CRITICAL ANALYSIS OF THE LONG-TERM EFFECTS OF RADIATION EXPOSURE IN MEDICAL PROFESSIONALS.

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ABSTRACT

This article aims to thoroughly examine the long-term side effects of radiation in chosen professions in the medical industry. Following a thorough examination of the literature, which is related to health risks, security measures, and research studies on radiation exposure, occupational radiation exposure is outlined. The medics' health effects caused by radiation exposure, that is, cancer, cataracts, and their genetic changes, are well studied. Moreover, issues connected with potential radiation exposure degrees, including the type of job, the conduct in the workplace, and the protective measures, are specified. Practical Pointers on Improving Radiation Safety Procedures and Advocating for the Health of Medical Workers are discussed to minimize the Negative Health Implications for Medical Personnel Who Work in Radiation Environments.

Keywords: radiation exposure, medical professionals, health effects, occupational safety, protective measures

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DOI: 10.53555/ecb/2022.11.9.116

INTRODUCTION

Radiation hazards are a major occupational issue for medical personnel, especially those who work as diagnosticians in X-rays and corps, practitioners of interventional treatment, radiologists, and radiotherapy oncologists. Even though imaging apparatuses or radiation-based therapies contribute to the detection and elimination of different kinds of diseases, working with ionizing radiation as a healthcare worker can pose a health risk through prolonged and insufficient doses. The importance of knowing the health consequences of radiation exposure for medical workers cannot be overestimated. It necessitates the development of safety techniques and a reduction in the level of health risks. This paper's purpose is to critically assess the current evidence about the health effects, risk factors, and corrective strategies related to depression (Gargani et. al 2020).

BODY

Health Effects of Radiation Exposure:

Ionizing radiation is the most energetic form of electromagnetic radiation, which is capable of pushing tightly bound electrons out of the atoms, making them anions (ions), and leading to further damage to human tissues. The ways ionizing radiation affects the biology of one's body may differ if the amount of radiation, time of exposure, and type of radicals are different. It is of great importance to be aware of the possible health consequences of varying radiation exposure levels to accurately estimate the revealed risks and potential hazards for medical staff.

Radiation ionization and biologically related effects.

Radiation by ions is the descriptive term for the kind of radiation that includes X-rays and gamma rays, among other types of radiation that contain alpha and beta particles. Ionizing radiation causes the electrons within the human tissues, the atoms, to acquire charges through this process, resulting in the formation of free radicals and reactive oxygen species. These reactive species, if not managed accordingly, have the ability to attack DNA, proteins, and cell membranes, which play critical roles in normal cell functioning and can lead to the development of health disorders.

The biological effects of ionizing radiation are classified into two categories: deterministic and stochastic effects, or effects attributed to them. Two sorts of effects can be induced by radiation. The first one is also called non-stochastic effects. These are caused when the exposure exceeds a certain threshold and results in determined and observable damage to the tissue. Examples of those produced by the deterministic effects are skin burns, cataracts, and radiation-induced organ-enduring damage. Conversely, the stochastic effects, also known as probabilistic effects, are non-deterministic and have no fixed dose-response, nor is there a level of exposure that does not indicate any results. Stochastic effects include the development of cancer through radiation and the mutation of genes, which could potentially start manifesting during or even decades after exposure.

Evidence of Increased Cancer Risk:

Many cancer epidemiological studies have already provided adequate evidence of the connectivity between radiation exposure from workplaces for medical workers and cancer risk. Those medical workers who are engaged in fluoroscopic procedures and need guidance using this technique, such as interventional radiology or cardiac catheterization, are particularly vulnerable to radiation exposure. Studies have specifically pointed out that the incidence of specific types of cancer or one particular category of cancer, such as leukemia, thyroid cancer, or breast cancer, among these groups of professionals is significantly greater than for the general population.

