REVIEW ARTICLE

Pol J Aviat Med Bioeng Psychol 2022; 28(1): 22-30
DOI: 10.13174/pjambp.28.03.2025.02

CARCINOGENIC FACTORS IN THE MILITARY ENVIRONMENT: THREATS AND CHALLENGES TO THE HEALTH OF SOLDIERS AND MILITARY PERSONNEL

Magdalena ZAWADZKA[1,3], Marcin NOWIK[2], Ewelina EJCHMAN-PAC[3], Paweł SZYMAŃSKI[4,5], Mateusz CURYŁO[6], Justyna MARSZAŁKOWSKA-JAKUBIK[3]

1 Department of Epidemiology and Public Health, Medical University of Łódź, Poland
2 District Sanitary and Epidemiological Station in Biała Podlaska, Poland.
3 Department of Hygiene and Epidemiology, Military Institute of Hygiene and Epidemiology, Warsaw, Poland
4 Department of Radiobiology and Radiation Protection, Military Institute of Hygiene and Epidemiology, Warsaw, Poland
5 Department of Pharmaceutical Chemistry, Drug Analyses and Radiopharmacy, Medical University of Łódź, Poland
6 University of the National Education Commission, Institute of Health Sciences, Kraków, Poland

Source of support: Own sources

Author's address: J. Marszałkowska-Jakubik, Military Institute of Hygiene and Epidemiology, Kozielska 4 Street, 01-163 Warsaw, Poland, email: justyna.jakubik@wihe.pl

Abstract: The military environment involves exposure to numerous carcinogenic factors, including chemical substances, ionizing radiation, and technological processes that generate harmful emissions. Long-term exposure to these factors may lead to the development of cancers and other chronic diseases. The aim of this article is to analyze the risks associated with contact with carcinogenic substances in the military and to present strategies for risk reduction.

Chemical Carcinogenic Factors Soldiers are exposed to hazardous substances found in engine fuels, lubricants, and explosives. Petroleum distillation products, such as benzene, formaldehyde, and polycyclic aromatic hydrocarbons (PAHs), have well-documented carcinogenic effects. Similar risks are associated with exposure to lead and TNT, present in ammunition and explosives.

Physical Carcinogenic Factors Ionizing radiation poses a significant threat to military personnel, especially in medical diagnostics, combat operations, and the use of depleted uranium ammunition. High doses of radiation can cause DNA damage and increase cancer risk.

Carcinogenic Processes Emissions from diesel engines, crystalline dust, and wood dust are additional significant sources of exposure in the military. Elemental soot and toxic

Cite this article: **Zawadzka M, Nowik M, Ejchman-Pac E, Szymański P, Curyło M, Marszałkowska-Jakubik J. Carcinogenic Factors in the Military Environment: Threats and Challenges to the Health of Soldiers and Military Personnel. Pol J Aviat Med Bioeng Psychol 2022; 28(1): 22-30. DOI: 10.13174/pjambp.28.03.2025.02**

Copyright: © Military Institute of Aviation Medicine, 54/56 Krasinskiego St., 01-755 Warsaw, Poland • **License:** CC BY-NC 4.0 • **Indexation:** Ministry of Science and Higher Education (Poland) • **Full-text PDF:** http://www.pjambp.com

chemical compounds present in diesel exhaust fumes can lead to lung and respiratory tract cancers. Wood dust, especially from hardwood species, is recognized as a carcinogenic factor and is present in the military environment during carpentry and construction work.

Reducing exposure to carcinogenic factors in the military requires a comprehensive approach, including the implementation of personal protective measures, monitoring exposure levels, and applying alternative technologies to reduce carcinogenic emissions. Regular screening and workplace condition control also play a crucial role.

Keywords: carcinogenic factors, military, occupational exposure, ionizing radiation, cancer prevention

INTRODUCTION

The military environment involves specific health hazards, including exposure to carcinogenic substances, which pose a significant risk to soldiers, civilian employees, and veterans. These factors, present in materials and technological processes, may lead to the development of cancers and other chronic diseases. Despite advances in research, knowledge about the effects of long-term exposure remains limited. This article analyzes the main sources of these factors, their mechanisms of action, and health implications, as well as presents strategies for risk reduction.

Cancers develop over years, and their growth rate depends on many factors, including exposure to carcinogenic substances. These can lead to DNA mutations, increasing the risk of disease [11,12]. The International Agency for Research on Cancer (IARC) classifies carcinogenic factors into four groups based on their origin, nature, and mode of action as follows:

- Group 1: The substance/factor is carcinogenic to humans.
- Group 2A: The substance/factor is probably carcinogenic to humans.
- Group 2B: The substance/factor may be carcinogenic to humans.
- Group 3: The substance/factor cannot be classified as carcinogenic to humans [10].

