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How Can We Prepare for and Respond to Radiological Incidents During Armed Conflicts?

Serie | All-Hazards Preparedness and Response

ISGlobal Barcelona Institute for Global Health

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[This document is one of a series of discussion notes addressing fundamental questions about global health. Its purpose is to transfer scientific knowledge into the public conversation and the decision-making process. These documents are based on the best information available and may be updated as new information comes to light.]

15 December 2023

Photograph: President of Ukraine Official website (www.president.gov.ua)

Preparedness for and response to radiological incidents involves multiple factors that can be integrated into the framework of an all-hazards approach, as radiological incidents have many similarities with other emergency or disaster situations. Current systems need to be improved as effective planning and response is crucial to safeguarding public health in the event of an emergency. Read more about the all-hazards approach here.

The war in Ukraine has renewed fear that nuclear powers will deploy **nuclear weapons** or **launch an attack on a nuclear power plant**, such as the one in Zaporizhzhia. Since early in the war, Russia has threatened to use tactical nuclear weapons and suggested that Ukraine and the United States may do the same.[1,2,3]

In recent months, a number of institutions have undertaken efforts to increase awareness about the **protective measures necessary in case of a nuclear emergency**. The International Commission on Radiological Protection (ICRP) has published a number of reports that are available for public consultation, such as *ICRP Publication 146 Radiological Protection of People and the Environment in the Event of a Large Nuclear Accident* (2020) and *Advice for the Public on Protection in Case of a Nuclear Detonation* (end of 2022). Other institutions such as the US Centers

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[1] The New York Times (2022). With Bluster and Threats, Putin Casts the West as the Enemy, https://www.nytimes.com/2022/09/30/world/europe/putin-speech-ukraine-russia.html

[2] Cadena Ser (2022). Rusia alimenta el temor a una escalada nuclear en Occidente tras acusar a Ucrania de preparar la 'bomba sucia, https://cadenaser.com/nacional/2022/10/24/rusia-alimenta-el-temor-a-una-escalada-nuclear-en-occidente-tras-acusar-a-ucrania-de-preparar-la-bomba-sucia-cadena-ser/

[3] El Periódico (2022). Joe Biden: Joe Biden: "El armagedón nuclear está más cerca que nunca desde la crisis de los misiles de Cuba", https://www.elperiodico.com/es/internacional/20221008/biden-armagedon-guerra-fria-ucrania-putin-76954446

for Disease Control and Prevention have published similar recommendations.

This document analyses different **types of radiological incidents** that a war can cause and examines potential health effects. It also presents **lessons learned** from past responses and **recommendations** on how to prepare for and respond to future radiological incidents •

1. Impact of Radiological Incidents

"The nuclear event considered most likely in the Ukraine war is use of a small tactical nuclear weapon. Although these weapons have short ranges, their yield may exceed that of the bombs dropped on Hiroshima and Nagasaki."

Radiological incidents at times of armed conflict can have dramatic direct and indirect effects on human health, including a significant loss of life.

Nuclear weapons

Nuclear fission weapons, such as the bombs dropped on Hiroshima and Nagasaki in 1945, involve a series of chain reactions that cause a nuclear explosion. Deployment of a nuclear weapon, whether by missile or a portable tactical weapon, would trigger a chain of events endangering the population in affected areas. These events include:

- **A shock wave** capable of destroying buildings within several kilometres of the blast site.
- **A thermal pulse**, or fireball, containing extremely hot gases that can cause skin burns, eye injuries and the ignition of combustible materials within several kilometres of the blast site.
- **Initial radiation from the fireball**, which can cause injury up to several kilometres away.
- **Radioactive fallout**, which is residual radioactive material that is swept into the atmosphere following a blast and then falls back to earth.

Dirty bombs

Dirty bombs use nonradioactive explosive material, such as dynamite, to detonate a blast that carries radioactive material in the form of dust or pellets into the atmosphere. The blast wave can cause severe injuries and property damage, and is generally considered the greatest threat. The radioactive material used in dirty bombs is unlikely to cause serious injuries beyond the blast site and its immediate surroundings, but the radioactive dust and smoke produced can spread and, if inhaled, cause adverse health effects further afield.[4]

Nuclear power plant attacks.

