Austrian Academy of Sciences

Possible Effects of Nuclear War

An Austrian Perspective

Abstracts

CONTEXT

In December 2021, the UN General Assembly decided to establish an independent Scientific Panel on the Effects of Nuclear War, on the background of a renewed prospect of nuclear war and the catastrophic, potentially global humanitarian and environmental consequences that would result from it. It called on international organisations, the scientific community and other relevant stakeholders to support the work of this panel, which is tasked with providing a comprehensive report to the UN.
It is in this context that a workshop is organised by the Austrian Academy of Sciences, together with some members of the UN Scientific Panel on the Effects of Nuclear War and the Scientific Advisory Group for the Treaty on the Prohibition of Nuclear Weapons. It aims at fostering dialogue among international experts and the Austrian research community. We warmly invite researchers from across disciplines – ranging from physical and environmental sciences, public health to social sciences, including novel approaches such as data science – to share their work and perspectives. The workshop offers a unique opportunity to engage with leading international initiatives, contribute to a globally relevant research agenda, and explore avenues for collaboration in a field of profound societal importance. For more information on the UN Panel, see https://disarmament.unoda.org/en/panel-effects-nuclear-war/home

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Cover image: „Hood“ by Dona Jalufka, 2009, oil on canvas, 80 x 120 cm (courtesy of the artist)

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The threats of nuclear war: a natural science perspective

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What makes nuclear war an existential threat? It is the combination of the severe consequences of nuclear weapons use and the fact that such use is possible, even though proponents of nuclear deterrence seek to deny the latter. Nuclear explosions release energy in the form thermal and mechanical energy, and radioactivity. Consequently, immediate damage comprises setting ignitable materials on fire and causing burns, mechanical destruction of buildings and mechanical injuries, and dispersion of radioactive material in the atmosphere with subsequent acute or stochastic radiation damage to organisms. In addition to fires ignited directly by the explosion, damage to natural gas, petrol, and electricity infrastructure will cause additional fires. Depending on the environment affected, large amounts of soot can be produced and transported into the stratosphere where aerosol particles may remain for several years. Soot aerosol is able to block the incoming solar radiation to an extent that, in the case of nuclear war scenarios involving attacks on cities and industrial compounds, would lead to significant effects on climate. Temperatures could decrease on the order of degrees centigrade over the affected hemisphere, with subsequent impact on the hydrological cycle and even the ocean circulation. Furthermore, altered stratospheric chemistry would lead to significant ozone destruction, causing an increase of ultraviolet radiation on the Earth‘s surface. These effects would diminish agricultural yields to an extent that alone, without considering cascading socio-economic effects, is able to threaten, in the worst of scenarios published, billions of people with starvation.

Beyond the blast: cascading economic and societal impacts of nuclear war

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While our understanding of the atmospheric chemistry and health sciences surrounding nuclear warfare has deepened significantly over the last decades, the fundamental threat of nuclear conflict has transformed in ways previously unimagined. Today's risk is defined not just by direct physical devastation, but by the profound vulnerability of a hyper-connected, globalized world. The UN Scientific Panel on the Effects of Nuclear War conducts the first comprehensive assessment of the cascading, system-wide impacts of nuclear war on the modern global economy, finance, and digital society. This keynote will explore how contemporary global networks have created unprecedented single points of failure. From highly concentrated value chains, where a handful of facilities supply the entire world's life-saving antibiotics and semiconductors, to deeply integrated financial markets and digital infrastructures vulnerable to electromagnetic pulses, a localized conflict today could trigger catastrophic global collapse. Drawing from a massive systemic review of over 4,000 scientific papers spanning economics, finance, and electrical engineering, this address will highlight emerging knowledge gaps regarding critical goods like energy and medicine. Ultimately, the keynote argues that while science has long understood the effects of nuclear war on human metabolism, we are only now beginning to comprehend its devastating potential to collapse our „societal metabolism."

