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Fukushima Nuclear Accident Impacts on the EU Nuclear Arena

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ABSTRACT

The Fukushima Daiichi nuclear power plant accident happened ten years ago in Japan. It was the very first severe nuclear accident initiated by natural events, namely a tsunami which followed an earthquake. The consequences are numerous, extending well over geographical areas affected by radioactive contamination. The accident initiated major re-evaluation of nuclear and radiation safety regulatory regimes.

In European Union's (EU) members states several activities were conducted immediately after the accident, e.g. controls of passengers and vehicles coming from Japan and controls of food from affected areas. Long-term activities followed. The footprints of the accident can be systematically presented addressing short-term activities of the EU member states, EU legislation related to the Fukushima accident, stress tests and changes in the EU nuclear legislation, impacts on EU nuclear operators, EU member states attitude to nuclear energy and EU research areas. It should be also outlined that the vivid discussion taking place in 2021 on future of the nuclear energy in EU and related 'Taxonomy Regulation' is also very much influenced by the accident. In light of lessons learned, questioning and learning attitude as a basic of the safety culture seem to be the key to prevent such disasters.

1 INTRODUCTION

The Fukushima Daiichi nuclear power plant accident (Fukushima accident) happened ten years ago in Japan. It was the very first severe nuclear accident initiated by natural events, namely a tsunami which followed the 9-0. magnitude earthquake relatively near the Japan coast on March 11, 2011. The tsunami and earthquake did not influence only the Fukushima Daiichi nuclear power plant (NPP) by initiating nuclear accident but this natural disaster killed more than 18 000 people in Japan as the tsunami swept away whole cities. However, the Fukushima accident as a part of this disaster requires special attention in order to understand risks associated with ageing nuclear power plants (NPPs) as well as risks associated with any new NPP.

According to the IAEA/OECD INES scale used to rate the severity and consequences of nuclear accidents this accident is rated at the highest level of the scale, i.e. level 7. Till today only two accidents are rated so high. Namely, the Chernobyl accident which happened in 1986 and the Fukushima accident. Both accidents had a profound influence on the development of nuclear arena.

2 THE FUKUSHIMA ACCIDENT

The details of the Fukushima accident and its consequences are described elsewhere e.g. [1]. The Fukushima nuclear power plant (NPP) had six reactors located at the Japan coast. Due to the accident in some of them core meltdowns occurred. All of them were BWR produced by General Electric. When the earthquake with the epicentre 70 km from the NPP site happened, three reactors were working while other three units were in a planned shutdown. The operating units stopped working. The earthquake caused damage to the electric power supply lines to the site. Several waves of the tsunami followed in less than one hour after the earthquake. As the maximum tsunami height, i.e. up to 15 m, was well above the NPP protective dam designed for 5.7 m, the water flooded the NPP equipment designed to cool reactors and spent fuel as well as providing needed electricity for the NPP. The core meltdowns occurred, hydrogen explosions occurred and vast radioactive contamination of the environment followed in the next days despite the immediate remedial actions at the site. However, these actions had a limited influence as the whole country was confronted by the consequences of the disaster. Namely, it took about two weeks to assure sufficient external power and fresh water for cooling the NPP.

The major releases followed next several weeks. The evacuation of the general public was initiated nearly immediately after the flooding of the NPP, i.e. at the beginning the first evacuation of the general public in the vicinity was ordered while later the evacuation and the relocation of the population in the vicinity of about several tens of km was ordered. The weather strongly influenced the contamination of the land. Majority of the gas releases went to the Ocean. The overall releases, mainly ^{131}I and ^{137}Cs are estimated to be about 10% of releases related to the Chernobyl accident. Details of gas and liquid releases are published elsewhere, e.g. [1].

It is estimated that while no victim due to the radiation among the general public can be identified the evacuation of more than 150 000 people required its toll. Namely, clearly identified excess deaths among evacuated population emphasize the vulnerability of geriatric populations to the relocation [2].