An attack on a nuclear power plant can cause a nuclear accident. Although modern nuclear reactors are built to withstand direct attacks, indirect effects of war, such as power outages could cause the plant to explode, as electricity is crucial to controlling the fission chain reaction and cooling systems. In the current situation in Ukraine, which has no alternative sources of power, reactors are shut down and restarted according to the closeness of armed conflict.

The main danger in the event of a nuclear accident is the emission of large quantities of radioactive material and subsequent fires. The material can settle on nearby food, soil, animals, and water, from where it can enter the food chain. Depending on the magnitude of the emissions and the prevailing weather conditions, radioactive plumes can travel hundreds or even thousands of kilometres.

Within the context of the current **war in Ukraine**, the United Nations International Atomic Energy Agency (IAEA) conducts regular safety inspections of

[4] Centers for Disease Control and Prevention (CDC). More Information on Types of Radiation Emergencies, https://www.cdc.gov/nceh/radiation/emergencies/moretypes.htm

active nuclear power plants in the country and issues recommendations. These plants are in Zaporizhzhia (the largest in Europe), Khmelnitsky, Rivne, South Ukraine[5] and Chernobyl *(see Figure 1)*. The Director General of the IAEA has called for the creation of a safety and security zone around Zaporizhzhia, although no agreements have yet been reached,[6] with explosions continuing to occur in the vicinity of the plant and even on site.[6] In September 2023, the plant was still under the control of the Russian army and experiencing repeated power outages.

Figure 1. Active nuclear power plants in Ukraine

Source: Adapted from World Nuclear Association (2022). Safety of Nuclear Power Reactors, https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/safety-of-nuclear-power-reactors.aspx

Continuous improvements have been made to nuclear power plant safety and security systems since the accidents at Three Mile Island in the US state of Pennsylvania (1979), Chernobyl (1986), and Fukushima, Japan (2011).[7] Differential safety features at the power plant in Zaporizhzhia (built in the 1980s) compared with the Chernobyl plant (built in 1972) are **1)** containment structures to prevent radiation from being released into the atmosphere, **2)** power generators located inside a containment building to prevent flooding, and **3)** reactors that do not contain graphite, which contributed to the fires in Chernobyl.[8]

The **nuclear event considered most likely** in the Ukraine war is use of a small tactical nuclear weapon. Although these weapons have short ranges, their yield may exceed that of the bombs dropped on Hiroshima and Nagasaki ● [9,10]

[5] International Atomic Energy Agency. Nuclear Safety and Security in Ukraine, https://www.iaea.org/es/seguridad-nuclear-tecnologica-y-fisica-en-ucrania

[6] International Atomic Energy Agency (2022). Update 128 – IAEA Director General Statement on Situation in Ukraine, https://www.iaea.org/newscenter/pressreleases/update-128-iaea-director-general-statement-on-situation-in-ukrain

[7] Adapted from World Nuclear Association (2022). Safety of Nuclear Power Reactors, https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/safety-of-nuclear-power-reactors.aspx

[8] BBC (2022). En qué se diferencia la central nuclear de Zaporiyia de la de Chernóbil (y cuáles son los riesgos de los combates entre Ucrania y Rusia), https://www.bbc.com/mundo/noticias-internacional-63702727

[9] La Razón (2022). Esta es la diferencia entre las armas nucleares tácticas y las estratégicas, https://www.larazon.es/internacional/20221018/irbtcki5hbbmrlowpwf5gwkwby.html

[10] CNN (2022). ¿Qué son las armas nucleares tácticas y qué pasaría si Rusia desplegara una?, https://cnnespanol.cnn.com/2022/09/26/armas-nucleares-tacticas-rusia-trax/

2. Health Effects of Radiation

"Radiation affects our body in a number of ways, but mainly by interacting with our DNA: it directly breaks DNA bonds and produces free radicals that can damage cells and organs."

