THE CHALLENGES OF NUCLEAR WASTE DISPOSAL – INTERNATIONAL ENVIRONMENTAL LAW PERSPECTIVE[1]

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ABSTRACT: *Nuclear energy is a central part of European and worldwide energy production since it is a component in the energy mix of 13 EU Member States, accounting for almost 26% of the electricity produced in the European sphere. Also, it provides about 10% of the world's electricity from about 440 power reactors. Nuclear energy also fits the plan of a climate-neutral European continent because the direct* CO_2 *emission is significantly lower than in the case of fossil fuels. On the other hand, there is a significant concern about nuclear energy production and nuclear technologies in general – radioactive (nuclear waste). Since the beginning of the first experiments with fissile materials, radioactive waste disposal has been an unsolved problem. Especially high-level radioactive waste and spent fuel causing severe issues for the international community. This article focuses on radioactive waste disposal from an environmental point of view, includes the main categorisation of radioactive waste, and provides an informative description of disposal solutions. The Fukushima accident also unavoidable because it highly influenced some countries energy policy and decisions concerning nuclear energy in general. Nuclear energy always has been a "grey" area of energy production, in the centre of opposing benefits and great threats. The paper aims to answer whether nuclear energy remained a dream that never lived up to the expectations or just the benefits shadowed by the harsh reality of unsolved nuclear waste disposal.*

KEYWORDS: *nuclear waste; challenges; environmental law; multinational storage; spent fuel.*
JEL Code: *K32*

1. INTRODUCTORY REMARKS

The plan of a climate-neutral European continent is one of the most grandiose ideas in combating global environmental problems. To achieve the European Green Deal goals, every country has to find a way to low carbon solutions cut to carbon dioxide (CO_2) emissions (European Commission, 2018). The European energy policy highly relies on nuclear energy. On the other hand, Member States has the right to freely choose

[1] *This research was supported by the project nr. EFOP-3.6.2-16-2017-00007, titled Aspects on the development of intelligent, sustainable and inclusive society: social, technological, innovation networks in employment and digital economy. The project has been supported by the European Union, co-financed by the European Social Fund and the budget of Hungary.*

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the energy mix' elements (Eurostat, 2017). Some countries have given up on nuclear energy, especially after the Fukushima nuclear plant accident in 2011. Still, most EU Member States are counting on nuclear energy, even expanding the already functioning capabilities. Later, the article analyses the main effects of the Fukushima accident. In the Author's opinion, nuclear energy has always been a "grey area" for the pros and cons. An obvious benefit that the EU would like to exploit is the low CO_2 emission, fitting perfectly to the new era of energy policy. Nevertheless, there is a long list of concerns about nuclear power plants, particularly radioactive waste[2] and spent nuclear fuel. How can we guarantee nuclear safety and security in the long run if we cannot control cybercrime threats and natural occurrences, such as earthquakes and tsunamis? How can stakeholders spare future generations from the burden of radioactive waste management? Is nuclear energy really the only way to achieve climate goals? The line of raised questions could be continued.

Besides, the environmental aspects also must be evaluated, especially in connection with radioactive waste facilities. Today, there are still more than 150 operating nuclear facilities across Europe. However, according to some views, major accidents, together with the unresolved problem of radioactive waste, have led to the realisation that nuclear energy remained a dream that has never really lived up to its promise. Furthermore, due to the high cost of nuclear power generation, it is unlikely that the currently available nuclear capacities will be expanded (DEBELKE, 2019, p. 207).

Several disturbing happenings came to light in the last decades about leaking disposal facilities and radioactive contamination of soil and underground water. In 2020 the Japanese government announced that several million litres of radioactive cooling water to be distributed into the Pacific Ocean. The disputed plan that constantly has been criticised by States and environmental NGOs was accepted at the beginning of 2021. The mentioned happenings also show a strong correlation between nuclear law and environmental law, but the first instruments of international nuclear law were not including these aspects (EMMERECHTS, 2008).

The fact that fissile materials could later be put at the service of humanity for energy production was clear from the very first moment – at least to scientists. Nuclear power has been considered an inexpensive and easily accessible method of energy production.[3] Had they calculated the cost of radioactive waste storage? Not so sure. Lewis L. Strauss, chairman of the Atomic Energy Commission, declared in his speech to the National Association of Science Writers in 1954 that nuclear energy would be "*too cheap to meter*".

"*It is not too much to expect that our children will enjoy in their homes electrical energy too cheap to meter; will know of great periodic regional famines in the world*

[2] Radioactive waste and nuclear waste are used as a synonyms in the scope of this paper.