Today operators at the NPP are still challenged by needed remedial activities which are going to last next 30-40 years. In particular, contamination and management of vast volume of contaminated water are complex issues. The regulatory authority in Japan is managing the contaminated sites, providing decontamination and managing vast volume of radioactive waste. Whenever possible, the decontamination assured levels of radionuclides so low that the general population might return home. Self-protective activities such as dose rate measurements by the general public organized by the SAFECAST, took place [3]. However, areas in the vicinity of the NPP is going to be unpopulated by the general public for a very long time.

It must be noted that nuclear arena has been immediately involved in the analysis of the accident and its consequences from the beginning, e.g. as given for example in [4] and reference therein. However, the scientific research related to the analysis of the accident, i.e. how the accident developed in the destroyed NPP, and its consequences are still going on addressing basic physics, emergency preparedness and response and post-accident management, e.g. as noted in [5]. In 2021 several publications have been published tackling experiences and knowledge taken from the Fukushima accident, e.g. [6, 7, 8].

3 THE FUKUSIMA ACCIDENT AND THE EUROPEAN UNION

Although geographically very far from Europe the accident has a profound effect on the nuclear arena in the European Union (EU) as a whole in addition to its impacts on Member State's (MS) nuclear frameworks. Not only short-term consequences can be identified but also its long-term footprints might be foreseen, i.e. the EU nuclear arena is going to be affected for several decades. All effects can be systematized in several groups, i.e.:

- short-term EU MS activities,
- EU legislation related to the Fukushima accident,
- stress tests and changes in the EU nuclear legislation,
- EU nuclear operators,
- EU Member States,
- EU research areas.

3.1 Short-term EU MS Activities

The immediate consequences of the Fukushima accident on EU MSs were related to protection of EU citizens in Japan in the regions immediately affected. The EU MS informed their citizens on risks associated with residence in Japan and on safety measures to be implemented. In addition, some of them also organised their return home, i.e. to the EU MS, implementing all precautions related to possible contamination of humans as well as vehicles and cargo. In parallel, all trafficking from Japan was a subject of a control assuring that no contaminated goods, airplanes and ships were either imported in the EU or landed in EU MSs as appropriate. In very first days of the accident not only trafficking from but also trafficking to Japan was heavily affected. Full control of contamination of food has been implemented, details are further elaborated in section 3.2.

The immediate effect of the accident was also the contamination of the environment in particular the atmospheric releases which took place for weeks. Atmospheric discharges were eventually, i.e. after about a week as they should make a long way from Japan to Europe, also measured in the EU MSs. The MSs organized specific measurement related to contamination of air and specifically subsequent contamination of food on their territories to assess the influence of the Fukushima accident. A special attention has been given to milk. As a rule, the measurements identified low levels of radionuclides which did not require protective measures.

Several EU MSs also strongly participated in supporting Japan authorities when managing the accident.

3.2 EU Legislation related to the Fukushima Accident

Very first attention of the EU was devoted to the contamination of food, i.e. either food from Japan or food from fishing areas affected by atmospheric and liquid releases from the Fukushima Daiichi site in the Pacific Ocean. As soon the consequences of the accident were identified, the so-called “future accident” regulations addressing a control of contaminated food and feed have been implemented. Namely, after the Chernobyl accident such regulations has been prepared but they were called “sleeping regulations”, i.e. regulations to be used only in a case of any future nuclear or radiological emergency. The EU legislation related to the control of food and feed due to the Fukushima accident required regular updating or amending, e.g. from regulations from 1987 to regulations published in 2019 [9], as the situation in Japan evolved. It can be concluded that so-called “future accident” regulations set a good background preventing contaminated food or feed from the Fukushima accident to enter in the EU MSs. These experiences also led to the updated “future accident” regulations published in 2016 [10].