The European Union applies a similar classification, distinguishing categories based on evidence concerning humans and animals. According to this regulation, carcinogenic factors are classified into one of two categories:

- Category 1A: has potential carcinogenic effects on humans, with classification based primarily on human data,
- Category 1B: has potential carcinogenic effects on humans, with classification based on studies conducted on animals,
- Category 2: substances suspected of being carcinogenic to humans [19].

The aim of the article is to analyze the risks arising from exposure to carcinogenic substances in the military, their mechanisms of action, and health consequences. It also presents research findings and preventive strategies, taking into account both historical and contemporary data. Based on reports from Military Occupational Medicine Centers (2018–2019), the most common carcinogenic factors in Polish military units were identified, including chemical substances (e.g., benzene, formaldehyde), ionizing radiation, and technological processes associated with the emission of harmful compounds [15].

Understanding their mechanisms of action, the scale of exposure, and the health consequences for soldiers and military personnel is becoming a key public health issue.

CHEMICAL CARCINOGENIC FACTORS

In the modern world, the functioning of armed forces requires the use of advanced technologies and materials, which may pose health risks. Among the many factors adversely affecting soldiers' health, particular attention is given to chemical carcinogenic factors. Soldiers, both on the battlefield and in daily service, are exposed to contact with carcinogenic chemical substances.

Engine Fuels and Other Petroleum Distillation Products

In today's world, fuels are a crucial element of military operations, enabling the armed forces to maintain mobility and operational efficiency in both peacetime and wartime conditions. The military uses various types of fuels, ranging from gasoline and diesel to aviation fuels (kerosene, jet fuel) and specialized blends designed for naval units, land vehicles, and aircraft. Jet engines require high-performance fuels, while tank engines, armored personnel carriers, and support vehicles are primarily powered by diesel fuel, which ensures adequate power and efficiency in difficult terrain conditions. In addition to engine fuels, the military also utilizes other petroleum distillation products such as oils, lubricants, hydraulic fluids, and solvents. These substances support the daily maintenance and operational readiness of military equipment [16].

Both soldiers and civilian employees are exposed to numerous chemical and physical hazards, as well as the toxic effects of crude oil and its derivatives, including their physicochemical properties, explosiveness, and flammability. Most petroleum distillation products are harmful to the respiratory tract and skin, and prolonged exposure has been shown to have carcinogenic or potentially carcinogenic effects [16].

The chemical composition of petroleum distillation products depends on the type (i.e., origin) of crude oil from which they are derived, as well as the refining process (i.e., fractional distillation and/or cracking, followed by additional treatment through solvent extraction, hydrodesulfurization, or hydrogenation) used to meet the performance requirements of the final products. Due to the complexity and variability of their composition, petroleum-derived substances pose a unique challenge for regulatory authorities, particularly in characterizing their chemical composition [22]. Various carcinogenic substances may be present in petroleum products. The most commonly found include benzene, formaldehyde, polycyclic aromatic hydrocarbons (PAHs), aromatic amines, and buta-1,3-diene [14].

The Regulation of the Minister of Family, Labour, and Social Policy of June 12, 2018, on the maximum allowable concentrations and intensities of harmful factors in the work environment [12] specifies the maximum allowable concentrations of these substances. Table 1 presents the values of the maximum allowable concentrations and short-term exposure limits for selected carcinogenic substances in petroleum products.

Ammunition and explosives

One of the main sources of chemical carcinogenic factors in the military environment is ammunition and explosives [23]. Their production, storage, transportation, and use are associated with exposure to harmful chemicals that can have a long-lasting negative impact on the health of soldiers and military personnel involved in this area.

One of the main components present during the production and use of ammunition is lead. Lead is used as a component in projectiles, and contact with it may occur at various stages, from production, through maintenance, to use of ammunition, as residue from firing [6]. Lead, and exposure to it in the form of prolonged exposure – especially through inhalation of gases or direct skin contact – can lead to the development of cancers, as well as serious health problems such as damage to the respiratory, neurological, digestive, cardiovascular, and urinary systems [5].

Another significant hazard in the use of ammunition and explosives are organic substances, such as 2,4,6-trinitrotoluene, commonly used in explosives, TNT. TNT is associated with the risk of cancer development with prolonged exposure [4]. Military personnel who have direct contact with TNT may absorb it both through the skin and the respiratory system.