[3] As it was strengthened in Einstein's letter to President Franklin D. Roosevelt warning the United States of America about the new "*extremely powerful bombs of a new type*" might be used by the Nazi Germany. But the two-page letter also referred to the "*recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future*." Source of letter: Atomic Heritage Foundation, it can be read in full length at BAKER, Sinéad: Albert Einstein wrote to the US pleading with the government to build an atomic bomb 80 years ago. Here's what he said. Insider, 2 August 2019 at https://www.businessinsider.com/albert-einstein-wrote-letter-us-roosvelt-atomic-bomb-2019-8.

only as matters of history; will travel effortlessly over the seas and under them and through the air with a minimum of danger and at great speeds, and will experience a lifespan far longer than ours, as disease yields and man comes to understand what causes him to age. This is the forecast of an age of peace." (STRAUSS, 1955)

The history of radioactive waste management dates back to the beginning of the "*nuclear age*". Since the first applied methods, significant technical, terminological and regulatory developments took place. Besides, one cannot ignore the problems yet to be solved – among them, the biggest is how to ensure the safe storage of radioactive waste, even for hundreds of years, so that it does not pose a disproportionate burden or danger to future generations. In contrast, Dr Hans Blix, former director of the International Atomic Energy Agency (1981-1997), stated in 1983: "*in our age of environmental awareness, when the effects of pollution and conventional toxic wastes are of major concern to man and his environment, I think we must conclude that the record of the nuclear industry in waste management is remarkable compared to that of other industries*" (BLIX, 1983).

In this article, the Author would like to concentrate on the debate about radioactive waste management, focusing on the European sphere and in the light of international environmental law. First, the article analyses the definition of radioactive waste and spent nuclear fuel. Then, the different categories will be explained. Then, the main challenges from an international environmental law perspective will be discussed at the centre of the paper, highlighting new ideas such as multinational waste disposal facilities. Last but not least, some solutions and concerns will be raised.

2. THE DEFINITION AND CATEGORISATION OF NUCLEAR WASTE

To understand the actual depth of concerns regarding radioactive waste management, the definition and categories must first be settled. Generally saying nuclear waste is a by-product mainly from nuclear reactors and fuel processing plants. However, radioactive waste is generated by hospitals and research facilities and via decommissioning and dismantling of nuclear reactors and other nuclear facilities.[4] In the broadest sense, nuclear waste is a subcategory of hazardous waste. Three main types of hazardous waste can be distinguished: chemical, elementary and radioactive. Waste management practices and strategies are similar in all three cases, but there are significant differences due to specific characteristics. Chemical wastes such as dioxin can be distributed or disposed of through appropriate procedures. Elemental hazardous wastes – such as heavy metals, lead, arsenic – remain toxic forever and can lead to severe poisoning and accumulation in the environment. These are usually stored in underground geological repositories – mine like underground cavities, caves. Radioactive waste contains radioactive isotopes that decompose over time into non-radiating isotopes. These wastes emit alpha, beta, neutron, or gamma rays during decomposition, harming and destroying biological tissues. Proper disposal method means the complete isolation of radioactive waste from humans and the environment until the radionuclides in the waste decompose to safe levels. Incidentally, both heavy metals and radionuclides are found in the natural environment on Earth. Above specific concentrations, these substances also pose a threat to the ecosystem and

[4] Backgrounder on Radioactive Waste at https://www.nrc.gov/docs/ML0501/ML050110277.pdf.

human health. For any waste, the concentration of hazardous components that make the waste hazardous must be determined. The rate of radioactive decay is measured by the half-life of the radionuclide (FORSBERG, 2003, pp. 643-659).

The Joint Convention defines radioactive waste as the following: „*radioactive waste means radioactive material in gaseous, liquid or solid form for which no further use is foreseen by the Contracting Party or by a natural or legal person whose decision is accepted by the Contracting Party, and which is controlled as radioactive waste by a regulatory body under the legislative and regulatory framework of the Contracting Party*."[5] Spent nuclear fuel "*means nuclear fuel that has been irradiated in and permanently removed from a reactor core*."[6] It is crucial to distinguish between radioactive waste and spent fuel. The latter is considered as waste only if it is permanently removed from the reactor core without the willingness of reprocessing.[7]

Spent fuel needs to be seen as a resource because only a segment of extractable energy is utilised during the first five years of use. Unfortunately, mainly due to economic concerns, most of the States stopped reprocessing spent fuel, increasing the amount of high-level nuclear waste. In this way, the nuclear cycle became "*once-through*", so nuclear fuel used only once in reactors. The great pioneers of reuse were the United Kingdom and France, while the United States of America had changed its policy as early as the 1970s. However, in addition to economic factors, it is worth examining the other side of the coin. Recovered plutonium is well suited for non-peaceful purposes, such as armaments, so the high risk of polymerisation had also influenced States' decisions regarding reprocessing. In the Cold War period, avoiding the possibility of proliferation and reducing risk are ultimately understandable objectives. The enriched uranium reserves released after the Cold War have made the single fuel cycle even cheaper thus more attractive. Re-extraction is indeed a much more expensive option (National Research Council, 1999).

