

# Recommendations to the population in case of damage to the Zaporizhzhia Nuclear Power Plant and a subsequent release of radioactivity

Greenpeace Radiation Protection Advisory Group

## General information

The Zaporizhzhia Nuclear Power Plant in Ukraine was attacked and seized by Russian armed forces and the State Nuclear Corporation, Rosatom, on the 4th of March 2022. As a result of this illegal and unprecedented event in the history of nuclear energy, the safety and security of the six reactors and high-level nuclear waste at the Zaporizhzhia site is severely compromised. As demonstrated by Russia's deliberate destruction of the Kakhovka dam on the 6th of June 2023, anything is possible in terms of their action to deliberately damage the Zaporizhzhia nuclear plant site. There are a wide range of scenarios as a result, including what potential releases of radioactivity could look like, some of them unknowable until and if they were to happen. The people of Ukraine, most especially the people of South Ukraine, including those under Russian military occupation, are living and are confronted with this reality every day. It is one of the many reasons why Russia's occupation of Zaporizhzhia must end immediately and all military forces and Rosatom personnel must leave the territory of Ukraine. As long as there is no strong international pressure against Russia, including comprehensive sanctions against nuclear trade with Rosatom, unfortunately, there appears to be no prospect of this happening any time soon. Therefore the possibility of a significant radioactive release caused by deliberate Russian action remains. Given the continuing deterioration of conditions at the plant, and despite the determined efforts of the remaining Ukrainian workers, the longer the Rosatom-led occupation continues the higher the risks are of radioactive contamination being released into the environment. These recommendations, prepared by Greenpeace radiation specialists, are intended to support and complement the existing Ukraine public guidelines and procedures of the relevant Ukraine emergency planning and regulatory authorities. In preparing these recommendations, we have also strived to not further create unnecessary and wholly unjustified additional stress and anxiety to Ukraine's population who are already suffering under the conditions of the war.

Although the six reactors at the Zaporizhzhia Nuclear Power Plant have been shut down since September 2022, the hot radioactive fuel inside the reactor pressure vessels and spent fuel pools still needs to be cooled, cooling water and electricity to run the circulation pumps. The long shutdown period of over one year means that the residual heat of the nuclear fuel is less hot compared to an actively operating reactor. If the reactors were to remain shutdown there would be more time for

worker intervention to try and avoid fuel damage and radioactive releases. However, Russian actions could or possibly are likely to prevent such intervention. In the case of the destruction of the cooling pond of the Zaporizhzhia Nuclear Power Plant, there is in principle still enough water in other reservoirs to cool the radioactive fuel for several months. This will require the workers at the plant to intervene. However, if the cooling pond is destroyed on purpose by Russia, such intervention could also be blocked.

In the case of a loss of electricity supply to the power plant through the electricity grid, there are still diesel generators available. This situation is dangerous, but it will not directly lead to a radioactive release. Again, this will depend on workers' intervention, which could be blocked by the Russian occupiers. Since the start of the Russian occupation of the plant, it has already happened seven times that the Zaporizhzhia power plant had to rely on diesel generators to secure its critical cooling.

In the case of a total loss of cooling (electricity and/or cooling water, including from diesel generators), of the spent fuel pools, there should still be a reaction time of several days before any start of release of radioactivity. During those days, it might be possible for the plant workers to restart the cooling functions with alternative backup systems. However, this is not certain, especially because Russian troops might block such life-saving interventions.

During those critical days, the Ukrainian authorities will strive to have the most reliable information about what is happening at the power plant and its direct environment, but due to the Russian occupation, that information is already limited and restricted. Rosatom and Russian armed forces are now blocking access to radiation measurement data transfer. Only data provided by the IAEA mission experts at the site with a delay of 2-4 days is available.

Under these uniquely difficult circumstances, the Ukraine population must follow the official information channels, official information on the radio and official social media outlets, such as the State Emergency Service of Ukraine, SNRIU, SSTC NRS, the Ukrainian Hydrometeorological Center, local authorities, military administrations and police. Only they can have a proper assessment of what people need to do before and after a possible release of radioactivity based on the available information.