The medical dimensions of nuclear war – IPPNW and the Austrian experience in providing data since the publication of the „Last Aid"- documents

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The presentation informs about IPPNWs medical publications about the health consequences of nuclear bomb explosions and possible nuclear wars, various scenarios, since the 80ies. IPPNW (International Physicians for the Prevention of Nuclear War) was founded by Harvard Cardiologist Bernard Lown and Jevgenij Chasow, Russian Cardiologist and member of the Academy of Sciences in Moscow. Both physicians derive their demand for a prohibitioan of nuclear weapons from their scientific knowledge about health consequences of NW-explosions. Soon, Physicians in many countries founded IPPNW sections. In Austria founding president was pediatrician Prof. Walter Swoboda.
The presentation explains the „Seven Medical Reasons for a Prohibition of Nuclear Weapons" (Renoldner) as well as activities and experiences of the Austrian chapter of IPPNW such as

- Meetings with the respective chairpersons of the department for disarmament, arms control and non-proliferation in the Austrian Ministry for Foreign Affairs (BMEIA), changes after the end of USSR and after Austria has joined the EU. Meetings with members in the Austrian parliament and in the Diplomatic Academy of Vienna.
- IPPNW's medical campaign for a CTBT till the achievment of the traety and the opening of CTBTO in Vienna
- IPPNWs camapaign for extending Nuclear Weapon Free Zones (NWFZ) and its delegation to OSCE in Vienna.
- Cooperation with Joseph Rotblat and Enil Blix
- Austrian IPPNW doctors' activities at VIC (NGO-Cte.-on-peace, IAEA, NPT-prep.com etc.)
- Founding the International Campaign to Abolish Nuclea Weapons in 2007 together with other NGOs on the basis of positive experiences in the campaign for a prohibition of anti-personal mines.
- Focusing on the danger of AI in NW systems, events and activities with AI specialists prof. Michael Schrevel and prof. Toby Walsh

After years of multiple efforts for disarmament and a wide support and consensus about its necessity, today we are confronted with new wars and a new wave of and call for further armament including the nuclear. How do we as doctors face these new challenges?

Literature: Klaus Renoldner: Austria and ist Efforts Towards a Prohibition of Nuclear Weapons
In: Medicine, Conflict and Survival, Routledge, Vol 34, Nr. 4, Dec. 2018 pp 258 - 262.

Chornobyl experience for assessing radiological processes in Austrian forest ecosystems

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Forests cover approximately 48% of the territory of Austria. In the event of radioactive fallout, forest ecosystems may act as major long-term reservoirs of artificial radionuclides, influencing their migration in the environment and their potential transfer to humans.
A unique opportunity to investigate the processes of radionuclide accumulation and redistribution in forest ecosystems was provided by the accident at the Chornobyl nuclear power plant. Long-term studies conducted in the Chornobyl Exclusion Zone have made it possible to trace the behaviour of 137Cs, one of the most environmentally significant anthropogenic radionuclides, in natural forest ecosystems over several decades following large-scale contamination [1]. The results showed that about two to three years after the radioactive fallout event, root uptake becomes the dominant pathway of 137Cs transfer into trees. With the onset of this stage, biological characteristics of plants and ecosystem processes prevail over meteorological factors in controlling radionuclide dynamics. Studies of Pinus sylvestris revealed pronounced seasonal variability in the distribution of 137Cs among tree organs, with the highest activities in needles and young shoots in spring–summer and maximum concentrations in wood in winter. Concentrations of 137Cs in above-ground tissues varied by nearly an order of magnitude over the course of a year, despite the absence of new external inputs, indicating strong internal redistribution processes [2].
These results may be applicable in Austria, where a substantial proportion of the territory is forested and forest products are widely used by the population. The identified patterns may be important for assessing potential pathways of radionuclide transfer to humans and reducing associated risks in case of forest contamination.

[1] Zarubina N. (2023) Circulation of 137Cs in Various Forest Plants in the Chornobyl Exclusion Zone during the Year. Ecologies 4(2), 310-324. https://doi.org/10.3390/ecologies4020020.

[2] Zarubina N.Y. and Koeberl C. (2026) The influence of weather conditions on the redistribution of 137Cs in forest ecosystems. Science of the Total Environment 1012, paper no. 181246, https://doi.org/10.1016/j.scitotenv.2025.181246.