Working as a medical professional exposes one to some radiation types, like ionizing radiation. In some instances, leukemia-type cancer is one of the leading radiation-induced malignancies developing among colleagues. Radio epidemiological investigations reported an increasing probability of leukemia onset notably that of acute myeloid leukemia (AML), among radiologic specialists, radiologic technicians, and nuclear medicine workers exposed to radiation during their careers.

Thyroid cancer is a neoplasm that can occur as a result of working in a radiation environment as well as in the healthcare industry within the group of occupations that are exposed to radioactive iodine isotopes (isotopes of iodine used in diagnosis and treatment). The thyroid gland is the organ most sensitive to tumor genesis caused by radionuclides, specifically iodine, which is concentrated by the gland and can thus become an etiological agent in the development of cancer by radioactive iodine isotopes (Gargani et. al 2020).

After all, the breast cancer risk is on the increase among radiology medical professionals exposed to radiation during imaging processes like mammography and fluoroscopy. Research has indicated the occurrence of increased cases of breast cancer in workers in that particular field, and their higher levels of radiation exposure increase their risk.

Occupational irradiation radiation

Moreover, work-related radiation exposure may have a strongly negative impact on health, namely, cataracts, cardiovascular diseases, and genetic malformations. Cataracts, which could be the blackening of the lens of the eye, is also determined to be an excellent consequence of ionizing radiation exposure, mainly for an interventional radiologist or nuclear medicine personnel working in the nuclear power plant using scattered radiation during a fluoroscopically guided procedure.

The cumulative effects of cardiovascular diseases have also been found to be associated with physicians and healthcare professionals undergoing chronic radiation exposure. The treatment mechanisms and the involvement of radiation exposure in the development of cardiovascular problems are not yet fully understood. However, there is evidence implying that radiation-induced inflammation, oxidative stress, and endothelial dysfunction may contribute to the pathogenesis of cardiovascular diseases (Gargani et. al 2020).

In addition to that, occupational irradiation radiation increases the chance of hereditary genetic mutations, in some cases bringing risky malignancies to the offspring of the exposed people. Chromosomal abnormalities and genetically induced mutations were reported as radiation-exposed individuals' offspring's excessive frequency, implying a pronounced impact of ionizing radiation on human genetics as a heritable component.

Risk Factors and Exposure Pathways:

The situation varies widely among professionals in this field, based on multiple conditions like their job role, frequency of performed procedures, and proximity to radiation. Knowing about these risk factors is vital for making hermetic radiation safety protocols and reducing the source of occupational radiation exposure in healthcare institutions.

Factors influencing radiation exposure levels:

1. Job Role:

Radiation exposure differs across medical specialties. Some of them require only minimal radiation perception, whereas others rely on it a lot. For instance, by contrast, interventional radiologists, interventional cardiologists, and radiologic technologists who perform fluoroscopically-guided procedures top the current list of jobs with the highest radiation exposure levels because they have this direct involvement with the patients and in procedures involving the administration of ionizing radiation. In contrast, healthcare workers like nurses and clerical staff may have lower levels of radiation exposure, which is relatively straightforward; they mostly come into contact with radiation in unison with their patient care activities.

2. Frequency of Procedures

Medical professionals may experience higher levels of cumulative radiation due to the frequency of radiation exposure and the amount of radiation dose from daily procedures. Staff members performing fluoroscopically-guided interventions, which include angiography, cardiac catheterization, and fluoroscopy-guided surgeries, have a greater possibility of radiation exposure. Green-colored workers who perform only a limited number of radiologic procedures and those who work in the non-procedural departments of hospitals are at far lesser risk of radiation exposure (Amran et. al 2021).

Exposure Pathways:

1. Direct Exposure During Procedures

The radiation dose from a fluoroscopically guided procedure is directly assigned to medical professionals who work covering patients during college examinations and interventions. Instant discharge occurs when medical officials are situated quickly into the main lines of the X-ray or fluoroscopic device while performing the procedures, leading to radiation exposure to the body, particularly the head, hands, and other body parts that are exposed (Søvold et. al 2021).

