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Scientists warning on the ecological effects of radioactive leaks on ecosystems

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A nuclear leakage or tactical nuclear weapon use in a limited war could cause immense and long-lasting ecological consequences beyond the direct site of exposure. We call upon all scientists to communicate the importance of the environmental impacts of such an event to all life forms on Earth, including humankind. Changes to ecosystem structure and functioning and species extinctions would alter the biosphere for an unknown time frame. Radiation could trigger cascade effects in marine, atmospheric and terrestrial ecosystems of a magnitude far beyond human capabilities for mitigation or adaptation. Even a "tactical nuclear war" could alter planet Earth's living boundaries, ending the current Anthropocene era.

KEYWORDS

tactical bomb, radiation, pollution, nuclear war, biodiversity loss, ecosystem services, species extinction

One sentence summary

We describe the devastating effects of nuclear radiation and its long-lasting consequences on Earth's ecosystems.

Main text

Recent events related to the armed conflict in Ukraine have been linked to the possibility of radioactive leaks, the risk of using "tactical nuclear bombs," or even full-scale nuclear war. The shelling of the Zaporizhzhia Nuclear Power Plant represents a particular risk. As environmental scientists, ecologists, and conservationists from all corners of the world, we would like to call upon all scientists to communicate the risks associated with radiation to the public and policymakers. We must be proactive and explain to our people the stark implications of an accidental nuclear leak, the use of tactical bombs, or a full-scale nuclear war if any of these were to happen. Our ethical and professional duty is to communicate the multiple potential consequences to life on Earth, including humankind. We propose a key summary of facts to communicate our concerns to leaders, stakeholders, and society effectively.

In any socioecological system, many variables, components, and processes can be affected by human intervention. Radiation leakage and nuclear explosions can severely affect natural (and anthropogenic) systems. Adding a major disturbance to the intrinsic uncertainty and unpredictability of these systems (Battisti et al., 2016). Any nuclear explosion can trigger ecological consequences far beyond the site where it occurs. Nuclear weapons can release massive radiation with total burdens of radionuclides amounting to millions of curies of strontium, cesium, plutonium, and carbon (Leaning, 2000; Pereira et al., 2022). Those consequences are long-lasting, affect ecosystem structure and function, lead to decline and local extinctions, severely hamper life on Earth, and reduce opportunities for humans to sustain our civilization (Leaning, 2000; Burkitbayev et al., 2011).

A nuclear bomb detonation spreading radiation causes direct physical effects to all life forms, including multiple species mortalities, mutations (Schmitz-Feuerhake et al., 2016), and impairment of species' capacity to continue reproducing and playing their ecological roles in nature. Abiotic elements and nutrient cycles will suffer severe radiation contamination and cascading effects on terrestrial and marine life (Paraskevi et al., 2021). Atmospheric dynamics, freshwater resources, underground water, and ocean currents can move particles containing radioactive substances far beyond the point of explosion. Their contamination can last hundreds or even thousands of years (Burkitbayev et al., 2011).

While there has rightly been a focus on the tragic consequences of the ongoing Russian-Ukrainian conflict on the civilian population of Ukraine and its broader implications for geopolitics, the world economy, food security, and human lives, the impacts on ecosystem services have been largely overlooked. We need to recognize urgently the immediate effects of the war on air quality, biodiversity loss due to deforestation, wildfires, habitat loss, and their effects on water resources, soils, and landscape morphology. These impacts would increase significantly in the event of an accidental or deliberate release of radiation (Balonov, 2019; Dombrovski et al., 2022).

Beyond the immediate devastating effects of a nuclear blast, the impact of a nuclear plume, depending on its magnitude, is to obstruct solar radiation, altering climate locally, regionally, and potentially globally. Increased UV radiation, less available atmospheric oxygen, and lower atmospheric temperature will affect plant primary productivity, causing a decline in crop production in the area affected by the plume (Tinus and Roddy, 1990; Nakanishi and Tanoi, 2016). Food security globally could be affected, with more significant plumes, compounding the effects already seen from the restrictions on food exports from Ukraine. Food chains may be contaminated in areas affected by the plume, making any agricultural products unfit for human consumption.

Biodiversity loss can be massive in places where nuclear bombs explode. Large fires can also extend the damage and spread radioactive particles beyond the explosion site, leading to soil erosion and nutrient depletion (Tinus and Roddy, 1990; Gudkov et al., 2011). Nuclear explosions can potentially destroy forests, wetlands, and biodiversity hotspots. Ecosystem services such as pollination would be affected by species extinctions (Møller et al., 2012; Nakanishi and Tanoi, 2016). Multiple nuclear explosions could accelerate the demise of many species already threatened with extinction because of climate change and other anthropogenic causes. Endemic species could be lost as the radioactivity can spread over hundreds of square kilometers, potentially eliminating entire populations of endangered animals and plants. The 1986 explosion of the Chernobyl nuclear reactor and the subsequent open reactor core fire significantly contaminated more than 100,000 km^2. Radioactive dust from the site was identified throughout most of Europe (except for the Iberian Peninsula).

Despite much data about the effects of radiation exposure from bomb detonation sites or nuclear accidents such as Chernobyl, the public and decision-makers are generally unaware of the long-lasting consequences for whole ecosystems. The Chernobyl Forum (Balonov, 2007) summarized the effects of immediate and middle-term radioisotope exposure. The report concluded that long-lasting bioaccumulation pervaded at all trophic levels. The radionuclide fallout could reach regions far beyond the detonation site with a severe nuclear exchange. Earth's carrying capacity to sustain life could be seriously hampered, if not crippled. Contrafactual results suggest that following the Chernobyl accident, biodiversity boomed after a few decades in the surrounding area (Møller and Mousseau, 2011; Deryabina et al., 2015). However, as that accident occurred at a single site, it cannot be used as an argument to suggest that

the impact of multiple nuclear bomb detonations will be minimal. The cumulative effect of nuclear bombs exploding in different locations would have an additive effect with devastating consequences for multi-taxa species abundance and richness, a decline in species recruitment, and artificially changing species composition in communities affected by radiation (Balonov, 2007).

All these cascading effects could directly hamper human survival and living conditions as we know them. The Chernobyl explosion, the Fukushima disaster, and other radiation leaks may have misled decision-makers to underestimate the grave consequences of a nuclear war, even on a limited basis. Global food web disruption, abrupt changes in climate caused by a nuclear winter, and radioactive air, water, and soil pollution could result in the deaths of many people. The direct consequences of a nuclear explosion will be widespread hunger, radiation toxicity, and large areas of uninhabitable ecosystems (Balonov, 2007; Burkitbayev et al., 2011). A "tactical nuclear war" could end the Anthropocene era by moving Earth far from the living boundaries that make the planet habitable for humans and many known species.

In essence, what humanity has failed to recognize, thereby causing extensive damage to the planet, is the value of all life on Earth. All humans must stand together to prevent a catastrophic nuclear event.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

CB completed the idea, writing, and references compilation. The first drafts were discussed with WR. All other authors commented, added, and proposed ideas and editing changes to the main manuscript. TF helped to format the final manuscript. CA reviewed the grammar. RM also helped handling the first stages of the submission process. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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