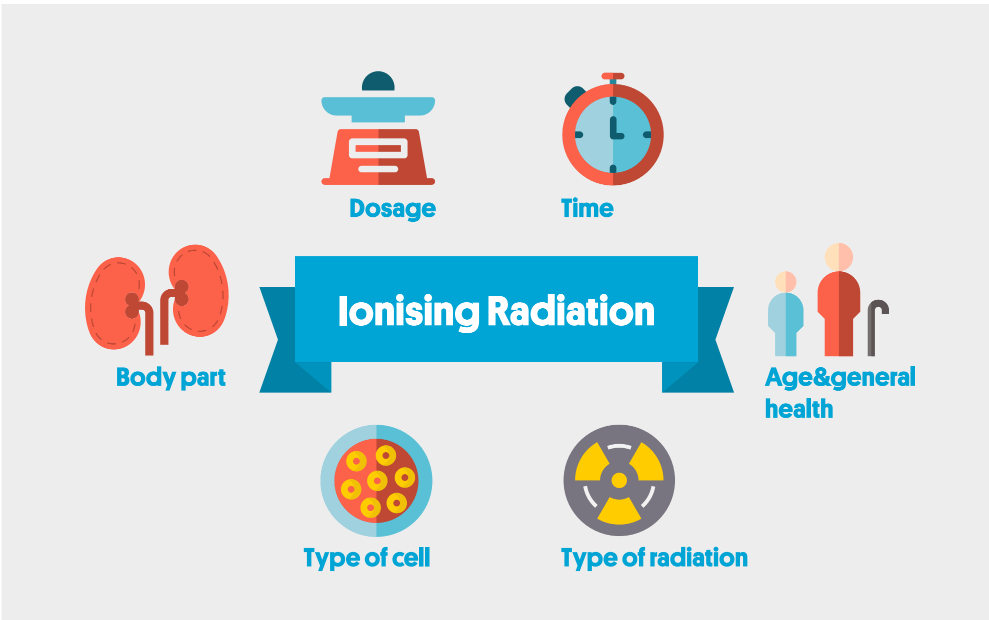
Detonation of a nuclear device, whether a missile, tactical weapon, dirty bomb or small-scale device, produces a shock wave, shrapnel, and, in the case of a nuclear weapon, intense heat. It also produces radiation, which has both **short- and long-term health effects**, which vary according to *(see Figure 2)*:

- the dose received
- the exposure time (e.g., exposure to radioactive particles in the atmosphere over years does not cause the same effects as acute exposure following a nuclear blast)
- the extent of exposure (entire body or part of it)
- the person exposed (foetuses, infants, children and immunocompromised people are more vulnerable)

Radiation affects the body in a number of ways, but mainly by interfering with DNA. It directly breaks DNA bonds and produces free radicals that can damage cells and organs. Damaged cells can:

- repair themselves
- repair themselves incorrectly or not at all, which can lead to cancer
- die in the event of extensive damage. Widespread cell death can lead to organ failure and death.

Figure 2. Factors that affect how the body reacts to ionizing radiation



Source: Let's Talk Science 2019. https://letstalkscience.ca/educational-resources/backgrounders/radiation-effects-on-body

Acute radiation syndrome (ARS) is a **short-term** health effect that occurs when a person receives a high dose (>700 mGy) of external radiation in a very short period of time. Early symptoms are nausea, vomiting, headache, diarrhoea and skin redness, which can last for minutes or days. These symptoms are common to many disorders and do not necessarily indicate ARS. A person with ARS, however, will experience similar symptoms within several days or weeks, and, depending on the dose received and the time over which it was received, may develop hematopoietic syndrome (for doses of 1-10 Gy), gastrointestinal syndrome (for doses >7Gy), or neurological syndrome (for doses >20 Gy). All these syndromes are potentially life threatening. High external radiation doses and ARS, however, are **very rare**. Of the more than 600 000 people involved in cleaning up the Chernobyl plant and limiting exposure after the accident, just 134, all first responders, were diagnosed with ARS. None of the residents around the plant, or anybody in Fukushima, developed ARS.