2. Scattered Radiation

Medical staff exposed to scattered radiation can be another example of likely exposure, especially for staff who are engaged near fluoroscopy machines. X-rays, when they interact with patient tissues, may undergo scattering, which can produce secondary radiation that mainly reaches the health care providers located in nearby areas. Dispersion of radiation presents an excellent danger for medical workers—especially those who are not wearing adequate shielding, those located in a less protected area, or those who are working in places with a higher level of radiation.

3. Contamination from Radioactive Materials

Other medical staff face the risk of radiation together with the medical professionals contaminated with either treatment or diagnostic radioactive material. Nuclear medicines employ different radioactive isotopes, for example, technetium-99m, iodine-131, and fluorine-18, mostly in imaging and therapy. Actual leaking or mishandling of radioactive instruments or the absence of personal protective equipment (PPE) can cause skin contamination or the acquisition of particles of radioactivity, which will lead to internal ionizing shocks (Leo et. al 2021).

In summary, radiation exposure risk factors and pathways of exposure facing medical professionals need to be fully understood, as they are of critical importance for better organization of radiation security practices and reduction of occupational health risks. Such facilities can establish healthcare radiation safety protocols triggered by recognized hazardous working environments, scientific methods, or exposure pathways. Continual personnel education and training and the implementation of proactive engineering controls and personal protection measures will allow them to guarantee the safety and health of healthcare professionals.

Safety standards and safe protection strategies.

In reaction to the potential health problems that may occur to medical professionals when using ionizing radiation, the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) serve as regulatory bodies that also set guidelines and regulations that protect healthcare workers from radiation hazards.

Radiation safety guidelines and regulations:

The ICRP and NCRP are the leading organizations that have produced recommendations and standards on radiation protection for medical settings, including occupational exposure limits, dosage monitoring, personnel training, and quality assurance measures. It is to decrease the radiation-related risks experienced by healthcare workers and, at the same time, continue to offer the advantages of medical procedures that include imaging as well as therapy (Che Huei et. al 2020). Obtaining regulations of this type is essential for healthcare facilities to maintain the safety of the clinic staff as well as the patients who are enduring the diagnostic and treatment procedures with radiation.

Protective Measures and Equipment:

✓ Lead Aprons

Among the workers in the medical field, worker ancillary defensive clothing (PPE), namely, the lead apron, is commonly used during fluoroscopically guided procedures to protect against radiation scatter. 'These aprons are created with lead or lead equivalence materials and are worn by healthcare workers to diminish X-ray rays and reduce radiation exposure to the torso and vital organs.

✓ Thyroid Shields

Thyroid shields are lead shields that are specifically developed protective devices used to protect the thyroid gland during head and neck imaging procedures that involve radiation exposure. Shields are usually worn around the neck as well; they protect radiation-sensitive areas that are believed to be highly susceptible to radiation exposure (Braunstein et. al 2020).

✓ Radiation Badges

Dosimeter badges, which are explosive radiation monitoring devices worn by health workers, have become an authentic, unaltered record of personal exposure levels over time. Within these badges, there are sensitive radiometers that quantify the level of radiation delivered to the wearer. This can assist in dose monitoring and also in maintaining the regulatory dose limits.

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✓ Shielding Devices

To minimize radiation scatter and protect healthcare workers from excessive exposure, fluoroscopy rooms and interventional suites implement additional shielding devices such as lowering barriers, padded lead clothing, and ceiling-mounted lead coverings. We place radiation protection gear (ask lens) to form partitions that allow for attenuation of X-ray scatter, ensuring optimal workforce security.

Through the use of these safety apparatuses and protective strategies, radiological departments inside healthcare settings can counteract radiation exposure risks and ensure that the employees who work with such radiological procedures have their health and well-being protected. Recurrent training, education, and commitments to radiation safety rules can play an essential role in safeguarding the patient's treatment's consistency with regulatory norms and giving impetus to the culture of safety in a healthcare system (Gaber et. al 2021).