Radioactive waste has different categories. *Low-Level Wastes* (LLWs) are wastes with a half-life short enough to allow institutional control of the disposal facility, as long as the substances have a high degree of hazard. This category includes large quantities of low-level waste such as protective clothing or damaged equipment. *Intermediate-Level Wastes* (ILWs) are wastes with a long half-life, but the concentration of radionuclides in the wastes is low enough to keep the heat production rate low. Therefore there is a need for storage capacity that ensures the safe storage ILWs without human intervention. *High-Level Wastes* (HLWs) are undoubtedly the most dangerous among the nuclear waste. High-level wastes composed of concentrations of long-lived radionuclides and longer-lived radionuclides capable of producing significant heat of decomposition. These include the ^{90}Sr, ^{137}Cs fissile materials and the actinides (fourteen chemical elements

[5] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management 1997 (2001) in the following: Joint Convention. Art. 2. Definitions (h).
The Convention was accepted in the frames of the International Atomic Energy Agency (IAEA) in 1997 and entered into force in 2001. This is the main international law instrument concerning nuclear waste management and spent fuel.

[6] Joint Convention, Art. 2. Definitions (n).

[7] Reprocessing: "*refers to the processes used to separate spent nuclear reactor fuel into nuclear materials (uranium, plutonium) that still can be recycled for use in new fuel and material that would be discarded as waste*." See LAW, Emma: Cleaning up our nuclear past: faster, safer and sooner at https://nda.blog.gov.uk/2018/10/23/what-is-reprocessing/.

numbered from 90 to 103) such as plutonium, americium and curium. Plutonium-239 (^{239}Pu) with a half-life of 24,000 years is typically included here (International Atomic Energy Agency, 2009, pp. 1-68).

Determining the activity of certain materials is an essential precondition for the proper classification of radioactive waste. Waste classification is also necessary for the storage and proper disposal of radioactive waste, but the determination of radionuclide content is a challenge for certain nuclide groups. These are the so-called difficult-to-measure isotopes. The latter cannot be measured by simple methods such as gamma emitters, so complex radiochemical and nuclear procedures are required. Due to the difficulties, an attempt is made to develop a uniform calculation method based on finding correlations between easy and difficult components to measure these so-called "*scaling factors*" (TÖLGYESI, 2002, pp. 1-10).

The international organisations are also interested in technology development, concerned with measurements and determination of radioactive decay. The SFCOMPO-2.0 (Spent Nuclear Fuel Assay Database)[8] database was published in 2017 due to a collaboration between the OECD NEA[9] , the Oak Ridge National Laboratory and the NEA Expert Group on Assay Data for Spent Nuclear Fuel group. The database consists of reviewed experimental data sets from a wide range of reactors (750 spent fuel samples used to construct the database, based on 44 different reactor types and 24,000 measurements). The database also includes the open-source bibliographic references from which the data were derived. Spent fuel storage capacity is coming to an end in the following decades, so several States have begun to look for final disposal solutions. Computer modelling and simulation are used to safely manage spent fuel and evaluate permits, thus widely supporting and ensuring nuclear safety. Determining the nuclide concentration of spent fuel is an essential prerequisite for fuel judgment and burnout. The new database contains reliable, well-documented experimental test data, thus helping NEA Member State authorities, scientific communities and operators (MICHEL-SENDIS & et.al., 2017, pp. 779-788).

2.1. Nuclear energy is beneficial concerning low carbon dioxide solutions – but where to store the waste?

When it comes law CO_2 technologies, nuclear energy seems like a preferable method. Although, some calculations pointed out that the whole picture – from the planning, thought the installation till the end of the nuclear cycle – is not so beneficial as it seems at first sight. The most significant concern is nuclear waste and the environmental and health risks that it holds. Since the first experiments with fissile materials, the world had to face a new challenge: radioactive waste storage. In the beginning, armament was the primary source of nuclear waste, but since the 1950' more and more reactors were built, and the main focus is on commercial energy production. In the United States of America, the National Academy of Sciences recommended geological disposal to store radioactive waste as early as 1957. The plan was included in a report asked by the U.S. Atomic Energy Commission (Committee of Waste Disposal, National Academy of Science,

[8] SFCOMPO 2.0 (Spent Fuel Isotopic Composition) at https://www.oecd-nea.org/jcms/pl_21515/sfcompo-2-0-spent-fuel-isotopic-composition.
[9] OECD NEA: Organisation of Economic Co-operation and Development Nuclear Energy Agency.

