Potential scenarios of an accident at the Zaporizhzhia Nuclear Power Plant

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NSSG®

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Our analysis covers the events happening until August 25, 2022.

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Executive Summary

▪ The Zaporizhzhia Nuclear Power Plant (NPP) has been under Russian occupation since the early stages of the war in Ukraine. The NPP is of strategic importance for both warring sides, since access to the energy produced by it is vital control of southern Ukraine.

▪ Recently, there have been increasing concerns regarding a Chernobyl-like nuclear disaster occurring again, due to shelling against the NPP in Zaporizhzhia.

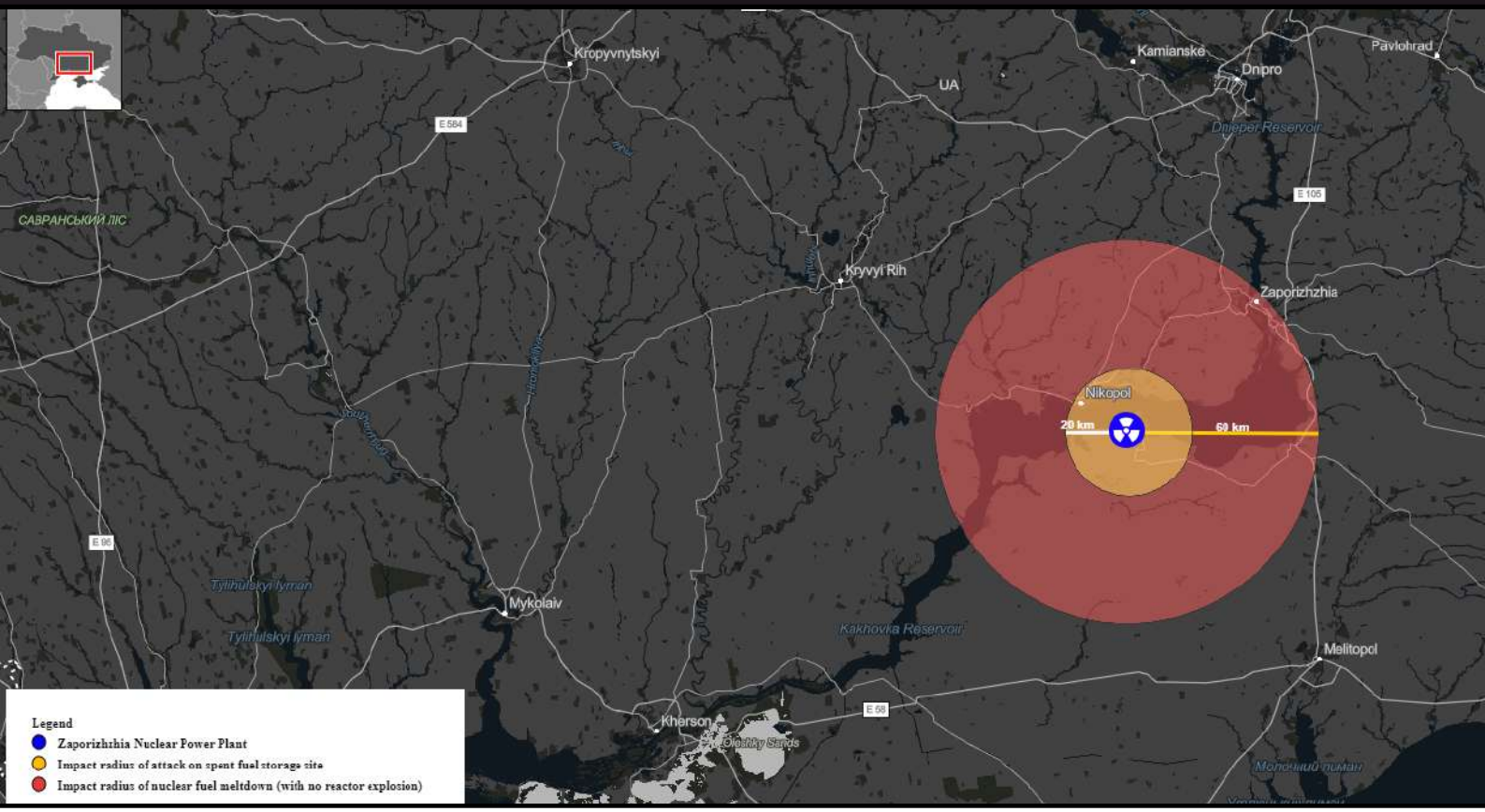
▪ However, we believe that such a scenario will be extremely unlikely to happen, since it would take a concerted and targeted military effort to breach the protection around one of the reactors, prompting it to explode. If this "doomsday scenario" were to happen, the impact would be extremely significant, with the fallout expected to reach most of central and western Ukraine, southern Russia, Belarus, Lithuania, Poland, Moldova, Hungary, Slovakia, and Romania.