Health monitoring and surveillance:

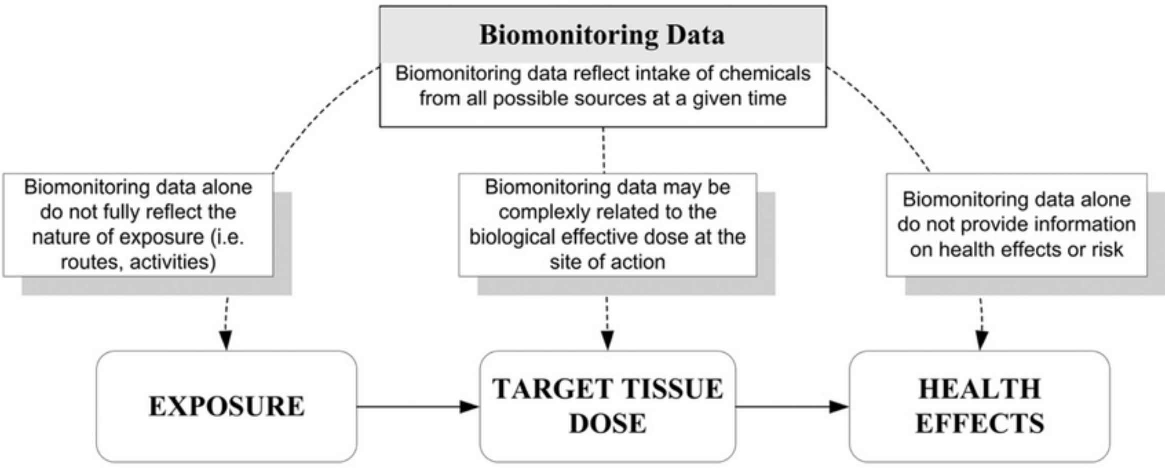
Sufficient health surveillance programs serve as a basis for controlling workers' exposure to radiation levels and prompt diagnosis of radiation consequences. At the same time, these programs serve the aim of assessing occupational radiation doses in healthcare workers and adhering to the system of regulatory dose limits.

The importance of health surveillance programs:

Medical workers exposed to ionizing radiation at their workplaces regularly undergo health program supervision, which is considered a systemic tool. Using regular screening and monitoring, these programs make it possible to detect radiation-induced health effects at the early stages, including tissue damage, genetic changes, and cancer risk plication's. Fastened health concerns at the beginning level let us healthcare providers carry on treatment and preventive measures at the right time to reduce the long-run radiation effect on medical professionals' health.

Role of Dosimeter and Biological Monitoring

Dosimeter, both external and internal, particularly for health workers with radiation exposure, is an integral part of radiation health surveillance programs. External dosimeters, like radiation badges and thermo luminescent dosimeters (TLDs), function to calculate the number of penetrates worn by workers in the medical field to measure the amount of radiation they are exposed to during their tasks. These dosimeters give us figures on the amount of radiation dose that each person receives. With this quantitative evidence, it is possible to optimize radiation dose and reach the requirements of radiation protection by setting these limits (Hussain et. al 2022).



The Role of Biomonitoring in the "Exposure? (Zimmerling & Chen 2021).

Biological monitoring encompasses the examination of biological samples like blood or urine, and it is a complementary method by which the absorbed internal radiation dose by medical professionals is assessed. Radiation cytogenetic techniques like chromosome aberration analysis and micronucleus assays give information about the new biological effects of radiation exposure at the cellular level. With evidence-based monitoring, medical professionals can associate biological indicators with dosimeter and thus better understand individual susceptibility to radiation-related health effects and use this information when planning follow-up testing and treatment.

Occupational Health and Wellness

Besides radiation-specific supervision, occupational health and general practices are pertinent to providing superior conditions for medics in radiation-dense workplaces. With the offering of biomechanics programs, adequate workload distribution, and psychological assistance services, employers will limit workers' stress levels and boost job satisfaction and productivity in the workplace.

