How Does Nuclear Wastewater Discharge Affect Fishery and Marine Environment: A Case Study of Japan

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Abstract. With the increasing use of nuclear energy, human lives have benefited from a variety of aspects since nuclear energy can produce carbon-free electricity. Nevertheless, governments must be cautious about the waste nuclear energy produces for it's extremely harmful to the environment and has detrimental impacts on human health. Since the nuclear water at the Fukushima plant was released in the following years after 2011, both Japan and its neighboring countries were seriously affected. Some other coastal areas also have varying degrees of pollution depending on the ocean current. The extent of the impact of nuclear wastewater namely the affected areas and the diffusion of elements in nuclear wastewater will be shown in the paper. Additionally, this paper will analyze and elaborate on how nuclear wastewater can affect the marine environment due to the structure of the marine environment and the properties of nuclear wastewater. Lastly, the impact of nuclear wastewater on the fishery in Japan and neighboring countries will be discussed by showing data from relevant research papers. This paper will focus on the impact of nuclear wastewater on the marine environment and the vicinity fishing industry.

1 Introduction

The Tohuko earthquake was one of the world's most intense earthquakes with a magnitude of 9.0 that caused almost 20,000 casualties and countless infrastructure damages. The high magnitude of the earthquake with the epicenter closely located on the east coast of Japan also induced a devastating tsunami which had a detrimental impact on the nuclear power plants on the north coast of Japan. According to the Earthquake Survey Committee, the epicenter was so close to the coastal cities that the distance to Fukushima was only 177km as shown in Figure 1 [1].

Fig. 1. Epicenter of the Tohoku earthquake.

Source: Earthquake Survey Committee, Japan 2011.
https://www.researchgate.net/figure/fig1_257807253

All the above factors contributed to the devastating impact on the nuclear power plants in the coastal area. When the earthquake happened, the 11 nuclear power plants in northeast Japan automatically stopped working to prevent further damage [1]. However, the cooling system of the reactor in Fukushima also stopped working which results in a dramatic rise in the reactor's temperature. The cooling system of the nuclear reactor requires an omni-seal environment to fully function as shown in Figure 2. Therefore, when the tsunami broke the omni-seal environment, the cooling system stopped functioning.

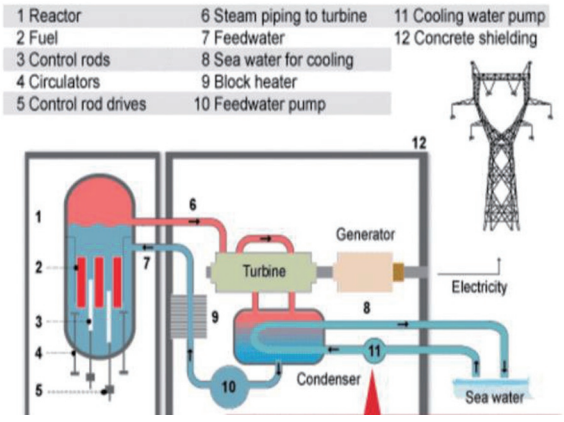

Fig. 2. Structure of nuclear power plant.

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Source: Deutsches Atomforum. https://www.chemanager-online.com/en/news-opinions/headlines/japan-crisis-most-recent-developments

To keep the temperature down, workers have to keep pumping water into the destroyed reactor to prevent it from overheating. Eventually, the wastewater was too much that it exceeded the maximum capacity for storage. On April 5th, 2011, the Tokyo Electric Power Co 11,500 metric tons of radioactive water into the Pacific Ocean. Furthermore, Japan's Cabinet of Prime Ministers Suga has approved the Tokyo Electric Power Co to continuously dump wastewater over the length of 30 years. Although the Tokyo Electric Power Co claimed that the disposed nuclear waste has low radiation. This paper will discuss the negative impacts nuclear wastewater has on the marine environment and to what extent it impacts fishery in Japan.