1957, pp. 1-146). The search for the exact location began in 1970, and the same year the city of Lyons, Kansas, was chosen. Two years later, however, the project was halted due to technical uncertainties and resistance. Finally, the Nuclear Waste Policy Act was passed in 1982, settling the principles for waste disposal. For many years, the Yucca Mountains seemed a possible location, but in 2009 the government decided that construction was impossible. In 2013, the administration issued its strategy for the management and disposal of spent fuel and high-level radioactive waste, which implements the recommendations of the Blue Ribbon Commission for the sustainable management of nuclear waste in the USA. The Blue Ribbon Commission on America's Nuclear Future was set up in 2010, and a recommendation on waste management was adopted two years later.[10]

The technology has constantly been developing, and some storage solutions are not accepted anymore under current regulation. Such as the USA disposed of low-level radioactive waste to oceans, and the barrels were put on the seabed in several sights (e.g., Pacific-Ocean). In many cases, social pressure influenced waste management methods, especially in connection the oceanic disposal (United States Nuclear Regulatory Commission, 2007).

The International Atomic Energy Agency differentiate among the following disposal facilities:

- specific surface landfills: similar to conventional landfills, but only for very low-level waste (VLLW).
- near-surface storage: for low-level waste (LLW) storage at a depth of a few tens of meters above ground or below ground level.
- underground facilities: in built-up caves and vaults or mines, up to a depth of tens of meters to hundreds of meters, underground, specifically for intermediate-level waste (ILW).
- deep geological repositories: mainly for spent fuel and other high-level waste (HLW).
- boreholes: from a few hundred meters to a few kilometres deep for HLW reservoirs, primarily for plutonium disposal (IAEA, 2011/2019).

The main source of low-level waste are contaminated shoe covers and clothing, everyday utensils used in nuclear power plants (wipes, scrubbing fibres, filters, equipment and tools, light discs), reactor water treatment residues, carcasses and tissues of laboratory animals. Such wastes are usually stored on-site for the required time. Then, the degree of hazard might be eliminated, and typical waste management methods can be used, or the waste is collected and later placed in the long-term storage capacity. Intermediate-level radioactive waste (ILW) requires a genuinely long-term solution, especially if they contain long-lived radioisotopes. Geological formations are used to store radioactive waste, where water-soluble compounds accumulate over millions of years, such as salt mines, clay rocks, granite and tuff. Additional engineering barriers are being built into geological formations. Nuclear waste is placed in containers made of stainless steel or reinforced concrete and placed inside the barrier system. With this method, only solid waste is stored. Liquid waste is solidified by cementation or bitumen.

[10] History of Nuclear Waste Management, 2016 at https://www.energy.gov/sites/prod/files/2016/04/f30/History%20of%20Waste%20Management_1.pdf.

The holes between the tanks are also filled with cement. Geological repositories have several dam systems (rocks, barriers) designed to separate radioactive waste from the environment. Low and medium intensity wastes decompose, and various gases (carbon dioxide, methane) are generated during the process. These released gases can cause an increase in pressure in the storage system, and radionuclides can leach out and migrate, thus polluting the environment (KÓNYA & M. NAGY , 2018, pp. 20-22).

Choosing the proper repository for spent fuel and high-level waste remains a challenge for all countries. High-level disposal facilities providing a final depository are still in the planning phase. To date, a total of three countries (Finland, Sweden, and France) *de facto* determined the location of the deep geological repository as part of an early completion process. HLW repositories' permits have been granted in some countries or are expected to do so in the next decade. Switzerland and Germany seek a suitable location and are expected to designate it over the next decade. Only incomplete information is available on the programs of some countries, such as China and Russia (HARMS, et al., 2019, pp. 68-70).

The limitation of nuclear waste is not just a need but also a principle of radioactive waste management (PETRANGELI, 2019, p. 289). In the Netherlands, radioactive waste is stored in a central interim storage facility with a planned lifetime of approximately 100 years. By checking the already conditioned waste activity, the containers are opened, sorted, and, after the activity has ceased, traditional waste treatment methods are applied. This solution applies to States where only a tiny amount or low level of waste is generated.