▪ More likely scenarios for a nuclear incident involve direct shelling damaging the water-cooling system of the NPP, causing a meltdown of the nuclear fuel (with no reactor explosion), or shelling of the spent fuel storage facilities, which would then cause a leak in radioactive fuel.

▪ In the scenario of a nuclear fuel meltdown, the aerial dispersal of radioactive particles would be estimated to be up to 60 kilometres in radius, reaching the Ukraine-controlled cities of Nikopol and Zaporizhzhia.

▪ In case of a leakage resulting from shelling against spent fuel storage facilities, the radius of the impact would be approximately 20 kilometres, reaching Nikopol.

Introduction



On August 25, the Zaporizhzhia Nuclear Power Plant was cut-off for the first time from the Ukrainian power grid following the shelling of a nearby coal power plant.

Even though power was restored late in the day, the incident highlighted the risk of a nuclear catastrophe at Europe's largest nuclear power plant, which is located in Enerhodar—a city in Zaporizhzhia Oblast. Russian forces have occupied the plant since initial phases of its invasion of Ukraine. **Nonetheless, the risk of a Chernobyl-like disaster is low.**

Over the past weeks, Ukrainian officials have accused Russia of using the facility to store heavy vehicles and weapons used to carry out artillery strikes against the Ukrainian-held city of Nikopol and its surroundings on the opposite bank of the Dnipro River.

Ukraine and Russia have since traded accusations over the strikes, with Ukraine saying Russia destroyed three radiation detectors and injured a factory employee.

Nonetheless, there have been no reports of damage to the reactor buildings and, although the spent fuel storage area at the complex was reportedly damaged, there has been no indication of any radiation leaks.

In this report, we will analyse three scenarios of nuclear incidents at the Zaporizhzhia NPP, assessing their likelihood and impact:

1. "**Most Benign Scenario"** – Radioactive leak from damage to spent fuel sites.

2. "**Realistic Worst-Case Scenario"** – Meltdown and fire caused by damage to the cooling system.

3. **"Doomsday Scenario"** (Extremely Unlikely) – Explosion of the nuclear reactor, with Chernobyl-like consequences.

The strategic importance of the Zaporizhzhia Nuclear Power Plant

▪ The plant, built in the Soviet era, is the largest nuclear reactor in Europe. Its six pressurised water-cooled reactors are important to Kyiv, as they can produce power for up to 4 million homes.

▪ Situated on the south bank of the Dnieper River at Enerhodar, southwest of the city of Zaporizhzhia, the plant occupies a crucial strategic position both for Russian and Ukrainian forces, since long-term control over Southern Ukraine will require continuous access to its energy supply.

▪ Ukraine aims to see the plant treated as a demilitarised area, which would achieve a military objective by denying Russian forces the use of an area from which they can shell with relative impunity, knowing that Ukraine cannot retaliate due to the presence of the water-cooled reactors, as well as a spent fuel storage facility. Therefore, Russia is using the plant as a shelter for artillery used to fire on Ukrainian positions in the belief that Ukraine would not respond and risk a nuclear accident.

▪ It is crucial to bear in mind that a deliberate nuclear incident at the Zaporizhzhia NPP by Russia would threaten southern Russian territory with radioactive contamination, so it is essential to distinguish between "nuclear blackmail" and actual intent to cause a serious incident that would have repercussions for Russia itself.

Safety and Security at the NPP

▪ At the Zaporizhzhia NPP, reactors are protected by up to 10 meters of concrete and steel, as well as fire protection systems. Therefore, only a significant targeted bombardment against the plant is likely to penetrate the reactor walls.

▪ The buildings housing the spent fuel are not built with a similar level of protection, meaning that a release of spent fuel material is probably a more likely risk than a catastrophic reactor breach.

▪ The situation at the plant regarding safety operations is also one of the most concerning issues, as a deteriorating safety regime caused by the conflict has been exacerbated.

▪ Finally, the main vulnerability lies in the cooling systems of the reactors, which is relatively exposed. The loss of coolant during the Fukushima Daiichi accident in 2011 resulted in three reactors undergoing some degree of a core meltdown. If the cooling is interrupted, in a matter of hours, the nuclear fuel can become hot enough to melt. Eventually, it can melt through the steel reactor vessel and even the outer containment structure, releasing radioactive material.

