The Investigation about Impacts of Fukushima Nuclear Leakage Accident and Effects on Public Attitudes

Yunxi Lin*
Shanghai Weiyu High school, Shanghai, China
*Corresponding author: 13221010791@stu.cpu.edu.cn

Abstract. The safety issues of using nuclear energy and its probability to become a reliable, efficient energy source in the future are controversial topics that people are arguing about. This essay focused on the analysis of specific nuclear energy accidents, which represented the safety problems of using nuclear energy, and discuss some personal opinions on the plausibility of nuclear energy becoming a dominant energy source in the future, which gave some understanding of nuclear energy use in environmental aspect and thus help people to gain a better understanding toward nuclear energy usage. In the illustration part, this essay collected data, research, and explanations from several articles and essays to provide a comprehensive analysis. At the end of this research, I found that damages caused by nuclear energy are severe and unneglectable, which can greatly pollute land, atmosphere, and ocean in a wide region. Therefore, a large number of people opposed further use of nuclear energy owing to its disastrous effects after the accident. However, nuclear energy has several benefits that can become a dominant energy source in the future. Overall, nuclear energy can become reliable in the future although the consequences created by the leakage after the Fukushima nuclear leakage accident are severe, which would be discussed in the following essay.

Keywords: Fukushima nuclear leakage; nuclear power plant; nuclear safety.

1. Introduction

In modern society, after the development of nuclear bombs, people started to realize the importance of nuclear energy usage and began to develop facilities that used nuclear power, including nuclear power plants. Furthermore, in many developed countries, nuclear power became a dominant source of energy for generating electricity [1]. According to the data collected in May 2022, the number of nuclear power plants in the United States, France, China, and Russia is 92, 56, 54, and 37. In addition, France derives about 70% of its electricity from nuclear energy, due to a long-standing policy based on energy security. Thus, it is crucial to make an analysis of the safety aspect of nuclear energy usage by showing a specific event and demonstrating the effects after the accident. Consequently, this essay focused on a case study of Fukushima nuclear leakage by providing an analysis of pollution on land and ocean and the amount of pollution caused by radioactive elements. Moreover, this essay also showed attitudes from citizens, and governments toward the accident and nuclear power, and concluded from that information to provide suggestions and personal opinions for the use of nuclear energy in the future [2].

2. Review of Fukushima Nuclear Leakage

On March 3, 2011, an earthquake with a magnitude level of 9 happened east of Fukushima, resulting in a tsunami. As the earthquake wave reached Fukushima nuclear power plants, the nuclear power plants were shut down due to the acceleration of ground movements, resulting in the controlling rods stopping the nuclear chain reaction. However, some of the controlling rods were not in an accurate position, and the monitor system did not detect it as well until the temperature of the power plant became extremely high. The nuclear leakage accidents contained several factors. Specifically, nuclear decay and fission were inevitable, and due to the arrival of the tsunami, which ruined the electricity devices for the cooling system, the temperature continued to rise. Although the electricity company from Kansai came for rescuing, the voltage and frequency of electric systems differed. Thus, without the water inside the power plant, the temperature rose until large amounts of hydrogen were released, causing the nuclear plants to explode and resulting in nuclear leakage. Generally, several elements were released from nuclear fission, including iodine, cesium, strontium, yttrium, etc. If the ocean water is polluted, humans will indirectly ingest radioactive elements in seawater by consuming seafood. Specifically, when humans ingest radioactive elements such as iodine-131, strontium-90, and cobalt-60, they will be directly absorbed into human blood and circulate in the body. Strontium-90 can congregate on the bone, damaging it and breaking the Hematopoiesis function. Iodine-131 can result in chronic radiation sickness, damaging Hematopoietic organs, cardiovascular system, endocrine system, and nervous system, which can cause several symptoms, including headache, limb weakness, and blindness. Furthermore, the risks of marine radioactive pollution are potential and long-lasting. Those harms often present in the next few generations rather than only a few weeks or years. Iodine was proven that the chromosome is the major determinant of genetic effects. However, the chromosome is extremely sensitive to nuclear radiation. After the body is irradiated, the chromosome will show different degrees of damage and may be distorted. When the chromosome of the germ cell is distorted, it may cause congenital malformations in the next few generations and increase the incidence rate of some diseases [3].