During the detonation of explosives, harmful combustion products are generated, including polycyclic aromatic hydrocarbons (PAHs), dioxins, and furans [29].

Tab. 1. Maximum allowable concentrations and short-term exposure limits for selected carcinogenic substances in petroleum-derived products [20].

Substance [Chemical Abstracts Service]	Maximum allowable concentrations mg/m3	Short-term exposure limits mg/m3
Benzene [71-43-2].	1.6	---
Gasoline: a) Extraction [8030-30-6]	500	1500
b) For paints [8052-41-3; 64742-82-1; 64742-92-0; 64742-48-9]	300	900
Polycyclic aromatic hydrocarbons (PAHs) – as the sum of the products of concentrations and carcinogenicity coefficients of nine carcinogenic PAHs, including naphthalene, benzo[a]pyrene, and chrysene.	0.002	---
Formaldehyde [50-00-0].	0.37	0.74
Aromatic amines, e.g., aniline [62-53-3].	1.9	3.8
Buta-1,3-diene [106-99-0].	2.2	---

PAHs are highly carcinogenic and can be absorbed through the skin or respiratory system [29], especially during combat operations or military exercises, where soldiers are directly exposed to smoke produced by explosions. Polycyclic aromatic hydrocarbons are widely recognized as a significant risk factor in the development of lung, skin, bladder, and other organ cancers [25].

Dioxins and furans are highly toxic and carcinogenic chemical compounds, and their presence in the environment is particularly dangerous due to their persistence and ability to accumulate in human bodies. Dioxins and furans can be released during uncontrolled detonations and combustion of explosives, posing a threat to both soldiers and civilians in the vicinity of such activities [2].

The above examples of chemical carcinogenic factors in the military environment come from only two sources of exposure. In reality, the list of potentially carcinogenic chemical factors is much longer and includes various factors that may pose a health risk to those exposed to them. Proper protective measures and safety procedures are crucial to minimize the risk of contact with these harmful factors.

PHYSICAL CARCINOGENIC FACTORS

Physical carcinogenic factors encompass a wide range of phenomena, such as different types of electromagnetic radiation, extreme temperatures (both low and high), mechanical injuries, and solid or gel-like materials that are insoluble or poorly soluble, which can cause cancers. However, both the physical properties and carcinogenic effects of these factors were often oversimplified during the process of identifying carcinogenic factors. The focus was mainly on their physical and mechanical aspects, rather than their chemical properties of action, which distinguishes them from chemical carcinogenic factors [24].

Ionizing radiation

Radiation is a stream of particles (photons, electrons, neutrons, alpha particles, and others) emitted by material systems (e.g., molecules, atoms, atomic nuclei). There are different types of radiation, creating an electromagnetic spectrum based on energy levels. Ionizing radiation can be preliminarily divided into: ionizing and non-ionizing [27].

Ionizing radiation can be defined as radiation carrying enough energy to directly or indirectly ionize atoms and particles of the medium through which it passes. The energy transferred to the atoms of the medium is so large that it causes the breaking of chemical bonds in previously stable atoms, leading to their ionization. This phenomenon has wide applications, ranging from medicine to industry, but it also has potential health and environmental consequences. Ionizing radiation has been a part of human existence since the beginning. Every day, we absorb radiation that reaches us from space as well as from rocks or soil. This is natural radiation. In addition to natural sources of

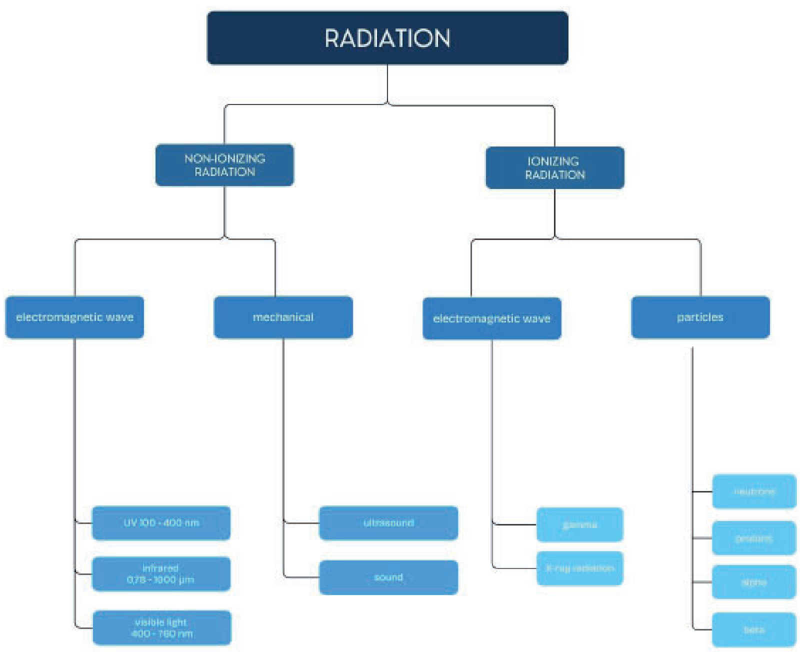

Fig. 1. Division of radiation [21].