Cancer is the most likely **long-term** effect of radiation exposure; the type of cancer varies according to the type and dose of radiation. At low doses, the risk of cancer is very low, similar to or even lower than that associated with genetic factors, diet or exposure to certain chemicals. Of the 100 000 survivors of the atomic bombings of Hiroshima and Nagasaki included in the Japanese Life Span Study, approximately 22 500 developed cancer between 1958 and 2009, but just 990 of these cases were attributed to exposure to radiation from the bombs [11]

Box 1. 1986. The Chernobyl nuclear power plant accident

The Chernobyl nuclear power plant accident occurred in Ukraine, then part of the Soviet Union, on **April 26, 1986**. The accident occurred during a test procedure, prior to which the operators had performed a series of actions, including disabling the automatic shutdown mechanisms. By the time one of the operators went to shut down the reactor, it was already extremely unstable. The result was an uncontrollable power surge, which caused the cooling water within the reactor to vaporize, causing yet another power surge and **a steam explosion that destroyed the reactor**. The **graphite** in the reactor caught fire, and despite control efforts, **burned for many days** and continued to release radioactive material until May 6, 1986.

Of the 600 workers at the plant on the night of the accident, **2 died** as a result of the explosions[12] and 134 received high doses of radiation (0.8-16 Gy) and became ill. Of these 134 people, **28 died in the first 3 months** and another 19 died, of various causes not necessarily linked to radiation exposure, between 1987 and 2004. More than 500 000 workers from across the Soviet Union involved in clean-up and recovery operations at the plant and in contaminated areas of Ukraine, Belarus and Russia between 1986 and 1990 received cumulative doses of between 0.02 Gy and 0.5 Gy.[13] Follow-up studies of these workers have detected a slight increase in the incidence of cancer, in particular leukaemia.[14]

[11] Grant, E.J.; Brenner, A.; Sugiyama, H. et al. Solid Cancer Incidence among the Life Span Study of Atomic Bomb Survivors: 1958-2009. *Radiat Res.* 2017 May;187(5):513-537. doi: 10.1667/RR14492.1. Epub 2017 Mar 20. PMID: 28319463.

[12] World Nuclear Association (Updated 2022). Chernobyl Accident 1986, https://world-nuclear.org/information-library/safety-and-security/safety-of-plants/chernobyl-accident.aspx

[13] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2008). Assessments Of The Radiation Effects From The Chernobyl Nuclear Reactor Accident, https://www.unscear.org/unscear/en/areas-of-work/chernobyl.html

[14] Cardis, E. y Hatch, M. (2011). The Chernobyl accident--an epidemiological perspective. *Clin Oncol (R Coll Radiol)*. 2011 May;23(4):251-60. doi: 10.1016/j.clon.2011.01.510.

The authorities **evacuated** approximately 115 000 people from surrounding areas and relocated about 220 000 people from Belarus, Russia and Ukraine in 1986. The accident caused major social and psychological upheaval among those affected, as well as major economic losses throughout the region. Large regions in all 3 countries were contaminated with radioactive material, and radionuclides released from the reactor were detected in all countries in the northern hemisphere.[13,15,16]

Close to 5 million people continued to live in what were considered the most contaminated areas of Belarus, Ukraine and Russia, and received a cumulative whole-body radiation dose of about 10 mGy (the average radiation dose received by the general population from all radiation sources is about 1-3 mGy a year). Follow-up studies have detected a significant increase in the incidence of **thyroid cancer** in people who were children or adolescents at the time of exposure. While the whole-body dose was very low, the potential dose to the thyroid ranged from hundreds of milligray to more than 10 Gy. Fortunately, thyroid cancer has a very good prognosis, with estimates placing the total number of related deaths in the first 2 decades of the accident at around 15. **Iodine deficiency**, which is quite widespread in contaminated areas, appears to have contributed to the risk of thyroid cancer among those exposed to radioactive iodine. **Supplementation with stable potassium iodine shortly after exposure** reduces the dose absorbed by the thyroid gland, and continued supplementation in subsequent years appears to reduce the risk of thyroid cancer in areas with high rates of iodine deficiency. Although increases in other types of cancer have been reported, they appear to be linked to other factors, such as improved data collection, diagnoses and reporting.[13,17]

For more information on the effects of the nuclear power plant accident in Fukushima in 2011, see the ISGlobal post Fukushima: 10 Years After.

