2024 "Huashu Cup" International Mathematical Contest in Modeling

MCM

Problem A: Radioactive Wastewater from Japan

Photo Credit: VCG

Background

The March 2011 earthquake off Japan's east coast triggered the Fukushima Daiichi accident, which resulted in meltdowns at three nuclear reactors and melted debris from nuclear fuel after a massive tsunami knocked out cooling systems at the plant. To cool the melted nuclear fuel, seawater is continuously injected into the reactor, resulting in a large amount of radionuclide-contaminated cooling water. Despite the opposition of the people of all countries, the Japanese government began to forcibly discharge the treated Fukushima radioactive wastewater into the Pacific Ocean on August 24, 2023. The total amount of radioactive wastewater contaminated with radionuclides is more than 1 million tons. The whole project is expected to last at least 30 years. The appendix is the four-wheel discharge plan announced by the Japanese government.

These nuclear effluents contain Tritium, a radioactive isotope that can remain in the environment for a considerable amount of time. The degree of contamination of radioactive elements refers to the amount of radioactive elements present in the environment and the degree of potential harm to humans and ecosystems. It is usually assessed by measuring parameters such as the concentration of radioactive elements, radiation levels, half-life, and so on. The highly radioactive nature of tritium gives it the potential to damage cells and tissues with radiation. In the Marine environment, tritium will be absorbed by organisms and enter the food chain, which will lead to radiation damage to species in the ecosystem, affecting the reproduction of Marine organisms and ecological balance.

The diffusion path of radioactive wastewater in seawater is affected by many factors such as water motion, seabed topography, water depth, tidal and seasonal changes, and environmental conditions. Understanding the transport and diffusion of radioactive wastewater in the environment can help us assess the enormous impact on surrounding Marine ecosystems and human health.

Requirements

Through the establishment of mathematical models and analysis, we can predict the diffusion range and path of nuclear waste water, to formulate environmental protection measures and emergency plans.

- Establish a diffusion mathematical model to describe the rate and direction of radioactive wastewater diffusion in seawater, taking into account water motion, environmental conditions, and other influencing factors. It has been known that 1,095 tons of radioactive wastewater was released into the marine environment from Japan until 12:00 AM, August 27, 2023. If no further discharge of radioactive wastewater, please predict the scope and extent of radioactive wastewater pollution in the marine vicinity of Japan on September 27, 2023.

- In 2023, the Japanese government have dumped radioactive wastewater three times. If it will not be dumped again in the future, please establish a mathematical model to study the diffusion path of radioactive wastewater after three times dumping. Considering factors such as oceanic circulation patterns, water dynamics, seabed topography, depth variations, tidal influences, and seasonal fluctuations. How long it will take to pollute China's territorial waters?

- Relevant departments have surveyed 10,000 Chinese residents after the Japanese government announced the dumping of radioactive wastewater. Including whether they would buy and eat seafood before and after the dumping of radioactive wastewater. The results are shown in Table 1. According to the survey results given in Table 1, analyzing the long-term impact of radioactive wastewater dumping on China's future fishery economy.

Table 1. Survey results on whether seafood was bought and eaten before and after the radioactive wastewater dumping incident.

	Eat seafood now	Not eat seafood now	ALL
Used to eat seafood	2238	6437	8675
Used to not eat seafood	67	1258	1325
ALL	2305	7695	10000

NOTE: *Eat seafood now* and *Not eat seafood now* refers to the attitude after the radioactive wastewater discharge into the sea.

- 30 years after Japan discharged the radioactive wastewater, please judge whether all the seas of the world will be polluted. What year will be completely contaminated? Among them, which place will be the most polluted?

- Based on your research, write a 1-page suggestion letter to the UN Environment Program.

Your PDF solution of no more than 25 total pages should include:

- One-page Summary Sheet.
- Table of Contents.

- Your complete solution.
- One-page letter.
- Reference List.

Note: The Contest has a 25-page limit. All aspects of your submission count toward the 25-page limit (Summary Sheet, Table of Contents, Report, One-page letter, Reference List, and any Appendices). You must cite the sources for your ideas, images, and any other materials used in your report.

Appendix

The end time of every round	Weight of nuclear-contaminated water discharged
September 9, 2023	7100 tons
October 23, 2023	7810 tons
November 20, 2023	7753 tons
February 2024	Around 7800 tons