ionizing radiation, there are also artificial sources. Ionizing radiation produced by humans arises as a result of changes occurring within atomic nuclei. These changes are accompanied by alterations in the energy of the nuclei, and often also in the number of nucleons. Isotopes of elements with an improper number of neutrons are particularly susceptible to this. Artificial sources of ionizing radiation include medical equipment (X-ray machines, cobalt bombs), nuclear power plants (reactors), and research devices, such as particle accelerators. Artificial radioactive isotopes, which are sources of α, β, and γ radiation, are commonly used in medicine, industry, and science. Ionizing radiation poses a health risk to humans and other organisms. The greatest risk is cellular damage at the molecular level, which can lead to mutations and even the development of cancers. High doses of radiation can lead to acute radiation sickness, and in extreme cases – death. Long-term exposure to radiation, even in low doses, can result in health problems many years later [27].

The primary legal act regarding safety and radiological protection in Poland is the Atomic Law of November 29, 2000 [1]. The Act regulates issues related to the use of nuclear energy and the handling of radioactive materials. It also covers environmental protection and the protection of human life and health from the dangers posed by ionizing radiation. For example, the Act specifies the dose limits for ionizing radiation for workers. The dose limit, expressed as an effective dose, is set at 20 mSv per calendar year.

Data from 2018-2019 indicate that the main source of ionizing radiation exposure for military personnel are devices used in medical diagnostics and radiotherapy (X-ray examinations, computed tomography, nuclear medicine, radiotherapy, etc.) [15].

Nevertheless, it is important to remember that ionizing radiation plays a significant role in the military due to its properties. It is used in advanced defense technologies that provide a strategic advantage. Ionizing radiation can originate from nuclear bombs, precision devices for detecting hazardous materials, as well as depleted uranium munitions, which effectively penetrate armor. Additionally, the use of radiation in detection devices, such as X-ray scanners or neutron detectors, helps prevent threats, such as controlling cargo in military ports.

CANCER-CAUSING PROCESSES

Another important group of factors that can lead to the development of cancers are the so-called carcinogenic processes. These are technological processes in which chemical agents, their mixtures, or substances with carcinogenic or mutagenic effects are released. Annex 1 of the regulation [20] lists particularly hazardous technological processes in which there is an increased risk of exposure to carcinogenic or mutagenic agents. Examples of such processes include, among others: the production of auramine, work involving exposure to polycyclic aromatic hydrocarbons present in soot, tars, and carbon residues, as well as exposure to dust, fumes, and aerosols produced during nickel refining. Particular attention should be paid to work involving exposure to wood dust and crystalline silica, as well as work related to exposure to exhaust gases emitted by diesel engines [20].

Exhaust Gases Emitted from Diesel Engines

The exhaust gases emitted from diesel engines are a mixture of combustion products of diesel fuel, with the exact composition depending on the engine type, operating conditions, additives, emission control systems, and the fuel composition itself. Diesel engines vary in terms of rotational speed, load, fuel composition, and emission control systems. Depending on these conditions, diesel engines can emit up to 200 times more particulate mass than typical gasoline engines equipped with a catalytic converter. Diesel engine exhaust gases consist of a non-polar fraction (57%), a moderately polar fraction (9%), and a polar fraction (32%). The inorganic fraction of particulate emissions is mainly composed of small particles of elemental carbon (soot) with a diameter ranging from 0.01 to 0.08 μm. Organic and elemental carbon account for about 80% of the total particulate mass. This carbon is chemically pure and can serve as a carrier for hydrocarbons, especially aromatic ones (including carcinogenic compounds). The remaining 20% consists of sulfates (mainly sulfuric acid) and metals (lead, platinum, aluminum, calcium, and barium) originating from engine wear products [26]. Occupational exposure to chemicals and particulate matter present in exhaust gases from diesel engines affects those who operate or maintain equipment fitted with such engines. Prolonged exposure to combustion products and exhaust gases can lead to numerous serious health problems.