3. THE MAIN CHALLENGES CONCERNING NUCLEAR WASTE FROM AN ENVIRONMENTAL LAW PERSPECTIVE

The main issue is how anyone can guarantee that radioactive waste disposal facilities will provide safe storage even for hundreds of years and will not jeopardise future generations. Even if one just considers the ordinary geological happenings and changes, safe storage is questionable. The World Nuclear Report – Focus Europe states, by 2013, almost 370,000 tons of spent fuel had been generated since the commissioning of the first reactor, and about a third of this had been reprocessed (HARMS, et al., 2019).

In the last decades, geographical storage facilities have been widely used for nuclear waste disposal. As earlier mentioned, salt mines and other exhausted mining sites served as an easily accessible solution. The idea of using salt mines to store radioactive waste was put into action in Germany. Several barrels of nuclear waste still lie in a shattered heap in the depths of an abandoned German salt mine – untouched since the 1970s. Between 1967 and 1987, a total of 47,000 m^3 of low and intermediate-level radioactive waste was deposited on the site of the former salt mine, called "Asse II." (DOSE, et al., 2016, pp. 16-20). Since the 1960s, the Asse II chambers in Lower Saxony have stored more than one hundred thousand barrels of low or intermediate-level nuclear waste. The treatment of low-level waste is not considered hazardous, but intermediate-level waste must be disposed of. In 2008, reports revealed that water leaking from Asse II since the 1980s proved to be radioactive. Fearing that the mine could fill up with water – causing radioactive contamination in the region – the German authorities are making an unprecedented attempt to collect and relocate hundreds of tons of waste. The project started in 2016.[11]

The safety of the facilities was often questioned, and other alarming cases can be brought as examples. For example, in the case of Maxey Flats (USA), as early as the 1970s, plutonium complexes were detectable outside the facility, originating from a large amount of waste disposed of (SHRADER-FRECHETTE, 1993, pp. 103-104).

Near ground or underground facilities strengthened with concrete parts and structures are much safer. This type contributes to establishing a base environment that creates a geochemical barrier, especially for leachates containing heavy metals. This design is used for both low and intermediate-level, as well as for long-life wastes. Under these circumstances, a facility was opened in Beatty, Nevada (USA) in 1962 with a clay seal and the waste is kept in precast rollers in a preconditioned form. Beatty closed its gates in 1992, by which time nearly 136 million gallons of waste had been disposed of here. Incidentally, the landfill later became notorious due to various administrative shortcomings and a major fire.[12]

3.1. The new idea of international storage facilities

Several ideas have emerged for the final disposal of high-level waste. One of the most recent is multinational or regional storage capacity, which could be used by several States. This idea is explored by the International Atomic Energy Agency (IAEA, 2004, pp. 1-62) and the European Union via the European Repository Development Organization, ERDO. The Arius Association was established in 2002 to promote the concept of multinational radioactive waste repositories. The aim is to have a safe, secure, and accessible geological repository for all nuclear waste producers. The ideal repository is small-scaled, contributing to international security as well. In 2002, the following states joined the Association: Belgium, Bulgaria, Hungary, Italy, Japan and Switzerland. Since then, the Netherlands and Slovenia have also joined the organisation. Other States have now supported the creation of the ERDO-WG (European Repository Development Organization Working Group): Austria, Denmark, Ireland, Lithuania, Poland, Romania and Slovakia.[13] However, joint planning since the establishment of the ERDO-WG is slower than expected and more regular consultation among the parties would be needed. The initial objectives have been expanded, and more emphasis is placed on sharing knowledge and experience. The International Atomic Energy Agency also welcomed the ERDO approach. The possibility of implementing the plan in other regions was raised, especially in the Gulf region and South Asia (CHAPMAN, et al., 2013, pp. 1-5).

The plan is certainly to be welcomed, but implementation raises many issues, especially from a practical perspective. Firstly, how will the costs be shared among the participating countries if the project is significantly delayed or needs to be abandoned? Secondly, what happens if the import of foreign waste becomes impossible due to social pressure or changing legislation. Furthermore, how State's stability in which the storage

[11] Nuclear Waste Pileup at https://www.nationalgeographic.com/history/article/100708-radioactive-nuclear-waste-science-salt-mine-dump-pictures-asse-ii-germany.

[12] Radioactive waste dump fire reveals Nevada site's troubled past 25 October 2015 at: https://www.theguardian.com/us-news/2015/oct/25/radioactive-waste-dump-fire-reveals-nevada-troubled-past.

[13] Membersip at http://www.arius-world.org/membership.html.

site is located can be guaranteed for the necessary time. Finally, another question arising from neighbourliness is whether such a facility pose a security risk to other States?