[15] Cardis, E.; Howe, G.; Ron, E. et al (2006). Cancer consequences of the Chernobyl accident: 20 years on. *J Radiol Prot.* 2006a Jun;26(2):127-40. doi: 10.1088/0952-4746/26/2/001. Epub 2006 Apr 24. PMID: 16738412

[16] Cardis, E.; Krewski, D.; Boniol, M. et al (2006). Estimates of the cancer burden in Europe from radioactive fallout from the Chernobyl accident. *Int J Cancer.* 2006b Sep 15;119(6):1224-35. doi: 10.1002/ijc.22037. PMID: 16628547 Free article.

[17] Hatch, M. y Cardis, E. (2017). Somatic health effects of Chernobyl: 30 years on. *Eur J Epidemiol.* 2017 Dec;32(12):1047-1054. doi: 10.1007/s10654-017-0303-6. Epub 2017 Sep 19. PMID: 28929329

3. How To Protect Yourself After a Nuclear Detonation?

> **“People are advised to seek shelter inside a building and to stay there, ideally in the centre of the building or in a basement to put as much material as possible between them and the radioactive material outside.”**

The effects of a nuclear detonation on the health and lives of citizens in surrounding areas depend on how **far they are from the blast site**, which is where the shock wave and thermal pulse form.

In November 2022, the ICRP published a document entitled “Advice for the Public on Protection in Case of a Nuclear Detonation”, which referred specifically to the detonation of a nuclear weapon (not the explosion of a dirty bomb or a nuclear power plant accident). The **first few minutes and 48 hours** are crucial. People are advised to seek shelter inside a building and to stay there, ideally in the centre of the building or in a basement to put as much material as possible between them and the radioactive material outside *(See Box 2)*

Box 2. Advice on how to protect yourself in case of a nuclear detonation

- After a nuclear blast, you have about 10 minutes before radioactive material starts to fall.
- The best thing you can do is go inside a building (in a basement, garage, or bomb shelter or similar). Do not attempt to flee the area on foot or by car.
- 12/24h
- The danger from fallout decreases quickly, but you should shelter in place for at least 12-24 hours after the blast, unless there is another imminent danger or you are informed by the authorities that it is safe to leave.
- Turn off all ventilation and air conditioning or heat pump systems and block the fireplace to prevent radioactive material from entering through the chimney.
- Stay tuned to updates on the nuclear emergency and use radios, text messages or, if there is access to the internet, social media to communicate.
- Do not flee the area on your own account until dangerous fallout areas have been identified and safe evacuation routes established.

Source: Reproduced with permission from the ICRP. https://www.icrp.org/page.asp?id=611

4. Preparedness For and Response to Radiological Incidents: The Challenges

"Most recommendations and action guides focus on technical problems and are aimed at experts in radiation protection, instead of providing support to affected populations."

Serious accidents at nuclear power plants have been rare, but their experience provides important information about what worked and what did not work in the response to the accident. The accidents at the **Fukushima** Daiichi nuclear power plant and **Chernobyl** nuclear power plant occurred 13 years and 37 years ago, respectively, and there are still lessons to learn from them regarding numerous issues, such as:

- **Radiation exposure assessment** and **medical follow-up** of emergency responders, evacuees and residents.
- Decisions to lift **evacuation** orders.
- **Communication** with responders and stakeholders.

These lessons are important for the prevention of future radiological events and the mitigation of their effects.

Nuclear accident response planning in the Soviet Union and Japan at the time of these accidents mostly had a technical focus (designed to reduce doses to the populations and workers), with less attention paid to **social, psychological and ethical issues**.

The accidents at the Chernobyl and Fukushima nuclear power plants, have resulted in large numbers of persons being exposed to ionising radiation.[18,19] They have also caused **major and continuing upheavals** in the lives of populations affected by fallout, both **directly** (emergency and accident responders and recover workers, evacuees, persons living in areas where dose reduction measures were taken) and indirectly (persons living in less contaminated regions).[20]

Some populations undeniably sustained health impacts from the radiological consequences of nuclear accidents, in particular early emergency workers in Chernobyl who suffered ARS[18] and young people who developed thyroid cancer as a result of fallout from the Chernobyl accident.[21,18] Many others, however, have suffered **serious consequences that were not directly related to the biological**

[18] UNSCEAR (2010). Summary of low-dose radiation effects on health, https://www.unscear.org/unscear/en/publications/2010.html

[19] UNSCEAR 2013 Report. Sources, effects and risks of ionizing radiation, https://www.unscear.org/unscear/en/publications/2013_1.html

[20] Oughton, D.H. (2013). Social and ethical issues in environmental remediation projects. *J Environ Radioact*. 2013 May;119:21-5. doi: 10.1016/j.jenvrad.2011.08.019. Epub 2011 Oct 7. PMID: 21982393.

