), lymphocytes with a dry leaf nucleus (SL), and Ridder lymphocytes (RL) for the period 2012–2024.

Thus, it was established that the residents of the Donetsk region, both displaced persons from territories not controlled by Ukraine and residents, have observed changes in psycho-emotional state and psycho-neuro-immune regulation, which are constantly deepening from 2014 to 2024. Changes in non-specific resistance cells indicate its tension at the level of disruption of

adaptation, and, in the immune system, a tendency towards immune deficiency and a decrease in control of the genetic homeostasis of the organism.

4. Conclusion

The Russian military aggression, which began in 2014, has catastrophic consequences for the economy, natural resources, and ecosystems of the Donetsk region and causes a significant negative impact on the health of the population of the Donetsk region, which is manifested by violations of psycho-neuro-immune regulation, a decrease in the ability to adapt non-specific resistance at the level of disruption, dysregulation, and a decrease in the functioning of the immune system.

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ВЛИЯНИЕ ВОЕННЫХ ДЕЙСТВИЙ НА РАДИОЭКОЛОГИЧЕСКУЮ СИТУАЦИЮ И ИММУНОЛОГИЧЕСКИЙ СТАТУС ЖИТЕЛЕЙ ДОНЕЦКОГО РЕГИОНА ВО ВРЕМЯ ВОЙНЫ УКРАИНЫ С РФ

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Резюме: Целью работы был анализ экологорадиационной ситуации и ее влияние на состояние системы иммунитета у населения Донецкого региона в течение войны Украины и РФ с 2014 по 2025 годы. Установлено, что с 2014 года, в результате военных действий, разрушается инфраструктура Донбасса и стремительно ухудшается радиоэкологическая ситуация, которая, в результате сверхиндустриализации региона, находилась в кризисном состоянии и до начала войны. Разрушение объектов химической, металлургической горнодобывающей, теплоэнергетической

промышленности приводит к загрязнению и распространению в окружающей среде ксенобиотиков и радионуклидов. Последние поступают, как из разрушенных промышленных объектов, так и из затопленных шахт и сельскохозяйственных угодий, расположенных в местах природных радиоактивных эманаций, входящих в состав геологической платформы Донбасса. В динамике наблюдения с 2014 г. по 2025 г. у жителей Донбасса наблюдаются негативные сдвиги психоэмоционального состояния и психонейроиммунной регуляции, которые постоянно углубляются. Изменения клеток неспецифической резистентности свидетельствуют о ее напряжении на уровне срыва адаптации, а состояние иммунной системы – о тенденции к формированию иммунной недостаточности и снижению контроля генетического гомеостаза.

Ключевые слова: война, Украина, экологорадиационная ситуация, система иммунитета.

UKRAYNA VƏ RUSİYA FEDERASIYASI ARASINDA MÜHARİBƏ ZAMANI DONETSK BÖLGƏSİ SAKİNLƏRİNİN RADİOEKOLOJİ VƏ İMMUNOLOJİ VƏZİYYƏTİNƏ HƏRBİ ƏMƏLİYYATLARIN TƏSİRİ

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Xülasə: Bu tədqiqatın məqsədi 2014-cü ildən 2025-ci ilə qədər Ukrayna ilə Rusiya arasında baş verən müharibə zamanı Donetsk vilayətinin ekoloji və radiasiya vəziyyətini və əhalisinin immun sistemə təsirini təhlil etmək olub. Müəyyən edilmişdir ki, 2014-cü ildən bəri hərbi əməliyyatlar nəticəsində Donbasın infrastrukturunu dağıdıb və radioekoloji vəziyyət sürətlə pisləşib. Regionun həddindən artıq sənayeləşməsi səbəbindən müharibədən əvvəl onsuz da kritik vəziyyətdə olan vəziyyəti daha da gərginləşib. Kimya, metallurjiya, mədən və istilik enerjisi sənayesi obyektlərinin dağıdılması çirklənməyə və ksenobiotiklərin və radionuklidlərin ətraf mühitə yayılmasına səbəb olur. Sonuncular həm dağıdılmış sənaye müəssisələrindən, həm də Donbas geoloji platformasının bir hissəsi olan təbii radioaktiv emissiya ərazilərində yerləşən su basmış mədənlərdən və kənd təsərrüfatı torpaqlarından gəlir. 2014-cü ildən 2025-ci ilə qədər müşahidə dinamikasında Donbas sakinlərinin psix-emosional vəziyyətlərində və psixonevroimmun tənzimlənməsində daim dərinləşən mənfi dəyişikliklər yaşadığı müşahidə edilmişdir. Qeyri-spesifik müqavimət hüceyrələrindəki dəyişikliklər onun adaptasiya çatışmazlığı səviyyəsində gərginliyini, immun sisteminin vəziyyəti isə immun çatışmazlığının inkişafına meyilliliyi və genetik homeostazın nəzarətinin azalmasını göstərir.

Açar sözlər: müharibə, Ukrayna, ətraf mühit və radiasiya vəziyyəti, immun sistemi.