When it comes to the possible sights, Australia and the South Asian region have also been identified as viable locations for multinational storage capacity. At the same time, it has also been suggested that uranium mining countries take fissile materials back at the end of their life cycle, along with other radioactive waste generated in the process (FEINHALS, et al., 2016, pp. 48-51).

3.2. The main effects of the Fukushima Power Plant accident on European energy policy

After 1986, the international community would not have assumed that another nuclear power plant accident would shake the world a few decades later. The incident in Japan, which took place barely a decade ago, points out that human negligence and the forces of nature can be a direct cause of a severe accident or breakdown. What were the consequences and effects of the Fukushima power plant accident?

The Fukushima Daiichi nuclear power plant was built between 1971 and 1979, consists of six reactor units, but only three of them were in operation at the time of the accident. On 11 March 2011, Japan was shaken by a powerful earthquake that caused several tsunamis. In 2011, Japan was hit by a triple disaster: a magnitude nine earthquake, a series of tsunamis and the accident of its most significant nuclear power plant. The operating reactors were shut down in time, but the power outage led to the insufficient operation of the cooling system in all reactors. In the days following the earthquake and after the failure, several explosions happened in the reactors, mainly because of the increased residual heat level and the reactor core's "melting". The level of radioactive radiation increased more and more. A large enclosed zone was created in the vicinity of the power plant, and an assessment was made of the exact amount of radiation released into the environment.[14]

However, a series of events, including the possibility of irreparable environmental damage, did not end with the explosions. In October 2020, the news was announced that 1.2 million tons of filtered but still radioactive cooling water currently stored on the power plant site would be released into the sea from 2022 onwards. It is planned that the contaminated water in the power plant area would be diluted before application, reducing its concentration. The process would last for a total of 30-40 years. Contaminated water is currently stored on the power plant site in huge tanks, but final disposal is a must since it is constantly leaking into groundwater. Following application, the diluted cooling water would enter the Pacific Ocean and, according to experts, pose a low level of risk to human and animal health and the environment, as Japan claims to be primarily contaminated with tritium.[15] Not surprising that the plan was protested not only by neighbouring States but also by a number of environmental organisations. According to the position published by Greenpeace in 2020, the Tokyo Electric Power Company operating the power plant and the Japanese government have been providing manipulated

[14] Fukushima accident Japan [2011] In: Encyclopaedia Britannica at: https://www.britannica.com/event/Fukushima-accident.

[15] BBC, Fukushima: Japan 'to release contaminated water into sea' 16 October 2020 at: https://www.bbc.com/news/world-asia-54566978.

information continuously since the accident, mainly concerning radioactive contamination of cooling water (BURIE, 2020, pp. 1-5). Besides all opposing opinions, the plan was approved in spring 2021, and the trial could start in two years.[16]

As mentioned earlier, the European sphere is still heavily reliant on nuclear power generation and is reflected in the energy policies of many States. However, in 2011 nuclear power generation and the safe operation of power plants were questioned again. Interestingly, the response was not uniform on the part of the European States and the international community. Germany is a highly striking example. Barely two weeks after the accident, elections were held in Germany. The Angela Merkel-led administration had to justify its decision to extend the life of old but still functioning reactors. Henceforth, in Germany, Fukushima had been in the centre of interest. In other States, such as the United Kingdom, the effects of the accident were negligible, and the media had been distracted by other events. Another reason is that in Germany, renewable energy sources have quadrupled since the 1990s, and technological development can be considered continuous. So, it has naturally emerged that investment should be made to develop renewable energy sources instead of relying on nuclear power plants. Precisely what factors influenced the echo of the Fukushima power plant accident can also be supported by historical and economic aspects, not only the composition of the State's energy production (WITTENBEN, 2012, pp. 1-3).

Council Directive 2009/71/Euratom of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations[17] was modified in 2014. The Council Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations[18] explicitly refers to the Fukushima power plant accident as the following: "*the Fukushima nuclear accident in Japan in 2011 renewed attention worldwide on the measures needed to minimise risk and ensure the most robust levels of nuclear safety*."[19]

The Fukushima accident had far-reaching consequences for the nuclear policy of the States, which is not uniform even in the EU Member States. Some Western European countries have made substantial changes to their nuclear policies, including Germany, where the entire energy production policy has been rethought after 2011. In those countries that have so far used nuclear power plants or are planning to build new ones, in most cases, they have not deviated significantly from their goals. However, the introduction of increased safety considerations and review mechanisms has slowed down the implementation and construction of power plants. The latter is essential; the effects of natural disasters and geological changes cannot be ignored. Based on the European Council conclusions (European Council, 2011, p. 11), the national competent regulatory authorities, together with ENSREG,[20] a Community-wide comprehensive risk and safety assessment of nuclear power plants was carried out. They are called 'stress tests'. The results identified several improvements which could be implemented in nuclear safety