Diesel engine exhaust gases are very complex mixtures, and no single component serves as a universal exposure indicator. Typically, measurements of particulate matter or elemental carbon are used because both parameters are significantly higher in diesel fuel combustion emissions than in other combustion products [3]. According to the regulation [20], the highest permissible concentration of diesel engine exhaust gases, measured as elemental carbon, is 0.05 mg/m^3.

In the military environment, the primary sources of diesel engine exhaust gases are combat, transport, and heavy equipment vehicles. Armored vehicles, such as tanks and armored personnel carriers, generate large amounts of exhaust gases during training exercises and combat operations. Diesel engines also power logistical vehicles, including transport trucks used to carry soldiers and supplies. Another source of emissions is power generators, which are used to provide electricity in field military bases, often operating for extended periods. Engineering equipment, such as excavators, bulldozers, and loaders, also emits exhaust gases during infrastructure construction in field conditions. Additionally, transport equipment at military airports, such as baggage vehicles and refueling tankers, also runs on diesel engines, increasing exposure for aviation personnel. The maintenance and repair of military equipment is another source of exposure to exhaust emissions, especially for mechanics and technical staff. In enclosed spaces, such as garages or hangars, the lack of proper ventilation exacerbates the risk of exposure to harmful exhaust gases [13,28].

Crystalline Dust and Wood Dust

During every technological process, by-products are generated. One such by-product is dust, which can form during combustion, abrasion, or crushing of solid substances such as inorganic minerals, organic materials, and metals. If inhaled, dust particles can be harmful to human health. The Regulation of the Minister of Family, Labor, and Social Policy of June 12, 2018 [20] on the maximum allowable concentrations and intensities of harmful factors in the work environment classifies different types of dust and fibers that may be present during technological processes. It categorizes them based on particle size and their impact on human health as:

- total dust, which consists of all airborne particles present in a defined volume of air,
- respirable dust, which consists of particles passing through a pre-selector with permeability defined according to particle size, described by a log-normal probability function, with an aerodynamic diameter of approximately 3.5 microns and a geometric standard deviation of about 1.5 microns,
- respirable fibers, which are fibers longer than 5 microns, with a maximum diameter of 3 microns, and a length-to-diameter ratio greater than 3 [20].

According to the above regulation, the maximum allowable concentration for the respirable fraction of crystalline silica is 0.1 mg/m^3 [20].

Quartz, the most common crystalline polymorphic form of silica, is present in large quantities in most types of rocks, particularly granite, sandstone, and quartzite, as well as in sand and soil. Materials containing crystalline silica are not hazardous until they are disturbed. Drilling, cutting concrete, bricks, tiles, and sandstone-common materials on construction sites across various industries-generate crystalline dust. Exposure to silica dust can lead to severe respiratory diseases, such as silicosis and chronic obstructive pulmonary disease (COPD), while also increasing the risk of lung cancer [17].

When crystalline silica is inhaled, lung tissue forms nodules and fibrosis around the particles. The accumulation of silica dust in the lungs prevents immune cells from effectively removing it, leading to prolonged inflammation. This persistent inflammation can damage lung cell DNA, and in some individuals, it may contribute to the development of lung cancer. The latency period for silica-related cancers ranges from 10 to 20 years [17].

Wood dust is another harmful by-product of woodworking and wood-based panel processing. In particular, dust from hardwood species (such as oak and beech) has carcinogenic properties, increasing the risk of respiratory tract cancers [17].

The properties of wood dust vary depending on the type of wood, the tools used, and the machining technique. These differences arise from density, hardness, specific gravity, and chemical composition of different wood species. Beyond their physical properties, wood dust may also contain secondary substances, such as terpenes, phenolic compounds, flavonoids, and nitrogenous compounds, which affect its toxicity and potential health hazards. The type of woodworking process significantly affects particle size. For example, sawing generally produces larger particles compared to sanding, which generates finer dust. Additionally, wood density influences particle size—lower-density woods produce smaller particles during machining. To assess particle size, the aerodynamic diameter concept is used. This refers to the diameter of a sphere with a density of 1 g/cm^3, whose settling velocity in air matches that of the measured dust particle. Wood dust is classified into four groups based on particle size:

very coarse (with an aerodynamic diameter greater than 10 μm), coarse (from 2.5 to 10 μm), fine (from 0.1 to 2.5 μm), and ultrafine or nanoparticles (below 0.1 μm). Most wood dust particles emitted during wood processing have an aerodynamic diameter greater than 10 μm, meaning they fall into the "coarse" or "very coarse" categories [7].