[21] Cardis, E. y Hatch, M. (2011). The Chernobyl accident--an epidemiological perspective. *Clin Oncol (R Coll Radiol)*. 2011 May;23(4):251-60. doi: 10.1016/j.clon.2011.01.510

effects of radiation, but rather induced by the event itself, the presence of radioactive contamination and consequent emergency and remediation measures taken, and/or uncertainties about radiation levels and health effects. These include avoidable deaths of intensive care patients and older institutionalised persons as a consequence of their evacuation after the Fukushima accident;[22,23] anxiety, depression, post-traumatic stress disorders and suicide ideation among clean-up workers,[24,25,26] and continued indirect health effects (on mental health and on chronic diseases) and social and economic disturbances resulting from raised levels of radioactivity in the environment of evacuees and residents of contaminated areas.[27]

Other important lessons relevant to planning and response include:

- **Difficulties identifying affected populations**, monitoring exposure, and providing adequate follow-up care. These difficulties are linked to a shortage of planning resources and population registries and challenges managing information from different sources (such as integrating health and radiation exposure data);
- **Negative effects of certain health surveillance strategies** (stress, stigma, distrust);
- **Problems developing the necessary skills and capacities**, to deal with radiological emergencies and breakdowns in chains of command and information transfer;radiológica;
- **Poor understanding** of responsibilities and procedures, as multiple stakeholders, including local populations, are not involved in their preparation;
- **Shortage of radiological protection experts**, insufficient expertise among health care personnel to manage the direct and indirect effects of radiation, and lack of awareness among the general population of the risks of radiation;
- **Difficulties ascertaining what and how** information should be transmitted to different members of the population and relevant stakeholders and **whom** should be targeted: these difficulties, which persist today, can lead to misinformation and distrust of authorities.

[22] Tanigawa, K.; Hosoi, Y.; Hirohashi, N. et al. Loss of life after evacuation: lessons learned from the Fukushima accident. *The Lancet*. 2012 Mar 10;379(9819):889-891. doi: 10.1016/S0140-6736(12)60384-5. PMID: 22405787.

[23] Yasumura, S. Evacuation effect on excess mortality among institutionalized elderly after the fukushima daiichi nuclear power plant accident. *Fukushima J Med Sci*. 2014;60(2):192-5. doi: 10.5387/fms.2014-13. Epub 2014 Oct 4. PMID: 25283975.

[24] UN Chernobyl Forum Experts Group, Bennet, B. et al. (2006). Health effects of the Chernobyl accident and special health care programmes -Report of the UN Chernobyl Forum expert group "Health". https://apps.who.int/iris/bitstream/handle/10665/43447/9241594179_eng.pdf?sequence=1

[25] Bromet, E.J.; Havenaar, J.M. and Guey, L.T. (2011). A 25 year retrospective review of the psychological consequences of the Chernobyl accident. *Clin Oncol (R Coll Radiol)*. 2011 May;23(4):297-305. doi: 10.1016/j.clon.2011.01.501. Epub 2011 Feb 16. PMID: 21330117.

[26] Shigemura, J.; Tanigawa, T.; Saito, I. et al (2012). Psychological distress in workers at the Fukushima nuclear power plants. *JAMA*. 2012 Aug 15;308(7):667-9. doi: 10.1001/jama.2012.9699. PMID: 22893158.

[27] Bromet, E.J. (2014). Emotional consequences of nuclear power plant disasters. *Health Phys*. 2014 Feb;106(2):206-10. doi: 10.1097/HP.0000000000000012. PMID: 24378494; PMCID: PMC3898664.

Strategies for preparedness and surveillance should aim to minimise both the **direct and indirect effects** of the radiological emergency and to meet societal needs for **accurate information** on doses and health effects and provide a **system of follow-up** that allows affected population both to feel, and to be, well-monitored for radiation and its possible effects.