[16] Dennis Normile: Japan plans to release Fukushima's wastewater into the ocean 13 April 2021 at https://www.sciencemag.org/news/2021/04/japan-plans-release-fukushima-s-contaminated-water-ocean.
[17] OJ L 172, 2.7.2009, p. 18–22 CELEX- 32009L0071.
[18] OJ L 219, 25.7.2014, p. 42–52 CELEX- 32014L0087.
[19] Directive 2014/87/EURATOM (5).
[20] The Commission in the framework of the European Nuclear Safety Regulators Group established by Commission Decision 2007/530/Euratom.

approaches and industry practices in the participating countries (ENSREG, 2012, pp. 1-53). The European Council also called on the Commission to review, as appropriate, the existing legal and regulatory framework for the safety of nuclear installations and propose any improvements that may be necessary. The European Council also stressed that the highest standards for nuclear safety should be implemented and continuously improved in the European Union.[21]

4. CONCLUSION AND CLOSING REMARKS

„*Atomic power can cure as well as kill. It can fertilise and enrich a region as well as devastate it. It can widen man's horizons as well as force him back into the cave*."[22]

Despite the close link between environmental protection and the use of fissile materials, the international treaties adopted in the field of nuclear law did not include environmental aspects in the beginning. Today, the rights of future generations and sustainability considerations have also found their way into international nuclear law. In particular, long-term storage should be addressed not to impose a disproportionate burden on future generations. International treaties and other binding sources have been adopted at both international and regional levels for radioactive waste management and the safe management of spent fuel. At the same time, the role of "soft law" is significant, mainly through the non-binding safety regulations and proposals adopted by international organisations. Although the internal regulations of each State differ significantly, their harmonisation and approximation are one of the main tasks of nuclear law. Legislation needs to be transparent and clear, taking into account the changes that have taken place in recent years, especially about the range of regulators. Ensuring social participation and access to information has become more critical, so it should also be required in decision-making in nuclear law. All relevant factors in the designation of deep geological repositories for long-term storage can be social understanding and acceptance.

Radioactive waste is generated during energy production and through the use of other technologies, including healthcare. The management of such waste is also an essential task for States. The final disposal and storage of high-level radioactive wastes (HLLs) and/or long-lived fission products (LLFPs) has not been resolved. Even in the case of intermediate-level waste (ILW), there are doubts, especially because several pollution cases have come to light in recent decades concerning existing repositories. States with a nuclear program see the solution in constructing deep geological repositories, but in most cases, their location is still in the planning or permitting phase. Spent fuels used in nuclear reactors are a separate issue, as their final storage is not solved at all. All the solutions used today – storage underwater or in concrete, often in the reactor at the field of a nuclear power plant – can only be considered temporary.

Further questions are raised because most States have been using fuels for only a few years and have stopped recycling them – primarily for economic reasons. It is essential to distinguish between the concepts of spent fuel and radioactive waste. Spent fuel shall only be considered waste if it is not re-used and the holder intends or is required to

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[21] *See* EU instruments for nuclear safety at http://www.ensreg.eu/safety-radioactive-waste-management/eu-instruments.

[22] Alvin M. WEINBERG, 1945 in front of the Senate's Special Committee on Atomic Energy.

dispose of it. The establishment of multinational waste storage facilities and sites, especially for deep geological storage, has become increasingly important. However, programs to this end have not yielded the expected successes, requiring closer cooperation, exchanging information, and commitment among States. Several aspects arise from site selection, from the state "taking over" the storage site to the solution of cross-border shipments of radioactive waste.

Nuclear power plant accidents in recent decades have highlighted the dangers of nuclear power generation. In the cases of Chernobyl (1986) and Fukushima (2011), the question arose as to whether it was worth relying so much on nuclear power generation and how to ensure the safety of nuclear facilities. In addition, the European Union's commitment to a climate-neutral continent relies heavily on nuclear power generation, which can be considered clean energy in terms of CO_2 emissions. However, since the events of 2011, several countries have re-evaluated their energy policies.

REFERENCES

BLIX, H., 1983. Radioactive waste management policies. *IAEA BULLETIN*, vol. 25.(no. 4.), p. 12..