2 Literature review

As a result of the Tohuko Japan Earthquake on March 11, 2011, radionuclides from the Fukushima Daiichi Nuclear Power Station (FDNPS) were spilled directly into the ocean. Despite the severe consequences it has on the vicinity areas, it doesn't end here since the debris was entrained in surface ocean currents and then carried across long distances. A group of researchers demonstrated that the current traveled from Japan to the California coast by monitoring the ocean's surface, which aggravated the negative impact brought by the disposed nuclear wastewater [2]. Similar statements have also been proved by other researchers claiming that within two years of the Fukushima Nuclear disaster, manufactured radioactive isotopes from FDNPS had reached the western Pacific Ocean edge and the west coast of North America [3]. In addition to the nuclear pollutant that can be spread by the ocean current, there were also isotopes such as 14C, 137Cs, and 134Cs that quickly accumulate on the seabed and in marine organisms close to Japan do not disperse with ocean currents and pose a long-term threat to the region's marine ecosystem [4]. The food chain connects marine and human life, resulting in an increased accumulation of creatures along food chains [5]. The degree of biological contamination by radioactive chemicals increases with the food chain level [6, 7]. Indicating that areas with a high concentration of nuclear pollutants will pose significant risks to the local people.

The aforementioned facts showed the detrimental consequences the disposal of nuclear wastewater had on the marine environment including the aquatic products that are consumed by humans not only appeared in Japan but also around the world. However, they failed to show the impact on the fishery in terms of the economy. Therefore, this paper will elaborate on the consequences of nuclear wastewater on the marine environment and compare and analyze Japan and countries in the affected areas' fishery economy before and after the discharge of nuclear wastewater.

3 Analytical framework and discussion

3.1 Impact on marine environment

It might seem like the amount of nuclear wastewater being discharged into the ocean is small compared to the vast ocean, and the wastewater has been treated so that the radioactive substance is even lower. Therefore, the effect it had on the marine environment is subtle that could be ignored. However, this is not the case because only after a few days of the disposal of nuclear wastewater, increasing quantities of radioactive cesium and iodine have been found in microscopic fish a few dozen miles south of Fukushima, and significant levels of radioactivity have been found in waters offshore, both of which are indications that radioactive material is spreading. Another main pollutant from the treated water Japan is planning to discharge is tritium. Researchers Yi Liu et al. conducted a stimulation of diffusion of tritium with appropriate parameters [8]. The research modeled the outcomes over a 10-year period for a unit relative concentration of 0.29Bq/m3 according to the discharge plan as shown in Figure 3. After 3600 days of the diffusion, the contaminants had engulfed nearly the whole Pacific Ocean.

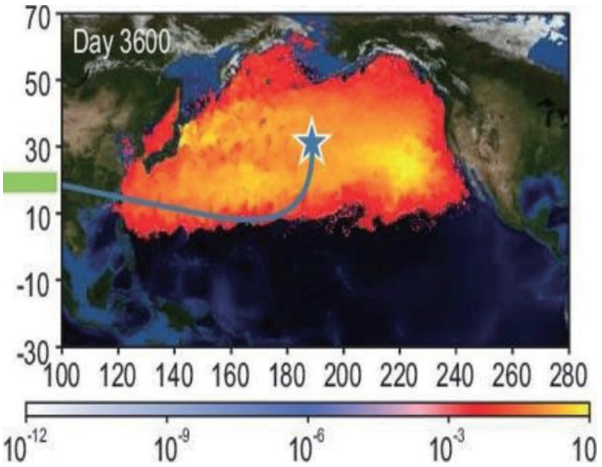

Fig. 3. 10 years after releasing tritium.
Source: National Science Review.
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In addition to the large-scale contamination of nuclear wastewater, it is also imperative to emphasize the long-lasting impacts of nuclear wastewater. Ken Buesseler mentioned that both short-lived radioactive elements like iodine and longer-lived elements like cesium, which have a half-life of around three decades, are likely to be absorbed by a wide range of marine organisms. Radiation can concentrate as it passes up the food chain, depending on the chemical type of radiation and the creatures that have taken it up. For instance, Radionuclides, an unstable atoms with excess energy, found in nuclear waste can be detrimental to marine organisms. Plankton and other organisms with a low volume-to-surface area ratio have a high rate of radioactive uptake. Since plankton is at the bottom of the food chain, higher trophic levels may be polluted. To sum up, nuclear contamination is likely to affect the

marine environment for an extended period of time for it is able to be radioactive for quite a long time and can infect countless marine organisms.