The releases from a shut-down nuclear reactor would be fundamentally different than the releases from Chernobyl in 1986 and the releases from the Fukushima Daiichi reactors. First, short-living isotopes (such as iodine-131 and noble gases) have already decayed for a long time and will not be released in any significant quantity. Compared to Chernobyl, it seems unlikely that significant quantities of plutonium, americium or strontium will be ejected from Zaporizhzhia because they are less volatile than cesium and the Chernobyl reactor was of another type than the reactors at the Zaporizhzhia plant. However, there are scenarios related in particular to severe damage to the spent fuel pools, with hundreds of tons of highly radioactive spent nuclear fuel, where major releases of these and other hazardous radionuclides are possible. Based on past Russian actions, including the destruction of the Kakhovka dam, all options to cause severe radiological consequences, despite defying all rationale and morality, are a possibility. Under any of these circumstances, the role of Ukraine's emergency services and authorities is critical.

Because the Zaporizhzhia reactors have been shut down for many months, there is no significant amount of short-living radioactive iodine within the nuclear fuel. Therefore, in case of a nuclear release, there is no need to take iodine tablets to protect the thyroid from exposure to radioactive iodine. If Rosatom and the Russian armed forces restarted one or more reactors, iodine would be produced again. But this is so far not the case.

Learning lessons from Fukushima, it needs to be noted that an evacuation can have negative effects if done disorderly; for example an evacuation of a hospital can put patients at risk. Also, self-evacuation during a radioactive release might put you and your family at risk. However, as it was shown by the dramatic destruction of the Kakhovka Dam, the Russian occupier did not perform any rescue actions for Ukrainians living under their occupation, including evacuation. So, in such conditions, self-evacuation can be the only option to save lives.

In many cases, sheltering from radiation inside your house or a building could protect you better than being outside at the wrong time at the wrong place. The authorities will make decisions on measures (like evacuation) depending on their assessment of the status of the nuclear power plant, the weather conditions (such as wind direction) and your location (whether a release is expected or happening in your direction or not, based on weather forecasting).

Greenpeace has been critical of nuclear authorities in Japan following the Fukushima nuclear disaster in 2011, and of European authorities after the 1986 Chernobyl disaster. But in the Ukrainian case today, we have every reason to believe that the best reference of information will be to listen to the Ukrainian authorities. Greenpeace will independently monitor the situation.

## **Radiation protection in a war context and its consequences**

Every radiation protection measure should be weighed against the threat of the ongoing Russian war and to not put you in danger from explosives or projectiles. The response to a release of radiation should seek to also minimise the destabilisation of Ukrainian society, which is already under immense pressure.

Some measures that would be taken in peacetime could be unfeasible or not justifiable under the threat of war. Any safety assessment needs to take a **wider view of the overall threats** to the population. Effective protection against radiation in a war context not only requires a competent public authority but also the **common sense** of each individual.

The better the wider public is informed about the risks of radiation before a release of radiation, the stronger the resilience of the society as a whole to deal with this new threat effectively. **The Ukrainian population has impressed the whole world with its demonstration of resilience in the face of war, and this spirit should guide the population through this potential threat.**

Furthermore, many people in Ukraine today have a **crucial life-saving role** in society. It can be justified for these individuals to receive a higher radiation dose than permissible for the public, to save the lives of others. The Ukrainian authorities have set up limits for such purposes.

A specific problem is the protection of the **Ukrainian population living under Russian occupation**. Many of the protective measures initiated by Ukrainian authorities will not be able to reach them. This is another reason why this war needs to end, and Russia needs to respect the territorial integrity of Ukraine.

## References:

### ■ Ukrainian authorities:

- These guidelines by the SSTC NRS are reliable in Greenpeace’s opinion
- Ukrainian State Agency SNRIU

### ■ The International Commission for Radiological Protection (ICRP) published Recommendation 146, a comprehensive document on the “Protection of the People and the Environment in the Event of a Nuclear Accident”.

- This is an update of ICRP 111, which was drafted following the Chernobyl 1986 nuclear disaster. The updated ICRP 146 included lessons from the 2011 Fukushima nuclear disaster. However, if a nuclear disaster were to happen at Zaporizhzhia, it would have a fundamentally different context and different contamination pattern, and some of these recommendations might not apply.
- Greenpeace has some criticism of ICRP 146, but in the context of a nuclear disaster, it would not be the moment to open a debate or search for controversy. ICRP 146 offers sufficient practical guidance as a basis for fast and effective decision-making in a crisis.