Lessons from previous accidents have been reviewed in depth and taken on board by national and international organisations such as the International Atomic Energy Agency, the ICRP, and the World Health Organisation. This has allowed the development of various **recommendations and guidance documents** targeting specific issues of radiation protection, training and communication, and socio-economic aspects, in order to prepare and improve decision making processes in the early and intermediate phases.[28,29,30]

However, **the majority of these texts focus on technical issues** and are directed towards radiation protection experts, rather than for the support of affected populations. The traditional approaches of emergency response and recovery —including evacuation, relocation and health surveillance— are largely based on dose levels. Although many recognise the importance of psychosocial or human factors, it has been difficult to adapt the approaches to better address the social, economic, ethical and psychological factors ●

[28] Carr, Z.; Clarke, M.; Akl, E.A. et al (2016). Using the Grade Approach to Support the Development of Recommendations for Public Health Interventions in Radiation Emergencies. *Radiat Prot Dosimetry.* 2016 Sep;171(1):144-55. doi: 10.1093/rpd/ncw234. Epub 2016 Aug 12. PMID: 27521205.

[29] International Atomic Energy Agency (2015). IAEA Safety Standards for protecting people and the environment. https://www-pub.iaea.org/MTCD/Publications/PDF/P_1708_web.pdf

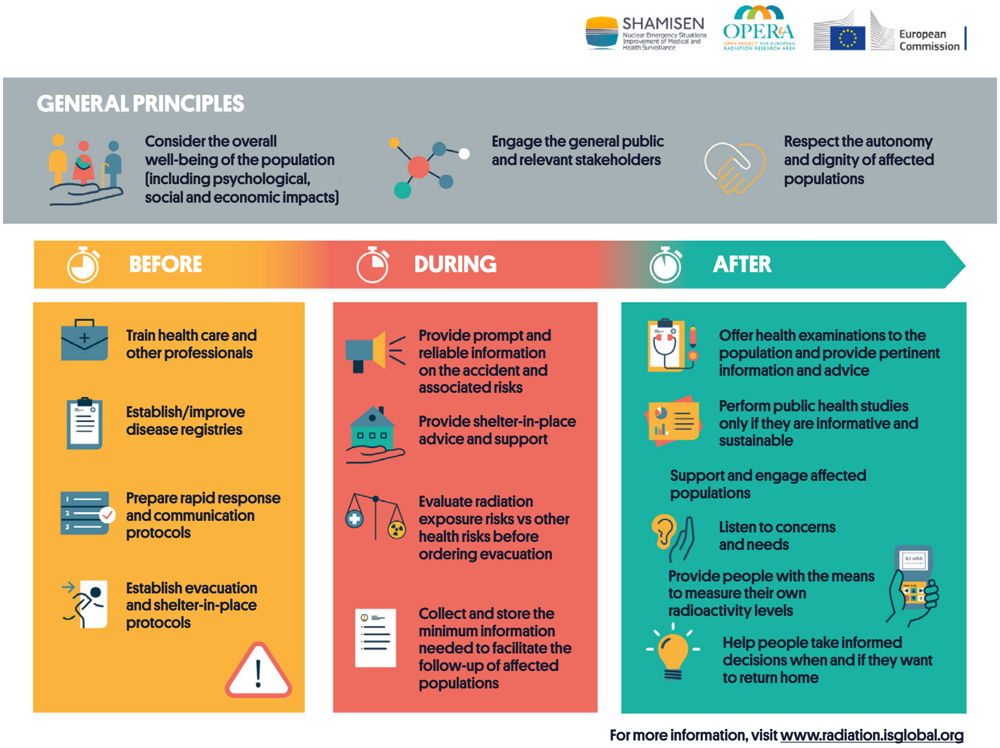
[30] Nisbet, A.F. et al (2009). Generic Handbook for Assisting in the Management of Contaminated Food Production Systems in Europe following a radiological emergency v2. https://www.eu-neris.net/library/handbooks/56-handbook-for-food-production-systemsversion-2pdf/file.html

5. Preparedness for and Response to Radiological Incidents: Recommendations

"The strategies required to prepare for and respond to a radiological incident are similar to those required to deal with any emergency or disaster situation, hence the importance of an all-hazards approach to preparedness and response."