Workstation ergonomics is focused on reducing the risk of musculoskeletal injuries and physical strains coming from suboptimal work equipment arrangements or the workplace environment. Such measures can cover the evaluation of their workstation, the setting up of adjustable equipment, and the use of proper lifting techniques, which are aimed at avoiding repetitive motion injuries and musculoskeletal disorders (Cipriani et. al 2022).

The principle tool of workload management is to create workloads that do not overwhelm by balancing the amount of clinical responsibilities and other burdens with rest and rejuvenation. Therefore, the risk of burnout and fatigue among medical professionals is reduced. Staffing ate staffing levels, employee scheduling, and distribution can all reduce stress and develop work-life balance in the radial-related health care setting. They are setting up the emotional and psychological aspects of the occupation as fundamental; psychological support services like counseling, peer support groups, and stress management programs have to be provided to the staff of radiation therapy departments and interventional radiology suites. Such services give medical workers tools such as stress management advisories, coping resources, and the ability to deal with work-related stress, anxiety, and trauma torturously.

Merging health surveillance programs with the general, occupational health, and wellness programs of healthcare organizations can create a safe and healthy working environment that is primarily focused on the health of medical professionals. In turn, the care of the patient is efficient and free from radiation exposure.

CONCLUSION

In conclusion, this article narrates the significant long-term effects that radiation exposure has on medical professionals. It showcases the significance of the implementation of comprehensive safety measures and radio protective strategies. Thus, the risk of occupational radiation is mitigated. Medical imaging and radiation treatments are life-saving methods used in modern medicine. That being said, the goal of minimizing radiation exposure when providing care and preserving the health and well-being of healthcare professionals must be prioritized. This continuing research, education, and teamwork of healthcare organizations, regulatory agencies, and professional associations will make radiation safety practices advance over time and have a positive effect on the health and job safety of medical professionals(Cipriani et.,al 2022).

RECOMMENDATION

- ✓ Take responsibility for strict observance of radiation safety restrictions and norms, as well as adherence to dose limits and monitoring standards.
- ✓ Develop complete training and education programs for healthcare personnel on radiation security practices, such as the proper method of putting on safety garments and radiation dose-minimizing techniques.
- ✓ Improve workplace practices and working conditions to reduce workers' exposures to the minimum level of radiation, including optimization of imaging protocols, dose reduction, and selection of alternative imaging modalities when applicable.
- ✓ Develop robust healthcare surveillance and tracking programs that will monitor radiation exposure levels and detect radiation-related health problems in health professionals early on (Al-Sharify et. al 2020, June).
- ✓ Cultivate a security culture in hospitals that calls for the provision of occupational health services, ergonomic support resources, and psychological aid to medical professionals who are constantly dealing with ionizing radiation.

REFERENCE

4. Ribeiro, A., Husson, O., Drey, N., Murray, I., May, K., Thurston, J., & Oyen, W. (2020). Ionising radiation exposure from medical imaging–A review of Patient's (un) awareness. *Radiography*, *26*(2), e25-e30. https://www.sciencedirect.com/science/article/pii/S1078817419301518
5. Schultz, C. H., Fairley, R., Murphy, L. S. L., & Doss, M. (2020). The risk of cancer from CT scans and other sources of low-dose radiation: a critical appraisal of methodologic quality. *Prehospital and disaster medicine*, *35*(1), 3-16. https://www.cambridge.org/core/journals/prehospital-and-disaster-medicine/article/risk-of-cancer-from-ct-scans-and-other-sources-of-lowdose-radiation-a-critical-appraisal-of-methodologic-quality/23464B0D825CD456741B77476F9997F7
6. Al-Sharify, Z. T., Al-Sharify, T. A., & Al-Sharify, N. T. (2020, June). A critical review on

medical imaging techniques (CT and PET scans) in the medical field. In *IOP Conference Series: Materials Science and Engineering* (Vol. 870, No. 1, p. 012043). IOP Publishing. https://iopscience.iop.org/article/10.1088/1757-899X/870/1/012043/meta