## Summary of the key guidelines for the Ukrainian population:

### In case of damage at the Zaporizhzhia Nuclear Power Plant

- Do not panic. Workers at the nuclear plant might still be able to intervene and avoid any release of radioactivity.
- If the damage to the nuclear power plant was caused deliberately by Russia, and an intervention by the workers at the plant to stop the accident is blocked by Russia, a large-scale release of radiation could be the result.

- If a release cannot be avoided, the Ukrainian authorities might know this several days before, which allows for a more planned reaction. However, if information from the nuclear power plant is not transferred by Russia or by the IAEA in time, such warning time is not guaranteed.
- Greenpeace has confidence in the information from the Ukrainian nuclear authorities and will monitor the situation independently. In case of a nuclear emergency, listen to the official information, and do not panic.
- Do not take iodine tablets or solutions, unless expressly told to do so by the authorities.

### First response in case of a release of radioactivity (phase 1)



**Get inside**



**Stay inside**



**Stay Tuned**

#### a. Important to know for a first response:

- A radiation release could be limited and mostly impact the area of a few kilometers around the power plant or it could be a large-scale release or anything in between. A large-scale release is still possible, even with the reactors in shutdown for several months.
- A release from Zaporizhzhia will be a **radioactive cloud** with mostly radioactive cesium and no significant radioactive iodine.
- You need to avoid being outside when such a cloud passes through because it could be very dangerous not only to contaminate your clothes and skin, but you will also inhale the radioactivity into your lungs.

#### b. What to do as a first response:

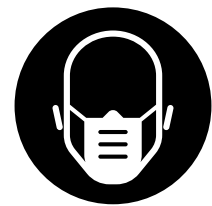
- The **first reflex** should be: **get inside**, stay inside and stay tuned for information.
- Only **evacuate** when instructed to do so by the authorities.
  - An unorderly (self-)evacuation can bring you and others into danger during a release of radioactivity.
  - If you get the order to evacuate, do it immediately (the wind might turn in a different direction if you wait too long).

- Go to the location you are instructed to go and where you know you will find protection.
- If you go to the wrong place in the wrong direction, you might worsen your situation, even if you move further away from the nuclear plant, because the contamination spreads very irregularly.

■ **Sheltering inside a building** will be the most effective measure for most people, except those living in the close area around the plant. A building can offer a higher level of protection compared to a car or public transport.

- Sheltering might not always be possible at home. You might be at work and instructed to stay there at least for the next few hours. Your children might be at school and not allowed to leave. In that case, you should not go and collect your children to bring them home, because it could endanger them and yourself. Wait until you get the approval from the authorities to reunite.
- Close windows and ventilation openings, especially during and directly after the period of the radioactive release. Turn off the air conditioning and ventilators. Seal your building for as long as the authorities ask you to.
- Avoid the top floor directly under the contaminated roof. If the roof is made of concrete, it will still offer a level of protection.
- Avoid the ground floor (closest to the outside ground surface) if possible.
- Avoid being close to windows or doors as much as possible. Walls (in stone, concrete) will reduce your exposure significantly, as well as distance from the outside surfaces that might be contaminated.
- A wooden house will protect much less. A wooden building where you can stay further away from the outer surface (roof, walls) can still offer relatively good protection, especially if it has a basement.
- You will be safer in the middle of a building, protected by stone walls or in the basement of a building.

■ To avoid the inhalation of radioactive dust, try to put on a filter mask of the best quality available (FFP3, and if not available at least FFP2) or fabricate some kind of filter with available cloth, and use it for the period recommended by the authorities.



## Next steps: what to do in the next days after a release (phase 2)

### a. Important to know for the next days:

■ The first release of radioactivity **can be followed by another release** in the coming days or weeks. A smaller release from one reactor building can be followed by a larger release from the same building. Furthermore, there are 6 reactor buildings with each 2 large sources of radioactivity at the Zaporizhzhia nuclear plant. Stay tuned for information.