Human exposure to low temperatures and increasing heating demand in a nuclear winter

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Various studies have addressed atmospheric perturbations following nuclear weapon detonations and their impacts on natural and managed ecosystems, including food security. Little research is done on how humans are affected by temperature change that may impair overall well-being, health, and ultimately habitability of strongly cooling places. Besides direct impacts on human well-being, these impacts can cascade through society in the form of mass displacement and loss of human capital among others, with repercussions in various sectors. Residential heating allows for adapting to cold temperatures but requires infrastructure and continuous energy supply.
Here we present a study that combines climate projections for a regional nuclear conflict, physics-based modelling, and data science to estimate the above human exposures. In the peak year of cooling, human populations subject to temperatures below 0°C increase by 500 million people, three quarters of which live in cities. Nearly 300 million of these also experience coldest-month temperatures below -5°C underpinning that this is a localized effect impacting substantial populations. Heating energy demand increases globally by nearly 30%, peaking in the fourth year post-conflict. Hotspots are the conflict region India-Pakistan and higher latitudes, i.e., North America, Europe, and East Asia. Urban areas are again over-proportionally affected with about 70-80% of additional energy demand. Notably, several of these hotspot regions are highly dependent on energy imports for heating, such as the EU or China, which further exacerbates their vulnerability in a geo-political conflict combined with weather disruptions.

Inventory and environmental distribution of key radionuclides from historic nuclear tests as possible analogues for nuclear war

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Historic atmospheric nuclear test data provide valuable though somewhat limited analogues for nuclear war scenarios. This study investigates the extent to which historic test data can inform assessments of nuclear war consequences. The goal is to draw lessons from the inventory and environmental distribution of key radionuclides which can be transferred to nuclear war scenarios. For the single test, individual historic tests are selected that have parameters like anticipated scenarios of individual nuclear weapons explosions. Regarding a large-scale nuclear war, the question is whether the accumulated effects of atmospheric nuclear tests might represent the effects of nuclear war. An updated list of 543 atmospheric nuclear tests is established, and the derived isotopic emission inventory is compared to the data presented in the UNSCEAR (2000) report. The environmental inventories of radionuclides are studied along three different time frames: (1) immediate local inventory of short-lived isotopes, (2) medium-term regional inventory of intermediate-lived isotopes with tropospheric transport, (3) long-term global inventory of long-lived isotopes with stratospheric transport.

State Advocacy for Nuclear Disarmament (StAND)

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Since the dawn of the nuclear age, state representatives have repeatedly affirmed their commitment to nuclear disarmament in countless speeches and documents. Even as nuclear arms competition resurges and arms control agreements erode, such declarations remain commonplace. Yet some states go beyond mere lip service: they persistently champion disarmament initiatives, promote a nuclear-weapon-free world in international negotiations, and challenge the nuclear order. While existing scholarship acknowledges the influence of these advocate states — such as Austria in the processes leading to the Treaty on the Prohibition of Nuclear Weapons (TPNW) — it rarely explains which states assume and sustain this advocacy role over time, and why.

The StAND research project addresses these questions by introducing a concept of state advocacy as the public promotion of political change through communication, rule-making, and practical contributions. It identifies state advocates through LLM-assisted classification of disarmament statements in the UNGA First Committee and develops a typology of state advocacy based on co-sponsorship frequency and priority of resolutions (1946–2024). In a second step, the project uses fuzzy-set Qualitative Comparative Analysis (fs/QCA) to explain which combinations of conditions — including domestic politics, military alliances, geographic proximity to nuclear arsenals, experiences with nuclear tests and accidents, and key individuals — are associated with the emergence and persistence of states advocating for this cause. By conceptualizing, measuring, and explaining state advocacy across the nuclear age, this project advances debates on norm and policy entrepreneurship and offers a framework for understanding how states promote change in response to global nuclear risks.

FALLAUT – Consequence Analysis of a Nuclear Fallout on Austrian Critical Infrastructure

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Due to the current geopolitical situation in Europe, the scenario of a nuclear explosion not only at a greater distance but in the immediate vicinity of Austria has become considerably more likely in recent years. The consequences for the affected population as well as for critical supply infrastructures and supply chains could be devastating. The KIRAS project **"FALLAUT"** investigates the potential consequences of a hypothetical use of nuclear weapons close to Austrian borders. Therefore, a **source term for atmospheric nuclear explosions** is developed and **atmospheric transport calculations using the Flexpart V.11 open-source model** are performed. These calculations subsequently serve as input for **radiological models** to estimate doses across Austria via the most important pathways. We look specifically at the possible **consequences for critical infrastructures** such as the countrywide food supply or the functioning of the national health service. Additionally, potential **effects on supply chains and other cascading effects** are analyzed using stochastic models. The results of the project will help to further develop suitable emergency planning also for close-by nuclear explosions. Thus, the resilience can be increased while at the same time knowledge on the cascading effects of even single nuclear weapon explosions are better understood.