7. Hardell, L., & Carlberg, M. (2020). [Comment] Health risks from radiofrequency radiation, including 5G, should be assessed by experts with no conflicts of interest. *Oncology Letters*, *20*(4), 1-1. https://www.spandidos-publications.com/10.3892/ol.2020.11876?fbclid=IwAR1OSpHHkLgMNAYCDuWSgDonWR-O0w0F0kQfqf2_YieLq1FrZDtDIaNtqaE
8. Awan, S., Diwan, M. N., Aamir, A., Allahuddin, Z., Irfan, M., Carano, A., ... & De Berardis, D. (2022). Suicide in healthcare workers: determinants, challenges, and the impact of COVID-19. *Frontiers in psychiatry*, *12*, 792925. https://www.frontiersin.org/articles/10.3389/fpsyt.2021.792925/full
9. Che Huei, L., Ya-Wen, L., Chiu Ming, Y., Li Chen, H., Jong Yi, W., & Ming Hung, L. (2020). Occupational health and safety hazards faced by healthcare professionals in Taiwan: A systematic review of risk factors and control strategies. *SAGE Open Medicine*, *8*, 2050312120918999. https://journals.sagepub.com/doi/abs/10.1177/2050312120918999
10. Kurniawan, T. A., Othman, M. H. D., Singh, D., Avtar, R., Hwang, G. H., Setiadi, T., & Lo, W. H. (2022). Technological solutions for long-term storage of partially used nuclear waste: A critical review. *Annals of Nuclear Energy*, *166*, 108736. https://www.sciencedirect.com/science/article/pii/S0306454921006125
11. Cipriani, C., Desantis, M., Dahlhoff, G., Brown III, S. D., Wendler, T., Olmeda, M., ... & Eberlein, B. (2022). Personalized irradiation therapy for NMSC by rhenium-188 skin cancer therapy: a long-term retrospective study. *Journal of Dermatological Treatment*, *33*(2), 969-975. https://www.tandfonline.com/doi/abs/10.1080/09546634.2020.1793890
12. Hussain, S., Mubeen, I., Ullah, N., Shah, S. S. U. D., Khan, B. A., Zahoor, M., ... & Sultan, M. A. (2022). Modern diagnostic imaging technique applications and risk factors in the medical field: a review. *BioMed research international*, *2022*. https://www.hindawi.com/journals/bmri/2022/5164970/
13. Gaber, T. A. K., Ashish, A., & Unsworth, A. (2021). Persistent post-covid symptoms in healthcare workers. *Occupational Medicine*, *71*(3), 144-146. https://academic.oup.com/occmed/article-abstract/71/3/144/6217385
14. Chang, A. Y., Cullen, M. R., Harrington, R. A., & Barry, M. (2021). The impact of novel coronavirus COVID-19 on noncommunicable disease patients and health systems: a review. *Journal of internal medicine*, *289*(4), 450-462. https://onlinelibrary.wiley.com/doi/abs/10.1111/joim.13184
15. Braunstein, L. Z., Gillespie, E. F., Hong, L., Xu, A., Bakhoum, S. F., Cuaron, J., ... & Khan, A. J. (2020). Breast radiation therapy under COVID-19 pandemic resource constraints—approaches to defer or shorten treatment from a comprehensive cancer center in the United States. *Advances in Radiation Oncology*, *5*(4), 582-588. https://www.sciencedirect.com/science/article/pii/S2452109420300658
16. Amran, M., Debbarma, S., & Ozbakkaloglu, T. (2021). Fly ash-based eco-friendly geopolymer concrete: A critical review of the long-term durability properties. *Construction and Building Materials*, *270*, 121857. https://www.sciencedirect.com/science/article/pii/S0950061820338617
17. Leo, C. G., Sabina, S., Tumolo, M. R., Bodini, A., Ponzini, G., Sabato, E., & Mincarone, P. (2021). Burnout among healthcare workers in the COVID 19 era: a review of the existing literature. *Frontiers in public health*, *9*, 750529. https://www.frontiersin.org/articles/10.3389/fpubh.2021.750529/full
18. Mumtaz, S., Rana, J. N., Choi, E. H., & Han, I. (2022). Microwave radiation and the brain: Mechanisms, current status, and future prospects. *International Journal of Molecular Sciences*, *23*(16), 9288. https://www.mdpi.com/1422-0067/23/16/9288
19. Zimmerling, A., & Chen, X. (2021). Innovation and possible long-term impact driven by COVID-19: Manufacturing, personal protective equipment and digital technologies. *Technology in Society*, *65*, 101541. https://www.sciencedirect.com/science/article/pii/S0160791X21000166
20. Søvold, L. E., Naslund, J. A., Kousoulis, A. A., Saxena, S., Qoronfleh, M. W., Grobler, C., & Münter, L. (2021). Prioritizing the mental health and well-being of healthcare workers: an urgent global public health priority. *Frontiers in public health*, *9*, 679397.