3. Impact of Fukushima nuclear leakage

3.1. Impact of Leakage on Land

After the nuclear leakage of Fukushima, large amounts of radioactive elements were released into the atmosphere, including I-131, Cs-134, and Cs-137. The Nuclear Industrial Safety Agency of Japan estimated that there were 160PBq of I-131, 18PBq of Cs-134, and 15PBq of Cs-137 were released, while The Nuclear Safety Commission of Japan estimated that there were 130PBq of I-131, 11PBq of Cs-137. Additionally, The Ministry of Education, Culture, Sports, Science and Technology, Japan, collected soil samples from approximately 2200 locations within nearly 100 km of the F-1NPP to analyze the deposited radionuclides. The deposition density of Cs-137 was more than 1000KBq/m^2 in the Namie and Iitate districts. The average ratio of deposition density of I-131 to that of Cs-137 was around 0.0059 for monitoring points located to the north of the nuclear plant and around 0.024 for monitoring points located south [4]. Specifically, about Cs-137, brought to the surface by dry and wet deposition, has a half-life of 30.1 years and was absorbed in the top layer of the soil that could remain for several years. This soil contamination was especially worrying due to its deleterious effect on stock farming and agriculture and its potential consequences on human health. Moreover, the soils around Fukushima have been contaminated with depositions of more than 100,000 MBq km^{-2}, and Cs-137 has strongly contaminated the soils in large areas of eastern and northeastern Japan. According to the data, in Japan, the limit for cesium concentrations in the soil is 5,000 Bq kg^{-1}. For food production, the upper limit for cesium in the soil is 2,500 Bq kg^{-1}. Therefore, food production in the eastern Fukushima prefecture was severely impaired. Fortunately, western regions of Japan were much safer since mountain ranges sheltered them [5].

3.2. Impact on Ocean

In the processes of releases, dispersions, and depositions, pollution was spread into the ocean. Generally, in the releasing process, the noble gases Kr-85 and Xe-133, with half-lives of 10.76 years and 5.25 days, respectively, contributed to external exposure from the plume of the atmospheric releases. The I-131, with a half-life of 8.02 days, contributed to the equivalent doses to the thyroid gland if ingested or inhaled. The Cs-134 and Cs-137, with half-lives of 2.06 years and 30.17 years, respectively, contributed to both equivalent and effective doses through external and internal exposure. While 131I decays relatively quickly, it can give rise to relatively high equivalent doses in the thyroid gland. In some areas, Cs-137 may continue to be present in the environment, and without remediation, it could remain a contributor to effective doses for individuals. Regarding the ocean impacts, most of the atmospheric releases dispersed over the North Pacific Ocean fell on the oceanic surface layer. Based on the data about the radioactive element releases, the peak was observed at the beginning of April 2011. The direct releases and discharges of I-131 and Cs-137 were 10–20 PBq and 1–6 PBq, respectively. However, for Cs-137, some estimations suggested that the releases were about 2.3–26.9 PBq. In the dispersion process, most radioactive elements released by the nuclear leakage that entered the sea were spread eastward with the Kuroshio current. Then, along with the dispersion, Cs-137 dominated the center of the Pacific Ocean and reached North America and South America on 17th March 2011. The speed of dispersion was fast. On 21th March 2011, Cs-137 dominated most areas in the Pacific Ocean and contaminated parts of the Arctic Ocean. On the next day, large parts of the Atlantic Ocean were polluted near the region in South America, and the pollution in the Arctic Ocean was still spreading. Finally, on 26th March 2011, the Pacific Ocean, Atlantic Ocean, and Arctic ocean were polluted with various degrees of Cs-137. Finally, in the deposition process, although it is difficult to measure the accurate estimation of the amount of Cs-137 released to the atmosphere, which was deposited on the ocean surface, some models had published for the estimation of Cs-137 deposits. Specifically, the density of Cs-137 deposition in the coastal region near Fukushima nuclear powerplants is around $10000Bq/m^2$, and the deposition density continued to decrease from the nuclear plant to the pacific ocean, which in most coastal regions, the density of Cs-137 is between $100\text{-}1Bq/m^2$ [6].

4. Methods used for the estimation of nuclear fission reaction products and nuclear leakage in the Fukushima nuclear power station

Assuming that Fukushima nuclear power plants used standard Uranium dioxide with low density as fuels, the percentage of Uranium-235 that might contain nuclear fission is 4%-5%. If the nuclear power plant used mixed fuels such as mixed oxide fuel (MOX), the percentage of plutonium that might contain nuclear fission is 7%. However, among the plutonium, only 67% of them can involve in nuclear fission. The amount of uranium-235 and fissionable plutonium-239 in spent fuels generally will not exceed 2%. Therefore, based on the information, the mass P of uranium dioxide and plutonium dioxide can be calculated by the equations below:

$$P_{min}=600\times4.5\%+2100\times2\%=69\ (ton) \tag{1}$$

$$P_{min}=600\times4.5\%+2100\times2\%=69\ (ton) \tag{2}$$

Since it is assumed that the Fukushima nuclear power station has 6 power plants, and 600 tons of nuclear fuels, the total storage amount is 2100 tons. But some reports stated that there are 800 tons of nuclear fuels and 3400 tons of fuel storage. As a result, in the calculation about the total mass of uranium-235 and plutonium-239 X can be calculated as below [8]:

$$X_{min}=69\times(235+239)/(235+239+4\times16)=60.8\ (ton) \tag{3}$$

$$X_{max}=104\times(235+239)/(235+239+4\times16)=91.6\ (ton) \tag{4}$$

Since nuclear fission follows rules of the conservation of masses, the conservation of charges, the conservation of energy, the conservation of momentum, the conservation of angular momentum, and the parity conservation, the energy (E) released during nuclear fission, decay, and fusion follow the formula of E=mc2, which the mass of uranium and plutonium are known, the energy released can be estimated. Fission yield refers to the probability of fission products produced in the fission process. Thus, according to the fission yield, the mass percentage of the nuclei of fission products(Y) by using Y=fission yield x mb/ma, and ma is the mass number of nuclei at the beginning of the nuclear fission, mb is the mass number of nuclei in nuclear fission. Furthermore, the mass of nuclei of fission products (Z) can be calculated as Z=X × Y=P × (u+p)/(u+p+4xo) × fission yield × mb/ma. In addition, the nucleus number N can be estimated by N=AT1/2/constant, and according to Avogadro's law, mass can be calculated using m=N/NA. Finally, in this formula, $T_{1/2}$ is the half-life, which can be calculated. In conclusion, Since the nuclear leakage happened, 20-40 trillion Bq of tritium was emitted to the Pacific Ocean. Every day, ten thousand trillion Bq of gaseous iodine were released into the atmosphere, and five thousand trillion Bq of cesium-137 were released into the atmosphere in the gaseous state [9].

5. Attitudes Toward Fukushima Nuclear Power Plant Disaster

After the disaster happened, the initial reaction by the government was to prevent any nuclear reactors that had ceased operations from restarting. Moreover, reactors were required to undergo strict tests to determine if they would withstand another natural disaster, and additional power supply units were installed. In coping with the emergency, personnel from TEPCO, contractors, and other Japanese NPPs were dispatched to the site to assist with various tasks, including restoring power and monitoring instruments, injecting cooling water into reactors, removing rubble, and monitoring radiation levels. Personnel from national Government agencies and organizations were also dispatched to the site. They helped with activities including operating the large equipment needed to pour or spray water onto the spent fuel pools and providing helicopter surveillance of the spent fuel pools. Owing to the reduced number of functioning nuclear reactors, it was projected in 2011 that there would be nationwide power deficits. In order to cope with this, blackouts were scheduled, and certain industries and institutions took additional holidays to reduce peak energy use. In the aspect of public health, evacuation policies were followed. On March 11th the Fukushima governor instructed the towns of Okuma and Futaba to evacuate residents who were within 2km of the disaster to other areas. Then, on March 12th, the Japanese government also instructed people within a 20km radius of the disaster to evacuate. The detailed process included evacuation, sheltering, iodine thyroid locking, restrictions on food consumption and drinking water, relocation, and the provision of information. However, there were difficulties in evacuation due to the damage caused by the earthquake and tsunami and the resulting communication and transportation problems. Significant difficulties were also encountered when evacuating patients from hospitals and nursing homes within the 20 km evacuation zone [10].

Regarding the public reactions, there was a report for collecting citizens' opinions about nuclear energy, which included three questions, the extent of agreement or disagreement toward the use of nuclear energy for producing electricity in Japan, the extent of agreement or disagreement toward the usefulness of nuclear energy in Japan, and the extent of agreement or disagreement toward the safety of nuclear energy in Japan. In conclusion, Before the accident, the results of question one in the 2011 surveys present that the Japanese public was supportive of the use of nuclear energy for electricity in Japan. There were as many respondents in favor of nuclear energy ('agree' 14.2%, 'tend to agree' 29.6%, and 'total agree', 43.8%) as against it ('disagree' 2.6%, 'tend to disagree' 11.2%, and ‘total disagree’ 13.8%). The results of question two show that many respondents have the cognition about the usefulness of nuclear energy for electricity in Japan ('agree' 21.2%, 'tend to agree' 40.6%, total agree 61.8%) as against it ('disagree'1.0%, 'tend to disagree' 4.4%, and total disagree 5.4%). Roughly six out of ten respondents had regarded nuclear energy as a useful energy source for Japan. The results of question three show nearly half of the respondents were anxious about the operation of nuclear power plants. Fewer than 20% of the respondents have the perception about nuclear power plant safety ('agree' 1.6%, 'tend to agree' 17.0%, and total agree 18.6%) as against it ('disagree' 10.8%, 'tend to disagree'39.0%, and total disagree 50.8%). However, after the accident, the number of opposition to the use of nuclear energy in Japan surged. The result of the first question showed a statistically significant difference as 8.4 %-point, 14.8% point and 12.0%-point decrease in response choice as 'agree' tend to agree' and 'neither agree nor disagree', while 19.2% point and 15.8%-point increase at 'disagree' and 'tend to disagree', respectively. In question two, the survey showed a statistically significant difference, a 10.0 % point and 11.0%-point decrease at response choice as 'agree' and 'tend to agree', while a 10.0% point and 8.8%-point increase at 'disagree' and 'tend to disagree', respectively. Finally, about the third question, the data demonstrated that a statistically significant difference of 12.4 % point and 7.6%-point decrease at response choice as 'tend to agree' and ' neither agree nor disagree', while 24.6%-point increase at 'disagree', respectively. Therefore, this research concluded that the Fukushima nuclear accident shifted citizens' opinions negatively to a huge extent. Regarding the international reactions [11]. The European Union (EU) has agreed to stress test all nuclear plants within the union for natural disasters, such as earthquakes and flooding, as well as for man-made catastrophes like terrorist attacks. In addition, in the United States, three Senators have requested a Congressional investigation of safety standards and federal oversight at nuclear facilities following a year-long Associated Press investigation detailing safety and regulatory problems at U.S. nuclear facilities.