The dual-use dilemma of nuclear technology

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The controversy over Iran and its enrichment program illustrates how difficult it is to separate military and civilian uses of nuclear technology, despite extensive international efforts such as agreements and safeguards measures. This problem will likely intensify in the future based on planned technologies. So-called advanced reactor systems, although considered proliferation-resistant, are often embedded in advanced fuel cycles with reprocessing, i.e., the separation of fissile materials from spent fuel. At the same time, a variety of current SMR concepts use HALEU. This significantly higher-enriched uranium than is usually employed for power reactors is much better suited for nuclear weapons.

This contribution analyzes the resulting implications for non-proliferation: The more actors have easier access to weapons-usable material, the more likely the construction and ultimately the use of such weapons becomes.

Learning from the past: Abundance and isotope signatures of (long-lived) radionuclides in the environment

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In the event of a nuclear detonation, rapidly identifying the source and nature of the fallout is critical for assessing public health risks, protecting the food chain, and enabling geopolitical attribution. In the past, man-made radionuclides have entered the environment by nuclear accidents or from the nuclear fuel cycle apart from atmospheric nuclear weapons testing. Long-lived radionuclides of uranium (U), plutonium (Pu) or caesium (Cs) will be part of our environment over thousands of years and require long-term monitoring and a comprehensive understanding of their environmental migration behaviour. For this purpose, contributions from sources other than the globally distributed nuclear weapons fallout need to be quantified to determine the distribution pathways. A validated, multi-isotope toolbox using Accelerator Mass Spectrometry (AMS) has the potential to significantly help resolve this problem. Especially isotopic ratios have proven to be useful signatures for contamination source identification. For example, the Pu isotope ratios 240,241Pu/239Pu as well as the Caesium (Cs) ratios 134,135Cs/137Cs have become important markers for recent emissions from reactor sources. The $^{233}U/^{236}U$ ratio is being validated as a novel and specific tracer for weapons fallout, resolving ambiguities from other uranium sources. ^{90}Sr, a major long-term internal dose contributor, can now be measured at ultra-trace levels thanks to recent instrumental advances. By this integrated isotope approach, we provide a robust and quantitative framework that can be also deployed for verification of protocols, and which offers a methodological contribution to the evidence base required by the UN Scientific Panel on the Effects of Nuclear War.

Cascading disruptions in natural gas, fertilizers, and crops following major conflicts

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Global food security depends on tightly coupled international supply chains including natural gas, mineral fertilizers, and staple crops. When key trading partners withdraw or critical supply routes close due to conflict, political instability, or infrastructure collapse, import-dependent countries face abrupt supply disruptions with limited alternatives. We integrate bilateral trade in natural gas, nitrogen, phosphorus and potassium fertilizers, and eleven staple crops accounting for approximately 70% of plant-based calories into a cascading-impact model spanning 208 countries, 20 geopolitical blocs, and the period 1992–2023.

Total trade isolation, reminiscent of the onset of nuclear war, could result in a loss of up to 22% of global caloric consumption, peaking during the most recently evaluated years. Structural vulnerabilities vary greatly. Regions largely lacking some parts of the supply chain face near-total crop supply collapse, while few countries can cover the whole nexus through domestic resource endowments and production capacities. Market power is most concentrated and most volatile in the upstream gas and mineral-fertilizer layers, from which shocks propagate downstream. Food stocks provide only limited resilience with half of humanity living in countries disposing of stock lasting less than three months. The non-aligned states and low- to middle income countries in the Global South face the highest food-insecurity rates, hold the smallest reserves, and trade least among each other. If the major economic and military blocs reduce or seize their external trade, these countries have no capacities and infrastructure to redistribute resources. Our results identify the structural bottlenecks of the global agrifood system and propose leverage points to enhance resilience.