From a legal perspective, wood dust is not classified as a hazardous substance under the European CLP Regulation (European Parliament and Council Regulation No. 1272/2008) [6]. Since it is a byproduct of wood processing, it is not directly regulated under hazardous chemical substance laws. However, wood dust present in the workplace has been recognized as potentially carcinogenic or mutagenic. Jobs involving exposure to wood dust are included in the list of technological processes with an increased health risk, where carcinogenic or mutagenic agents are released [21]. Regulations on maximum allowable concentrations and intensities of harmful factors in the work environment have set a permissible exposure limit of 2 mg/m^3 for all types of wood dust, with an official designation as a carcinogenic substance [19].

Both crystalline silica dust and wood dust pose additional risks in enclosed or poorly ventilated spaces, such as workshops, garages, bunkers, or storage rooms. In such conditions, without appropriate personal protective equipment, especially respirators with filters, the risk of inhaling harmful dust increases significantly. Furthermore, in carpentry and construction work, exposure to both types of dust often overlaps, further increasing health risks.

In the military environment, exposure to crystalline silica dust and wood dust is primarily associated with engineering, construction, and carpentry work. Studies conducted in Poland between 2018 and 2019 indicated that the most common technological process in the military environment involved exposure to hardwood dust [15].

CONCLUSIONS

Exposure to carcinogenic substances in the military environment poses a significant health challenge, particularly due to the diversity and intensity of exposure factors. Military personnel are regularly exposed to harmful chemical substances such as benzene, formaldehyde, and polycyclic aromatic hydrocarbons, which are present in fuels, petroleum products, and explosives. Additional risks include ionizing radiation and carcinogenic dust generated in technological processes and material processing. Long-term exposure to these factors can lead to severe health consequences, including an increased risk of cancer and chronic respiratory diseases.

Effectively addressing these threats requires a comprehensive approach that includes prevention, monitoring, and personnel education. Key countermeasures include: implementing personal protective equipment, regularly monitoring exposure levels, training personnel on potential hazards and safety practices, and strictly controlling technological processes that may release carcinogenic substances. At the same time, a long-term goal should be the development and implementation of modern technologies and alternative materials that minimize the risk of contact with carcinogenic substances. Through international cooperation and the exchange of best practices, it is essential to establish consistent health protection standards in the military environment. Such an integrated approach can significantly reduce health risks associated with military service and improve the quality of life for military personnel, both during and after their service.

Proposed mandatory preventive measures:

1) Engineering controls such as local ventilation systems in workshops, hangars, and storage areas. Air filtration (e.g., HEPA filters, carbon adsorbents) and monitoring of particulate matter (PM), volatile organic compounds (VOCs), and carcinogenic substances (benzene, formaldehyde, PAHs) will help reduce exposure. Closed operational systems, automation of technological processes, as well as isolation of workstations (e.g., decontamination booths), will significantly limit contact with harmful factors.
2) Personal protective equipment (PPE), including the use of carbon and HEPA filter masks tailored to the type of exposure, chemical-resistant gloves, and protective clothing with hydrophobic and barrier properties. Regular decontamination of clothing and protective equipment, as well as the implementation of air and clothing cleaning systems after duty, will reduce the risk of secondary exposure.
3) In addition to regular screening exams adapted to the type of exposure, it is also advisable to include tests for specific lung cancer markers, such as CYFRA 21-1. Creating a centralized database of screening results will facilitate long-term analysis of health trends and the implementation of effective preventive measures.
4) Replacing carcinogenic substances with safer alternatives. In the military, efforts should be

made to use fuels with reduced PAH content and low-emission technologies. Biodegradable lubricants and oils, non-toxic explosives, and modernization of cutting and welding methods (e.g., using lasers and ultrasound) will help reduce the emission of heavy metals and carcinogenic dust.

In summary, effective counteraction to the issue of exposure to carcinogenic factors in the military requires a multifaceted approach that combines control, the use of personal protective measures, medical supervision, and ongoing research. By implementing these actions, it is possible to significantly reduce health risks associated with military service and improve the overall quality of life for military personnel.

AUTHORS' DECLARATION:

Study Design: Magdalena Zawadzka, Marcin Nowik, Justyna Marszałkowska-Jakubik. **Data Collection:** Magdalena Zawadzka, Marcin Nowik, Justyna Marszałkowska-Jakubik. **Graphical representation of results:** Magdalena Zawadzka, Marcin Nowik, Justyna Marszałkowska-Jakubik. **Manuscript Preparation:** Magdalena Zawadzka, Marcin Nowik, Ewelina Ejchman-Pac, Paweł Szymański, Mateusz Curyło, Justyna Marszałkowska-Jakubik. The Authors declare that there is no conflict of interest.