6. Conclusion

Evidently, nuclear energy has several significant advantages, such as its reliability, safety, environmentally friendly property, and efficiency. Specifically, nuclear power plants generally can maintain their function available for 50 years, and if they receive proper check and repair, they can remain their function accessible longer, which can be supplied by uranium that can meet words' energy demands for more than one hundred years. Furthermore, nuclear energy has one of the lowest mortality rates in the world, which is supported by the fact that nuclear energy operations only create 90 deaths when every trillion kilowatts are generated. In addition, when a nuclear fission reaction is properly controlled, the process can generate power that can be used for up to 3 years, which means the efficiency rate of nuclear energy is more than 8000% better than traditional energy resources. Additionally, nuclear energy is one of the renewable energy sources which will not produce greenhouse gases during nuclear fission or fusion.” However, several disadvantages also exist, including safety problems for people and the environment. Specifically, in order to operate nuclear power plants, uranium and plutonium are needed. As a result, mining is necessary, which will cause damage to the environment. Moreover, nuclear energy has potential risks such as nuclear leakage and explosion, and accidents happened such as the Fukushima nuclear power accident and the Chornobyl nuclear power accident that created an enormous amount of pollution to the environment and mortalities. Nevertheless, nuclear energy is necessary for humans development because it is an efficient energy source that can meet peoples' energy demands. In addition, nuclear energy can apply to many uses, and the price is affordable, which can solve common problems people might face when consuming energy. Although some accidents happened in the past, the possibility of the occurrence of those events is small, while the technology is improving that can make nuclear power safer.

References

[1] Nuclear Power Reactors in Operation by Country 2022. Statista, 1 Aug. 2022, Retrieved from: https://www.statista.com/statistics/267158/number-of-nuclear-reactors-in-operation-by-country/.

[2] Nuclear Power in France, French Nuclear Energy - World Nuclear Association, Retrieved from: https://world-nuclear.org/information-library/country-profiles/countries-a-f/france.aspx.

[3] YueJing Jiang. Enlightenment and warning from marine radioactive pollution caused by nuclear leakage of Fukushima nuclear power plant. Compilation of papers and abstracts of the Symposium on tropical marine science, the 8th Guangdong Ocean and Limnology society and the 7th member congress of Guangdong Ocean Society, 2013:493-499.

[4] Yamada M. A brief review of environmental impacts and health effects from the accidents at the three mile islands, Chernobyl and Fukushima Daiichi Nuclear Power plants. Radiation Emergency Medicine, 2012, 1(1-2): 33-39.

[5] Zhan L, Bo Y, Lin T, et al. Development and outlook of advanced nuclear energy technology. Energy Strategy Reviews, 2021, 34: 100630.

[6] Catherine D. The Environmental Impact of the Fukushima Nuclear Power Plant Disaster, March 5. 2016, Retrieved from: http://large.stanford.edu/courses/2016/ph241/dong1/.

[7] Jiang Yuejin, Jiang Lan Rough estimation and association of nuclear leakage at Fukushima nuclear power plant .Journal of Guangzhou navigation college 2014 Vol. 22,172-175+178.

[8] Jeremy G, Fukushima Government Response, February 18,2017. Retrieved from: http://large.stanford.edu/courses/2017/ph241/guo1/.

[9] Research Report of Engineering Research Department of Fukui University Page109-114.

[10] Environmental and Energy Study Institute (EESI). “International Reactions to the Fukushima Nuclear Disaster: Summer Update. EESI. Retrieved from: https://www.eesi.org/articles/view/international-reactions-to-the-fukushima-nuclear-disaster-summer-update.

[11] Kim Y, Kim M, Kim W. Effect of the Fukushima nuclear disaster on global public acceptance of nuclear energy. Energy policy, 2013, 61: 822-828.