- The radioactive cloud will settle down. However, during the first period, radioactive contaminated dust will still be in the air, and wearing a mask is still recommended.
- Over the following days, maps will become available showing the concentration of radioactivity deposited on the ground. These maps will at first be less detailed but become more and more precise in the following days and weeks.
- In case of a large-scale release, the area with a high level of contamination on the ground will most likely not stretch further than a few hundred kilometres from the plant, and only in a certain wind direction, depending on the weather conditions (rain, air pressure, temperature) and the topography (hills, valleys, forests or other obstacles that might slow down the radioactive cloud).
- Some areas closer to the plant might have a lower contamination, whereas some areas further away might be higher contaminated. The **pattern of contamination might be very irregular**.
- In areas with lower contamination, more limited protective measures might be advised by the authorities.
- Recommendations by the authorities will be specific for different regions and even locations, depending on the distance from the power plant, weather conditions (wind, air pressure, temperature, humidity) and the local topography (mountains, valleys, forests and even large buildings or other obstacles). Contamination can thus differ over a short distance.
- A **higher dose rate can be justified during the first days and weeks** following a nuclear release, but this needs to be avoided over a longer period of time. This emergency phase needs to be as short as reasonably possible (see next phase below).
- As an **example and a rough estimation of external radiation exposure** with a dose rate of  $10\mu\text{Sv/h}$  (or  $0.01\text{mSv/h}$ ) outside (about 35 times more than natural background radiation):
  - assuming a person spends 1 hour outside and shelters 23 hours inside a well-protected stone or concrete building, the daily dose would be  $33\mu\text{Sv}$  and weekly  $231\mu\text{Sv}$ .
  - Inside a wooden house, this would be  $125\mu\text{Sv}$  a day and  $875\mu\text{Sv}$  per week.
  - Theoretically, without any sheltering and being outside the whole time, the dose from external radiation would be  $1680\mu\text{Sv}$  per week.
  - When following the recommendations, internal exposure from cesium contamination should be limited and the main risk is from external radiation.
  - As a reference, the average natural background radiation is about  $2500\mu\text{Sv}$  per year. The maximum annual additional effective dose to the public is set at  $1000\mu\text{Sv}$  ( $1\text{mSv}$ ) per calendar year. For classified workers in the nuclear industry, it is  $20,000\mu\text{Sv}$  ( $20\text{mSv}$ ). A CT-scan can be  $10,000\mu\text{Sv}$  ( $10\text{mSv}$ ).

- Any additional dose can be harmful, and even small doses need to be avoided where reasonably possible, including from natural sources such as radon gas. But as mentioned above, the radiation risk from a release of radioactivity from the Zaporizhzhia nuclear plant needs to be balanced with other risks within the context of Ukraine today.

- Special attention needs to be given to **hospitals and elderly houses**. Staff (doctors, nurses, cleaning, logistics) needs to remain in function until there is a decision to evacuate or not. A chaotic evacuation of a hospital can have severe consequences and put the lives of many patients at risk.

**b. What to do during the next days:**

- Only use bottled drinking water and food stored at home. Do not use fruits or vegetables from your garden, unless the authorities approve it for your location. Do not eat meat or dairy products from animals that may have become contaminated.
- If you cannot avoid **going outside**:
  - Limit the time outside.
  - Cover your skin as much as possible, wear long sleeves, trousers and cover your hair (cap, hat, etc.).
  - Wear a mask if you have one (see above) until the appropriate authorities advise the opposite.
  - Use a car instead of walking or cycling if possible.
  - Change your clothes when going back inside. Put the contaminated clothes in a (plastic) bag and take a shower.
  - Wear rubber boots instead of shoes if possible. They can be cleaned with water afterward.
  - Wipe everything clean that you bring inside that might be contaminated.
  - If you bring items into your home (e.g. food from a shop), pack them in a closed container or plastic bag before transporting them.
- Do not burn contaminated wood in your stove, especially if the stove is inside your building. Wood can be contaminated if it is stored outside during the radioactive release from the nuclear plant.
- Keep your house clean on the inside (preferably clean with water instead of a vacuum cleaner).
- Keep yourself clean, shower, especially after being outside and wash hands regularly and especially before touching food.