Scenarios
“Most Benign Scenario”

Radioactive leak from damage to spent fuel sites

Impact

20 kilometers radius

Likelihood

Most Likely

Description

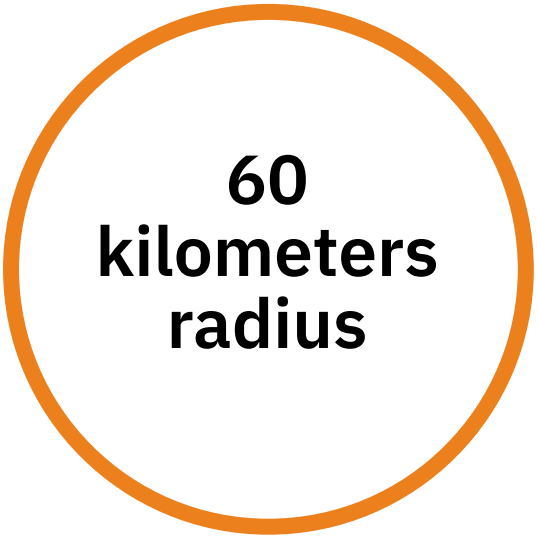
Considering that the spent fuel storage sites are less protected than the nuclear reactors, they are more likely to suffer significant damage in case of a direct artillery bombardment, elevating the risk of a radiation leak.

In this scenario, the impact would be relatively limited in geographical terms, because any radioactive material released would likely travel only **10-20 kilometres away, via aerial dispersion of radioactive particles. In this scenario, the main urban centre to be impacted would be the city of Nikopol.**

Scenarios
“Realistic Worst-Case Scenario”

Meltdown and fire caused by damage to the cooling system

Impact



Likelihood

Unlikely

Description

There are concerns about the shelling occurring around the facility, with the potential to damage critical infrastructure, which need to be constantly cooled by water passing through them. If that water supply is cut off, then the reactors would overheat, leading to core meltdown.

However, rather than the possibility of a reactor exploding because of the lack of cooling, there is a much more likely potential scenario, such as a meltdown and a fire that could release and spread radiation from the containment structures. Such a scenario would resemble the incident at Fukushima rather than that at Chernobyl.

In the scenario of a meltdown (with no explosion), the incident would likely cause massive damage only at the local level, with radioactive particles aerially dispersed in a **potential radius of 60 kilometres.**

If this scenario came to fruition, **both the cities of Nikopol and Zaporizhzhia would be within the radius of impact.**

Scenarios
“Doomsday Scenario”

Explosion of the Reactor

Impact

Likelihood

Extremely Unlikely

Description

While an explosion is not impossible, the likelihood of that happening is extremely low, considering that the NPP is heavily protected. The NPP is built with much more advanced technology than Chernobyl, and breaching the protection of the reactor would require extremely significant and precise bombardment against it. Such an action would be incompatible with any sort of “plausible deniability” for the perpetrator, meaning that it would be evident that the attack was premeditated with the intent of causing a nuclear accident. For this reason, we consider this scenario to be extremely unlikely since the cost of such a course of action would far outweigh the benefits for all parties involved.

A simulation carried out by the Ukrainian Hydrometeorological Institute estimated that an explosion at the NPP would lead to radiation spreading to most of central and western Ukraine, southern Russia, Belarus, Lithuania, Poland, Moldova, Hungary, Slovakia, and Romania.

Conclusions

At this stage, the Russian military occupation of the nuclear power plant has generated credible concerns over an incident. However, the potential for it also serves as a deterrent, as the belligerent force which caused it would likely incur very negative political risks.

If a nuclear incident were to take place, people impacted by direct exposure to radiation would likely suffer acute to terminal radiation sickness, depending on their exposure levels. In case of a radiation leak, the first and urgent matter is to evacuate everyone nearby the plant and foster their access to medical facilities for check-ups. However, as the plant is in a war zone, these initiatives will have their own set of complications.

Furthermore, **areas within the impact radius of the nuclear incident** (20-60 kilometres, in the most likely scenarios) **would become inhabitable for** several years. Estimating the exact number of years is challenging since it depends on the quantity and spread of the radioactive leak, but it would likely be **between 15 and 70 years.**

Lastly, for many people, the fear of radiation could be even more impactful than the radiation itself. There could be an uptick in patient care because of the psychological symptoms connected to the knowledge that radiation might have leaked from a nearby nuclear power plant. Therefore, another problematic issue would be how to deal with a large number of potential patients.

Recommendations

Organisations with interests in Ukraine and surrounding countries (and territories) should be assessing the potential implications on investments, operations, and staff, from a nuclear accident. The potential impacts on staff health and wellbeing can even precede an incident, particularly in terms of the anxiety over it, even if the likelihood is negligible. Given the state of conflict in Ukraine and the likely lack of resources to ensure the execution of an effective response, **it will be incumbent on organisations to have in place dynamic nuclear emergency action plans.**

These plans should cover three phases: preparation, response and recovery.

- The **preparation** phase should entail a risk assessment that evaluates the level of risk exposure from nuclear radiation, concluding with organisation-specific recommendations.

- An effective **response** plan should cover the logistics and processes for protecting assets and staff.

- In any **recovery** plan, it is paramount that an organisation has an accurate recording of the sequence of events and any supporting information (including previous lessons learned) to help shape the activities.

If you are interested in monitoring political risks affecting your company, reach us at support@nssg.global