REFERENCES

1. Act of 29 November 2000 – Atomic Law. [Ustawa z dn. 29 listopada 2000 r. Prawo atomowe]. Journal of Laws of 2024 item 1277. (in Polish).
2. American Cancer Society. Burn pits and cancer risk [Internet]. Atlanta: ACS; [cited 2024 Oct 21]. Available from: https://www.cancer.org/cancer/risk-prevention/chemicals/burn-pits.html
3. Barnes H, Goh NSL, Leong TL, Hoy R. Silica-associated lung disease: An old-world exposure in modern industries. Respirology. 2019 Dec;24(12):1165-1175. doi: 10.1111/resp.13695.
4. Bolt HM, Degen GH, Dorn SB, Plöttner S, Harth V. Genotoxicity and potential carcinogenicity of 2,4,6-TNT trinitrotoluene: structural and toxicological considerations. Rev Environ Health. 2006 Oct-Dec;21(4):217-28. doi: 10.1515/reveh.2006.21.4.217.
5. Boskabady M, Marefati N, Farkhondeh T, Shakeri F, Farshbaf A, Boskabady MH. The effect of environmental lead exposure on human health and the contribution of inflammatory mechanisms, a review. Environ Int. 2018 Nov;120:404-420. doi: 10.1016/j.envint.2018.08.013.
6. Brożek-Mucha Z. Trends in analysis of gunshot residue for forensic purposes. Anal Bioanal Chem. 2017 Oct;409(25):5803-5811. doi: 10.1007/s00216-017-0460-1.
7. Bujak-Pietrek S, Soćko R, Konieczko K, Kupczewska-Dobecka M, Jurewicz J. Wood Dust: Guidelines for Employers, Workers, and Occupational Safety and Health Services. [Pyły drewna: wytyczne dla pracodawców, pracowników i służb związanych z bezpieczeństwem i higieną pracy]. Łódź: Instytut Medycyny Pracy im. Prof. J. Nofera; 2023. E-edition published December 29, 2023. (in Polish).
8. Doe JE, Boobis AR, Cohen SM. A new approach to the classification of carcinogenicity. Arch Toxicol. 2022;96:2419–2428. doi: 10.1007/s00204-022-03324-z.
9. Felter SP, Boobis AR, Botham PA, Brousse A, Greim H, Hollnagel HM, Sauer UG, Hazard identification, classification, and risk assessment of carcinogens: too much or too little? – Report of an ECETOC workshop. Critical Reviews in Toxicology, 2020;50(1), 72–95. https://doi.org/10.1080/10408444.2020.1727843
10. International Agency for Research on Cancer. Agents classified by the IARC Monographs, Volumes 1–136. Lyon: IARC; [cited 2024 Oct 21]. Available from: https://monographs.iarc.who.int/agents-classified-by-the-iarc/
11. Jassema J, Kordek R. Oncology: A Textbook for Doctors and Students. [Onkologia: podręcznik dla lekarzy i studentów]. 5th ed. Wrocław: Wydawnictwo X; 2019. (in Polish).
12. Kastan MB; DNA Damage Responses: Mechanisms and Roles in Human Disease: 2007 G.H.A. Clowes Memorial Award Lecture. Mol Cancer Res 1 April 2008; 6 (4): 517–524. https://doi.org/10.1158/1541-7786.MCR-08-0020
13. Kelly KE, Wagner DA, Lighty JS, Sarofim AF, Rogers CF, Sagebiel J, Zielinska B, Arnott WP, Palmer G. Characterization of exhaust particles from military vehicles fueled with diesel, gasoline, and JP-8. J Air Waste Manag Assoc. 2003 Mar;53(3):273-82. doi: 10.1080/10473289.2003.10466151.
14. Kupryszewski G. Introduction to Organic Chemistry. [Wstęp do chemii organicznej]. PWN, 1981, 155-157.
15. Lemiech-Mirowska E, Zawadzka M. Exposure of military unit employees to carcinogenic factors in the work environment in 2018–2019. Med Pr Work Health Saf. 2021;72(5):501-508. doi:10.13075/mp.5893.01124.