This document has described different types of radiological incidents that can occur during an armed conflict, the health effects of radiation in general, and the protective actions to take if exposed. The strategies required to prepare for and respond to a radiological incident are similar to those required to deal with any emergency or disaster situation, hence the importance of an **all-hazards approach to preparedness and response**.

Figure 3. Recommendations for improving medical surveillance and the well-being of populations in case of a nuclear accident.



Source: SHAMISEN. https://radiation.isglobal.org/shamisen/infographics/

Previous events, such as the Chernobyl and Fukushima nuclear power plant accidents, have provided opportunities to learn from the past and draw up recommendations on how to prepare for and respond to future events. Some of the lessons learned were used to shape the recommendations presented in the SHAMISEN project *(see Figure 3)*. The full report, "Recommendations and procedures for preparedness and health surveillance of populations affected by a radiation accident", can be consulted here. The main recommendations are summarised below:

Governance and coordination

Plan for and ensure the existence of sufficient human and material resources to prepare for and respond to a radiological incident. Set up coordination and collaboration channels between stakeholders at different levels of governance. Build capacities for post-incident evaluation.

Response plans

Draw up emergency response plans with clearly identified roles and responsibilities. Run drills and simulations to identify gaps and needs. Establish early warning systems that activate emergency responses.

The above plans should cover aspects such as evacuation procedures (particularly for vulnerable populations), changes needed to health care systems, communication channels, identification of suitable shelters, and social support measures for affected populations.

Response efforts must take into account both technical aspects —how to reduce maximum doses, for example— and indirect effects.

Personal emergency plans: inform and educate the population

Inform the general population of existing threats and provide them with the information they need to develop personal emergency response strategies. Work within the community to define and inform about emergency plans and to build trust towards authorities. Include contingency plans in case there is no power or internet.

Develop educational and training material for health care workers and other stakeholders.

Pharmacological countermeasures

Certain drugs may be needed to counteract the effects of radiation. Potassium iodide, for example, can reduce the amount of radioactive iodine absorbed by the thyroid gland, a particularly important consideration for children. Plan for how these drugs will be acquired and distributed. Prioritise training for health care personnel on how to administer these treatments.

Surveillance and follow-up

Surveillance and follow-up of affected populations is needed to understand and mitigate short- and long-term effects on physical and mental health. Develop health surveillance strategies for affected populations and prepare resources to develop epidemiological surveillance protocols (questionnaires, consent reports, data capture protocols). Review existing surveillance systems, in particular cancer registries, and identify difficulties linking data from different sources and sharing information across countries.

Dosimetry

The population needs to be able to take informed decisions based on individual exposure data during the different response phases. Widely available radiation detectors, similar in concept to rapid diagnostic tests for infectious diseases during epidemics or pandemics, could be a useful tool.

Although the likelihood of a nuclear event is low, the magnitude of its consequences justifies adequate preparation. An all-hazards approach greatly facilitates this task. Because radiological incidents are similar in many ways to other emergencies, the design of easily adaptable core preparedness and response plans is a resource-efficient and effective solution •

TO LEARN MORE

- OIEA (2018). Nuclear security in big cities. This photo essay describes workshops and demonstration scenarios used to prepare for a dirty bomb. https://www.iaea.org/newscenter/multimedia/photoessays/nuclear-security-in-big-cities
- IAEA (2010). IAEA Safety Standards for protecting people and the environment. Arrangements for Preparedness for a Nuclear or Radiological Emergency. https://www-pub.iaea.org/MTCD/publications/PDF/Pub1265web.pdf" \h
- FEMA (2022). Planning Guidance for Response to a Nuclear Detonation. https://www.fema.gov/sites/default/files/documents/fema_nuc-detonation-planning-guide.pdf
- Sarukhan, A.; Cardis E.; Liutsko, L. et al (2020). COVID-19: What Can Past Nuclear Accidents Teach Us? Barcelona Institute for Global Health (ISGlobal). Series: COVID-19 & response strategy #24. https://www.isglobal.org/en/-/covid-19-que-nos-pueden-ensenar-los-accidentes-nucleares-pasados-

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