3.2 Impact on neighboring countries

As stated in Section 3.1, disposing of nuclear wastewater can contaminate almost the whole Pacific Ocean if given enough time. Therefore, the vicinity of the discharging spot will be affected even more, namely Japan, South Korea, and China. Although some experts claim that the hazards are negligible, consumer perceptions of the risk of marine contamination may nonetheless change the ultimate pattern of food intake. To make up for the loss of protein, people may decide to stop eating seafood or switch to protein-rich aquaculture products, terrestrial-based meals, or aquatic foods from unaffected or less affected areas. In this part of the paper, the impact of nuclear wastewater on China's fishery industry will be discussed and analyzed for it is one of the largest marine product suppliers in the world. One of the most direct impacts that China will suffer is open sea fishing. China's main fishing spot in terms of pelagic fishing is in the Pacific Rim. In the past few years, two third of the 2 million tons of long-distance fish catching were conducted in the Pacific Rim. China's distance-water fishing is relatively stable in the past decade with a gradually increasing trend. However, in 2019, the total output of this year breaks the pattern of previous years by decreasing by about 3.9% compared to 2018, which is about 88,000 tonnes. Additionally, the majority of the Chinese maritime region is linked to the Sea of Japan, particularly the East China Sea as shown in Figure 4 [9]. Thus, the quality and safety of China's aquatic goods are heavily influenced by the East China Sea's maritime environment, when it's contaminated by the nuclear waste disposed directly into the adjacent waters, the effect on aquatic products from the East China Sea is nonnegligible. Despite all the negative consequences nuclear wastewater had on seawater fishery, China's freshwater fishery industry has been fostered since following the contamination of the sea region, demanders may become concerned about the quality and safety of sea goods, leading to the substitution of aquatic items.

In addition to the effect on China's fishery, South Korea as the world's 12th largest fishery producer reaching about 3 million tonnes in 2010 also suffered the consequences of Fukushima's nuclear wastewater. South Korea's domestic sea area is even more closely connected to Japan compared to China for the Korea Strait, which connects Japan and South Korea is only 200km in length. The effect of nuclear wastewater is more obvious in Korea's fishing production from 2011 to 2012 decreased by about 19% around 200 tonnes. Similarly, South Korea's fishing production from inland waters decreased by about 14% which is about 4 tonnes. However, the total fishery production of South Korea was not largely affected since the distance water fishing production offset the production shortage of the inland and domestic seas.

Despite the aforementioned effect of nuclear wastewater on the two neighboring countries, there is more impact on other countries' fishery economies. Indicating that the effect of nuclear wastewater does not constrain the effect described above, it has far more consequences on many other areas' fishery as well.

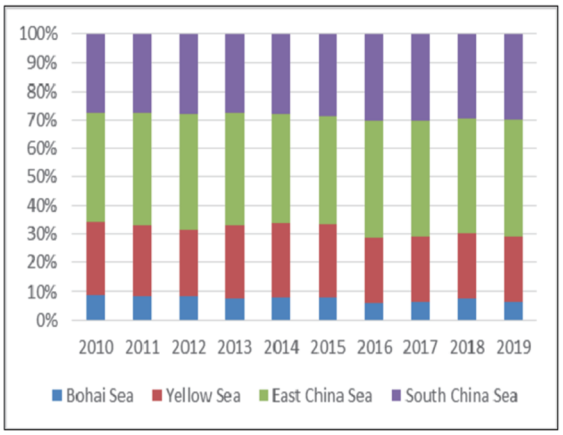

Fig.4 The percentage of production from marine fishing in China's four main seas.
Source: Web of Conference. https://www.e3s-conferences.org/articles/e3sconf/abs/2021/51/e3sconf_eilcd2021_02033/e3sconf_eilcd2021_02033.html

3.3 Consequences on Japan's Fishery

When nuclear wastewater is released from FDNPS, the most affected region is the coastal area of Japan. The local fisherman's aquatic product is most directly affected since it had direct contact with the most concentrated nuclear waste area. The most obvious aspect that shows the decline of the Japanese fishery industry is the amount of aquatic products they catch.