16. Makles Z. Work safety at the storage and transportation of petroleum and petroleum products. [Bezpieczeństwo pracy przy magazynowaniu i transporcie ropy naftowej oraz produktów ropopochodnych]. Bezpieczeństwo Pracy: Nauka i Praktyka. 2004;(1):15-20. (in Polish).

17. Meng E, Xin Z, Jianrui D, Jinzhu Y. Meta-Analysis of the Relationship Between Occupational/Environmental Exposure to Wood Dust and Laryngeal Cancer. Cancer Med. 2024 Oct;13(20):e70330. doi: 10.1002/cam4.70330.

18. National Toxicology Program. 15th Report on Carcinogens [Internet]. Research Triangle Park (NC): National Toxicology Program; 2021 Dec 21. Diesel Exhaust Particulates: CAS No.: none assigned. Available from: https://www.ncbi.nlm.nih.gov/books/NBK590901/

19. Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on the classification, labeling, and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006. [Rozporządzenie Parlamentu Europejskiego i Rady (WE) nr 1272/2008 z dnia 16 grudnia 2008 r. w sprawie klasyfikacji, oznakowania i pakowania substancji i mieszanin, zmieniające i uchylające dyrektywy 67/548/EWG i 1999/45/WE oraz zmieniające rozporządzenie (WE) nr 1907/2006]. Dz.U. L 353 z 31.12.2008, poz. 1–1355. (in Polish).

20. Regulation of the Minister of Family, Labour and Social Policy of 12 June 2018 on the maximum allowable concentrations and intensities of hazardous factors in the work environment. [Rozporządzenie Ministra Rodziny, Pracy i Polityki społecznej z dnia 12 czerwca 2018 r. w sprawie najwyższych dopuszczalnych stężeń i natężeń czynników szkodliwych dla zdrowia w środowisku pracy]. Dz.U.2018.1286 poz. 1286. (in Polish).

21. Regulation of the Minister of Health of 26 July 2024 on chemical substances, their mixtures, factors, or technological processes with carcinogenic, mutagenic, or reprotoxic effects in the work environment. [Rozporządzenie Ministra Zdrowia z dnia 26 lipca 2024 r. w sprawie substancji chemicznych, ich mieszanin, czynników lub procesów technologicznych o działaniu rakotwórczym, mutagennym lub reprotoksycznym w środowisku pracy]. Journal of Laws 2024 item 1126. (in Polish).

22. Roman-Hubers AT, Cordova AC, Barrow MP, Rusyn I. Analytical chemistry solutions to hazard evaluation of petroleum refining products. Regul Toxicol Pharmacol. 2023 Jan;137:105310. doi: 10.1016/j.yrtph.2022.105310.

23. Serol M, Ahmad SM, Quintas A, Família C, Chemical Analysis of Gunpowder and Gunshot Residues. Molecules 2023;28:5550. https://doi.org/10.3390/molecules28145550

24. Soffritti M, Minardi F, Maltoni C. Physical Carcinogens. In: Kufe DW, Pollock RE, Weichselbaum RR, et al., editors. Holland--Frei Cancer Medicine. 6th edition. Hamilton (ON): BC Decker; 2003. Chapter 21. https://www.ncbi.nlm.nih.gov/books/NBK13884/

25. Straif K, Baan R, Grosse Y, Secretan B, El Ghissassi F, Cogliano V; WHO International Agency for Research on Cancer Monograph Working Group. Carcinogenicity of polycyclic aromatic hydrocarbons. Lancet Oncol. 2005 Dec;6(12):931-2. doi: 10.1016/s1470-2045(05)70458-7.

26. Szymańska J, Frydrych B. Exhaust Emissions from Diesel Engines Measured as Elemental Carbon. [Spaliny emitowane z silników diesla, mierzone jako węgiel elementarny]. Podstawy i Metody Oceny Środowiska Pracy 2019;4(102):43–103 doi: 10.5604/01.3001.0013.6378. (in Polish).

27. Toxicological profile for ionizing radiation. Agency for Toxic Substances and Disease Registry. [Internet]. Atlanta: U.S. Department of Health and Human Services; 1999 Sep [cited 2024 Nov 5]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK597570/

28. War Related Illness and Injury Study Center (WRIISC), Office of Public Health, Department of Veterans Affairs. (2013). Military Vehicle and Aircraft Exhaust Exposure: A Resource for Veterans, Service Members, and Their Families. Department of Veterans Affairs. August 2013.

29. Warshawsky D. Polycyclic aromatic hydrocarbons in carcinogenesis. Environ Health Perspect. 1999 Apr;107(4):317-319. doi: 10.1mutage9/ehp.99107317.