Nuclear Bomb Glasses as Analogs for Natural Glasses

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Glasses can be produced during natural (impact, volcanism, friction melting, lightening…) or human-made (nuclear explosions) high-energy events, produced either from melting of the impacted rocks and/or the condensation of vaporized site material. Impact events produced a variety of impact glasses, including the rare tektites. The glasses formed during a nuclear explosion are called, e.g., the trinitites (produced during the first nuclear explosion, the Trinity test), the Hiroshima glasses, or nuclear glassy fallouts (atomsites). Nuclear fallout glasses were found and sampled from multiple American historical nuclear test sites , near the city of Hiroshima, on the Semipalatinsk Soviet nuclear testing site, and the Algerian French nuclear test site. These nuclear deposits have mainly two types of morphologies: a glass layer found on the explosion crater-shaped depression, or aerodynamic glassy droplets. The Trinity test happened on the 16th of July 1945, in the White Sand Missile Range, in the New Mexico desert (USA). This test had a yield between 21 and 25 kt (TNT equivalent). The most abundant type of trinitites is a two-centimeter-thick green glassy layer found at the surface of a 300 m radius shallow surface depression after the explosion. The other morphological families are pancake trinitites, red trinitites, and aerodynamic dumbbells. The mineral inclusions in trinitites revealed that the crater material was subjected to maximum temperatures in excess of a few thousand degrees and pressures of <10 GPa, the latter being mostly lower than for natural impact events. The formation of trinitites is generally explained by two possible scenarios: (i) the glasses are the product of the quenching of the melted surface materials that were pulled into the fireball and rained out on the nearby surface, or (ii) they result from the condensation of vaporized materials (from the bomb and the site materials) that could be mixed with molten site materials. The large ranges of variations found for the oxygen and silicon isotopic compositions of the Hiroshima fallouts demonstrated that those melts formed by condensation in the nuclear fireball.

Recent geochemical investigations of the oxygen and silicon isotopic compositions of trinitites allowed to refine their formation scenario (Asset et al., 2025). In contrast to Hiroshima fallout deposits (see below), no oxygen mass-independent isotopic fractionation was found in the trinitites. The chemical and isotopic compositions of the chemical groups indicate that the silica phases are molten fragments of the site material (in case of nuclear explosions, these would include anthropocentric materials, which would be particularly noticeable if, for example, a city or technical/industrial facilities are hit), while the CaMgFe and alkali phases are produced by mixing of condensates and molten site material. Thus the vaporized material condensed and grew by agglomeration with other condensates and liquid materials. These agglomerates rained on the surface and quenched, forming the trinitites.

This scenario is different from the formation of the Hiroshima glasses but shows some similarities to tektite formation. We recently conducted a study of the chemical composition, triple oxygen and silicon isotope compositions of a set of Hiroshima glasses collected on the beaches of Hiroshima Bay (Asset et al., 2024). The isotopic compositions allow to look for specific signatures due to condensation processes, either equilibrium or kinetic, and to chemical-isotopic trajectories, which are specific to a sequence produced by fractionated condensation in the Hiroshima fireball. Our analyses support the hypothesis that the Hiroshima glasses are gas phase condensates formed in the nuclear fireball, and the Hiroshima glasses may be the first analog to high-temperature inclusions in chondritic meteorites and may illustrate the different fractionation mechanisms that occur during gas-solid transition in the solar nebula.

Thus while nuclear explosions are undoubtedly not a desirable experimental method, the analysis of products from previous events have contributed to our understanding of natural high-temperature/high-pressure processes. This can also be discussed in the light of recent studies of surrogate nuclear explosion debris.

Asset N., Chaussidon M., Villeneuve J., Charnoza S., Koeberl C., Wannier M., and Robert F. (2024) Condensation of fallout glasses in the Hiroshima nuclear fireball resulting in oxygen mass-independent fractionation. Earth and Planetary Science Letters 626, paper #118473, doi.org/10.1016/j.epsl.2023.118473.

Asset N., Chaussidon M., Koeberl C., Villeneuve J., and Robert F. (2025) The formation of the trinitites unveiled by their oxygen and silicon isotopic compositions. Geochimica et Cosmochimica Acta 400, 214–226, doi.org/10.1016/j.gca.2025.05.011.

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