According to Figure 5, there is a dramatic decrease in the weight and value of Fukushima prefecture catches after the contamination of the ocean by nuclear wastewater. The average value of marine products caught after the nuclear accident from 2011 to 2018 dropped more than 7 times the previous value. Therefore, the local fishery undoubtedly had tremendous losses in terms of importing seafood to other countries. Some of the main demand parties for Japan's aquatic products were China (45%), the US (20%), and South Korea (17%). With most of its important partners voicing strong disapproval and resistance to the circumstances, the Japanese fisheries export market is treading water. South Korea, once Japan's top importer of fish, has dropped its seafood imports from roughly 81 thousand million tonnes in 2010 to 29 thousand million tonnes in 2019.

Furthermore, as more countries realized the seriousness of the nuclear waste issue, a total of 15 countries declared to ban or require a certificate of production for seafood importation from Japan, including Singapore, China, South Korea, etc. Moreover, around 50 countries or regions asserted import control

measures on Japanese aquatic products at the time. Another factor that might cause this drastic drop in importation is that other countries didn't know exactly how dangerous the aquatic product from Japan is since there is an information opacity of the kind of chemical that got released. Causing the inability for experts to fully analyze the risks. Therefore, some countries might simply follow other countries' actions, which is banning seafood imports. Despite the fact that the fishing sector contributes just around 3% of Japan's GDP, the worldwide social welfare loss might reach 219.8 billion US dollars in 2020, accounting for 0.26% of the global GDP [10].

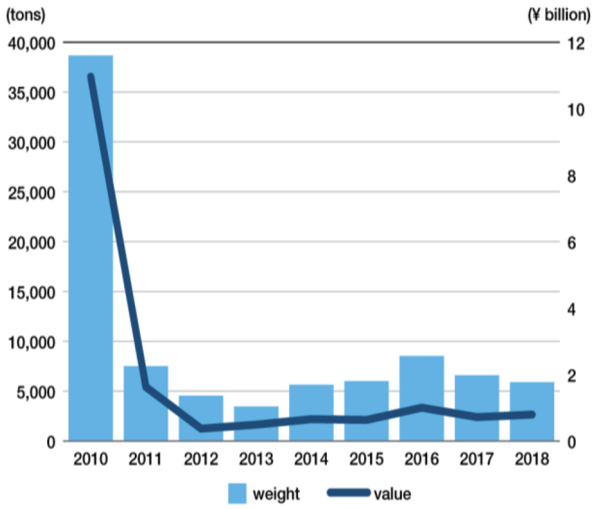

Fig.5. Weight and value of Fukushima prefecture catches. Source: Nippon. https://www.nippon.com/en/japan-data/h00664/fukushima-fishing-industry-still-far-from-recovery.html

4 Conclusion

In this paper, the consequences of releasing nuclear wastewater into the ocean in terms of the marine environment as well as the fishery industry have been discussed and analysed using data from other researchers. Some critical conclusions are as follows.

First, radioactive substances from nuclear wastewater will affect the whole marine food web since they can bioaccumulate. In this case, when infected species were consumed by higher-ranked organisms, the higher-ranked organisms will also be tant. Moreover, nuclear wastewater contains radioactive substances that have a half-life of 30 years, indicating that the wastewater can contaminate much more regions besides the discharging spots. This is also due to the ocean's current since a study showed the pollution will cover the whole Pacific Ocean only after 10 years of releasing a radioactive substance from nuclear wastewater.

Second, the Chinese fishing industry will be influenced in terms of open-sea fishing and ocean agriculture since it is the closest to the first-contaminated area other than Japan. Due to the fact that people are concerned about China's marine products, China's freshwater production has been facilitated after the disposal of nuclear wastewater. Lastly, the paper analyzed the reasons for the such sudden loss in Japan's aquatic product market which is a smaller number of catches and the information opacity that happened to other countries.

There is basically no solution for areas that are already contaminated by nuclear wastewater, however, it can be controlled from the beginning. In other words, the Japanese government could use alternative methods to treat the nuclear wastewater such as injection into the geosphere, regulated vapor release, subterranean burial, etc. However, it is up to the Japanese government whether they want to spend more money on nuclear wastewater treatment since any other approach will be more costly than releasing it into the ocean. Additionally, the affected countries should provide proper subsidies for the domestic fishery industry. Preventing the fishing industry from suffering excessive short-term losses is crucial since they might exit the market in the long run if they suffer economic loss for a long time. In this case, the proper amount stands for making the fishing firms break even.

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