BURIE, S., 2020. *Stemming the tide 2020 The reality of the Fukushima radioactive water crisis.* [Online] Available at: https://storage.googleapis.com/planet4-japan-stateless/2020/10/5768c541-the-reality-of-the-fukushima-radioactive-water-crisis_en_summary.pdf

CHAPMAN, N., MCCOMBIA, C. & VERHOEF, E., 2013. *Towards a European Regional Geological Repositry.* Proceedings of the 15th International Conference on Environmental Remediation and Radioactive Waste Management.

Committee of Waste Disposal, National Academy of Science, 1957. *The Disposal of Radioactive Waste on Land.* [Online] Available at: https://www.nap.edu/catalog/10294/the-disposal-of-radioactive-waste-on-land

DEBELKE, J., 2019. *Ten Personal reflections on the different journey towards climate neutrality.* New York: Routledge.

DOSE, J., LASKE, D., MOHLFELD, M. & WELLMANN, P. L., 2016. *The Asse II Mine – Tasks and Challenges.* International Conference on the Safety of Radioactive Waste Manageent.

EMMERECHTS, S., 2008. Environmental Law and Nuclear Law. A Growing Symbiosis. *Nuclear Law Bulletin,* vol. 40.(no. 2.), pp. 91-110..

ENSREG, 2012. *Post-Fukushima Accident Stress tests performed on European nuclear plants Final Report.* [Online] Available at: http://www.ensreg.eu/sites/default/files/EU%20Stress%20Test%20Peer%20Review%20Final%20Report_0.pdf

European Commission, 2018. *A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy.* Brussels: ismeretlen szerző

European Council, 2011. *Conclusion.* [Online] Available at: https://data.consilium.europa.eu/doc/document/ST-10-2011-INIT/en/pdf

Eurostat, 2017. Energy Statistics. pp. 1-11.

FEINHALS, J., KEMP, D. & SAVIDOU, A., 2016. *Disposal Facilities for countries without a Nuclear Power Programme.* National Policy, Strategy and Framework for Radioactive Waste Management International Conference on the Safety of Radioactive Waste Manageent.

FORSBERG, C. W., 2003. *Radioactive Wastes.* Third Edition. Academic Press.

HARMS, R., SCHNEIDER, M., JUNGJOHANN, A. & TURMANN, A., 2019. *The World Nuclear Waste Report. Focus Europe.* [Online] Available at: https://worldnuclearwastereport.org/

IAEA, 2004. *Developing multinational radioactive waste repositories: Infrastructural framework and scenarios of cooperation.* [Online] Available at: https://www-pub.iaea.org/MTCD/Publications/PDF/te_1413_web.pdf

IAEA, 2011/2019. *Disposal of Radioactive Waste.* [Online] Available at: https://www-pub.iaea.org/MTCD/publications/PDF/Pub1449_web.pdf

International Atomic Energy Agency, 2009. *Classification of Radioactive Waste.* [Online] Available at: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1419_web.pdf

KÓNYA, J. & M. NAGY , N., 2018. Nuclear Energy Production. In: *Nuclear and Radiochemistry.* 2nd Edition. Elsevier, pp. 20-22.

MICHEL-SENDIS, F. & et.al., 2017. SFCOMPO-2.0: An OECD NEA database of spent nuclear fuel isotopic assays, reactor design specifications, and operating data. *Annals of Nuclear Energy,* Issue vol. 110., pp. 779-788.

National Research Council, 1999. *Disposition of High-Level Radioactive Waste Through Geological Isolation: Development, Current Status, and Technical and Policy Challenges.* [Online] Available at: https://doi.org/10.17226/9674 2-4

PETRANGELI, G., 2019. Chapter 23 - Radioactive Waste. In: *Nuclear Safety.* Second Edition. Cambridge: Butterworth-Heinemann, p. 289.

SHRADER-FRECHETTE, K., 1993. Burying Uncertainty, Risk and the Case Against Geological Disposal of Nuclear Waste. *University of California Pres,* pp. 103-104.

STRAUSS, L. L., 1955. *New York Times,* Issue 7 August, p. 1..

TÖLGYESI, S., 2002. *Determination of uranium and transuranium elements in radioactive wastes of low and medium activity from a nuclear power plant.* [Online] Available at: https://repozitorium.omikk.bme.hu/bitstream/handle/10890/171/tezis_eng.pdf?sequence=3&isAllowed=y

United States Nuclear Regulatory Commission, 2007. *History and Framework of Commercial Low-Level Radioactive Waste Management in the United States, ACNW White Paper, NUREG-1853.* [Online] Available at: https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1853/index.html

WITTENBEN, B. B., 2012. The impact of the Fukushima nuclear accident on European energy policy DOI:https://doi.org/10.1016/j.envsci.2011.09.002.. *Environmental Science and Policy.,* vol. 15.(issue 1.), pp. 1-3.