When the Fukushima accident happened, the basic safety standards for protection against the dangers arising from exposure to ionising radiation in the EU MSs were drafted. The drafted document was going to repeal several directives, among them Council Directive 96/29/Euratom, i.e. so-called EU basic safety standards. Finally the *Council Directive of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom,* *90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom* (Council Directive 2013/59/Euratom) [11], i.e. new EU basic safety standards, has been published two years after the Fukushima accident. The Council Directive 2013/59/Euratom includes several provisions as a direct consequence of the lessons learned from the Fukushima accident, e.g.

- operational protection of members of the public includes "acceptance into service of the facility subject to adequate protection being provided against any… radioactive contamination liable to extend to the ground beneath the facility" as required in Article 65,
- emergency management system and emergency preparedness are described in detail as given in Articles 97 and 98,
- "default triggers or operational criteria such as observables and indicators of on-scene conditions" to be used in the emergency response plan as noted in Annex XI,
- "transition from an emergency exposure situation to an existing exposure situation including recovery and remediation" to be a part of the emergency management system as stated in Annex XI.

The so-called "post-accident" strategies started to be developed as the Fukushima accident revealed that in lack of them the post-accident phase might even worsen the life of the workers and general public.

In addition to the above mentioned legal act the *Nuclear Safety Directive* has been amended in 2014. Details are given in the following section, i.e. section 3.3.

In must be noted that a vivid discussion on nuclear energy in the EU has taken place in 2021. It is based on the *Technical assessment of Nuclear Energy with Respect to the 'Do No Significant Harm' Criteria of Regulation (EU) 2020/852* ('Taxonomy Regulation') prepared by the JRC in 2020 [12]. The discussion is strongly influenced by the accident.

3.3 Stress Tests and Changes in the EU Nuclear Legislation

The Fukushima accident somehow stressed the nuclear arena especially as the accident took place in well-developed nuclear country where the very first reactor, i.e. the Tōkai Nuclear Power Plant was commissioned already in 1966. Therefore, the accident posed the question how resilient to natural disasters of such scale are other NPPs as well as other nuclear objects, e.g. nuclear fuel reprocessing plants. This question has been raised all over the world.

To get the answer the so-called stress tests, i.e. peer review of nuclear facilities, took place in the EU MSs very soon after the Fukushima accident. Namely, the European Council requested already in March 2011 that the safety of all EU nuclear plants should be reviewed. In about three months after the tsunami the European Nuclear Safety Regulators Group adopted the outline of the stress tests, i.e. self-assessments conducted by operators, national reports prepared by regulatory authorities and finally peer reviews. The *Peer Review Report* has been adopted in 2012. The stress tests led to the *National Post-Fukushima Action Plans* to strengthen the resilience of nuclear facilities to cope with extreme unexpected events. The *Post-Fukushima National Action Plans* tackle regulators, such as Slovenian Nuclear Safety Administration, as well as operators. The details of the stress tests and mentioned plans to upgrade the NPPs are given in [13]. The stress tests resulted in the upgrading of the NPPs in EU MSs in order to prevent severe accidents and to mitigate their consequences. This upgrading which is still going on in some MSs are related to substantial investments.

In parallel with the stress tests, it became evident that requirements given in the *Nuclear Safety Directive* [14] needed to be strengthened. The amendment of the *Nuclear Safety Directive* followed in 2014 [15]. The amendment tackles nuclear frameworks in the MSs, e.g. strengthening the independence and the power of national nuclear regulators and setting safety objective to prevent accidents and avoid radioactive releases. Moreover, it sets a European system of peer reviews on specific safety issues every six years, i.e. so-called topical review. The very first topical peer review took place in 2017 and 2018. It was dedicated to the "ageing management" of nuclear reactors or, more specifically, to the ageing effects on structures, systems and components. The second topical review is dedicated to fire protection of nuclear installations. In addition, special requirements are related to new NPP and prevention of severe accidents addressing early radioactive releases as well as large radioactive releases. Furthermore, the cooperation among the EU MSs and the IAEA is strengthened. Namely, the amendment of the *Nuclear Safety Directive* addresses peer reviews of the MSs regulatory system which in practice means that the regular IRRS missions are required.