https://www.frontiersin.org/articles/10.3389/fpubh.2021.679397/full

21. Gargani, L., Soliman-Aboumarie, H., Volpicelli, G., Corradi, F., Pastore, M. C., & Cameli, M. (2020). Why, when, and how to use lung ultrasound during the COVID-19 pandemic: enthusiasm and caution. *European Heart Journal-Cardiovascular Imaging*, *21*(9), 941-948. https://academic.oup.com/ehjcimaging/article-abstract/21/9/941/5855021
22. Thompson, D. A., Lehmler, H. J., Kolpin, D. W., Hladik, M. L., Vargo, J. D., Schilling, K. E., ... & Field, R. W. (2020). A critical review on the potential impacts of neonicotinoid insecticide use: current knowledge of environmental fate, toxicity, and implications for human health. *Environmental Science: Processes & Impacts*, *22*(6), 1315-1346. https://pubs.rsc.org/en/content/articlehtml/2020/em/c9em00586b
23. Dennis, A., Wamil, M., Alberts, J., Oben, J., Cuthbertson, D. J., Wootton, D., ... & Banerjee, A. (2021). Multiorgan impairment in low-risk individuals with post-COVID-19 syndrome: a prospective, community-based study. *BMJ open*, *11*(3), e048391. https://bmjopen.bmj.com/content/11/3/e048391.abstract
24. Sridharan, S., Kumar, M., Singh, L., Bolan, N. S., & Saha, M. (2021). Microplastics as an emerging source of particulate air pollution: A critical review. *Journal of Hazardous Materials*, *418*, 126245. https://www.sciencedirect.com/science/article/pii/S0304389421012097
25. Chang, J. Y., Mehran, R. J., Feng, L., Verma, V., Liao, Z., Welsh, J. W., ... & Wang, X. (2021). Stereotactic ablative radiotherapy for operable stage I non-small-cell lung cancer (revised STARS): long-term results of a single-arm, prospective trial with prespecified comparison to surgery. *The Lancet Oncology*, *22*(10), 1448-1457. https://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(21)00401-0/fulltext
26. Mathisen, T. F., Ackland, T., Burke, L. M., Constantini, N., Haudum, J., Macnaughton, L. S., ... & Sundgot-Borgen, J. (2023). Best practice recommendations for body composition considerations in sport to reduce health and performance risks: a critical review, original survey and expert opinion by a subgroup of the IOC consensus on Relative Energy Deficiency in Sport (REDs). *British Journal of Sports Medicine*, *57*(17), 1148-1158. https://bjsm.bmj.com/content/57/17/1148.abstract
27. Maas, A. I., Menon, D. K., Manley, G. T., Abrams, M., Åkerlund, C., Andelic, N., ... & Zemek, R. (2022). Traumatic brain injury: progress and challenges in prevention, clinical care, and research. *The Lancet Neurology*, *21*(11), 1004-1060. https://www.thelancet.com/article/S1474-4422(22)00309-X/fulltext