## The following weeks and months (phase 3)

### a. Important to know for the following weeks and months

- **Ending the emergency phase:** Whereas a higher radiation dose can be justified during the first days and weeks following a nuclear release, this needs to be avoided over a longer period of time. The emergency phase needs to be as short as reasonably possible, and move towards what is called the “existing situation”.
- **Sheltering cannot be considered a permanent option** because of its high impact on a person’s life.
- Over a period of weeks or months, the emphasis will be increasingly on **optimisation**, or reducing the dose to the population as much as reasonably possible.
- Taking the complex war context into account, this will require an open-minded **consultation by the authorities with the population**. Learning from mistakes made after the 2011 Fukushima nuclear disaster, or the Chornobyl 1986 disaster, it will be **essential for the authorities to be trustworthy, and neither over- or underestimate the real risks and engage with the population as a full partner**, using their expertise on their local situation and their personal lives. In an honest relationship, many problems encountered during previous nuclear disasters can be avoided and many lives could be saved.
- As most (or virtually all) contamination will likely be cesium, **the contamination will be persistent over a long period of time**.
  - There are 2 sorts of radioactive cesium: cesium-137, which has a half-life of 30 years and cesium-134 with a half-life of 2 years. They might be deposited in roughly the same amounts. The shorter-living cesium-134 will decay faster and be halved over the first 2 years and reduced to 3% of the original activity after 10 years.
  - Furthermore, some of the original deposited radioactive dust will be washed away initially with rain and might concentrate in hotspots (which require special care) or washed further downstream in the river system.
  - Most of the contamination will stick to hard surfaces. In forests, most of the cesium contamination will remain in the top 5-10 cm of the soil.
- There are two groups of measures to be mentioned for this phase: relocation and decontamination.
- **Relocation** can be the best option for highly contaminated areas.
  - To compare, after the Chornobyl disaster, areas with a contamination of 1480kBq/m<sup>2</sup> of Cs-137 were designated for compulsory relocation and between 555-1480kBq/m<sup>2</sup> for voluntary relocation. However, given the different nature of the release (mostly cesium) and the specific war context, different criteria will have to be established, which might change over the following years.

- Some people will decide to self-relocate below a level where relocation will be compulsory, for instance, because they have young children and/or have the option to relocate to their family elsewhere.
- Relocation has profound consequences, both individually and collectively. The best approach is that local communities with the support of the nuclear safety authorities take an informed and concerted decision.
- Not only the individual dimension is relevant (of a household) but also the **collective** dimension of a local community. For example, it might be difficult for elderly people to remain, if most people decide to relocate and basic services such as shops or medical care are not available anymore.
- Relocation might be an option in highly contaminated rural areas, with small communities, where decontamination or larger areas is practically impossible or excessively expensive and the relocation of a small group is more feasible.
- Relocation can be delayed (relocating e.g. after several months or even more than a year), can be temporary (for some months or years, for instance until a decontamination operation is finalised) or it can also be permanent (for many years or even decades).

■ **Decontamination** is the technique to remove contamination from hard surfaces (roads, walls of buildings, roofs) or to remove a thin layer (of about 5 cm, depending on the contamination level and other variables) of the top soil and treat this soil as radioactive contaminated waste.

- During decontamination, radioactive contamination can be spread again, so it requires a careful approach and this can involve a relocation for a short period of time.
- In cities and areas with a high density of population, decontamination can be more effective and efficient than in rural areas and can not only involve cleaning but also more drastic measures such as removal and rebuilding of the top layer of roads (especially in city centers).
- Lessons can be learned from both the bad and good practices in Fukushima after the 2011 nuclear disaster.

#### **b. What to do during the following weeks and months**

We need to refrain from practical recommendations for this period. First, because of the war context, an **overall risk assessment** will need to be made. Secondly, it will be important for **local communities** in cooperation with the safety authorities to work out a practical plan that takes all safety aspects into account. Thirdly, it is important that **both the individual and collective dimensions** are taken into account in the justification of the measures.

## What can you do to prepare for a hypothetical radiation accident?

- Make sure you have a storage battery-powered radio. It can turn out that it will be the only way of communication in case of emergency.
- Store bottled water and food sufficient to last a few days.
- Store filter masks of the best quality available (e.g. FFP2 or even better, FFP3).
- Prepare an emergency bag or suitcase so you can leave quickly when advised by the authorities.
- It is highly unlikely that iodine intake will be required, as long as the reactors at the Zaporizhzhia Nuclear Power Plant are not restarted by Russia. Do not take any iodine unless explicitly advised by the authorities.
- Keep calm and don't panic.