3.4 EU Nuclear Operators

As already mentioned nuclear operators in the EU MSs introduced several actions after the accident to cope with severe accidents. As a rule, some of them were conducted very soon after the accident, e.g.:

- procurement of additional portable equipment such as diesel generators, pumps and compressors including quick connection points for this equipment,
- amendments to the emergency operating procedures and severe accident management guidelines enabling the use of new equipment,

while others required more time, e.g. assuring:

- flood protection of the nuclear island,
- spent fuel pool alternative cooling,
- installation of emergency control room,
- upgrade of bunkered building for electrical power supply,

just to mention few actions.

In addition, it is noteworthy that so-called "emergency response forces" have been initiated as described in [16] where EDF's regional nuclear emergency bases are presented. Equipment and the staff are available at the particular dislocated site from the NPPs. Mentioned "emergency response forces" are capable of rapidly responding to a serious accident at any French nuclear power plant.

3.5 EU Member States

One particular issue related to any nuclear accident which might happen in Europe is the cross border coordination of protective actions. Namely, it was noted that unharmonized approach in case of a nuclear accident might even worsen consequences of the accident, e.g. when one MS might order evacuation without any harmonization with neighbouring MSs which might be also highly affected by the same accident, Therefore, in 2014 the Heads of the European Radiological Protection Authorities (HERCA) and Western European Nuclear Regulators' Association (WENRA) prepared guidance related to zoning around NPPs [17] addressing:

- evacuation up to 5 km around an NPP,
- sheltering and iodine prophylaxis up to 20 km,
- general strategy to be able to extend evacuation up to 20 km and sheltering and iodine prophylaxis up to 100 km.

The holistic approach to such measures has been underlined in order to protect the most vulnerable members of the public in such zones. The guidance is called „HERCA-WENRA approach".

Regarding EU MSs it should be also pointed out that the attitude to the NPPs either to the present or the new ones, has changed in some EU MSs. For example, in Germany eight NPPs stopped to operate immediately after the Fukushima accident and so-called „phase out" of nuclear energy has been introduced again. The deadline is 2022.

3.6 EU Research Areas

The accident initiated several research areas which were subject of intensive research within the EU HORIZON 2020 [18] or Horizon Europe. A list of initiated research areas is very long and includes:

- physical phenomena related to nuclear fuel during a severe accident, e.g. interaction of melted core with other materials,
- implementation of more robust safety systems in a design of new NPPs, e.g. passive systems,
- upgrading of existing NPPs,
- use of drones and robots in extreme high dose fields,
- justification of evacuation of elderly people in a case of an emergency,
- justification of thyroid screening after a nuclear accident,
- implementation of "citizen-science" in a nuclear arena.

These are only some of research areas which were or are going to be a subject of research supported either by EU research programs or by MS national research programs.

4 CONCLUSIONS

Today's nuclear arena in the EU MSs would be very different without the Fukushima accident and the message it offered. While in two decades after the Chernobyl accident the EU MS nuclear arena somehow recovered and the nuclear renaissance has been foreseen in the first decade of the 21st century, the Fukushima accident initiated the re-evaluation of nuclear safety in the EU MSs.

As any other disaster, the Fukushima accident gives opportunities to take lessons learned to designers, researchers, operators, investors, governments and other stakeholders involved in nuclear safety. Moreover, it gives opportunity to crisis managers of other disasters to take experience gained, e.g. to managers of pandemic due to COVID-19 as already noted for example in [19]. In light of incoming changes of a climate and foreseen disasters in next decades it seems that such lessons shall be taken with due attention. As pointed out by the IAEA [20] safety culture is based on questioning attitude. Namely, questioning and learning attitude as given there seems to be the key to prevention of such disasters.

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