Model simulation and cost-benefit assessment of countermeasures to reduce the ^{137}Cs load from un-decontaminated dam lakes in Fukushima, Japan

Hideki Tsuji*, Yumiko Ishii, and Seiji Hayashi

Fukushima Institute for Research, Education and Innovation, 10-2, Fukasaku, Miharu, Tamura, Fukushima, 963-7700, Japan

* *e-mail: TSUJI.hideki.t5a@research.f-rei.go.jp, corresponding/presenting author*

The lakes in the area affected by the Fukushima Daiichi Nuclear Power Plant accident have not been decontaminated even 14 years after the nuclear accident in 2011, and there are concerns that the desorption of radiocesium (^{137}Cs) from the lake sediment will prolong the radioactive contamination of the benefit area of the dam. In this study, we considered two scenarios (1. dredging, 2. aeration of the lakebed) as countermeasures to reduce the ^{137}Cs desorption, and simulated the effect of each scenario to decrease the discharge load of ^{137}Cs using a mathematical model that reproduces the ^{137}Cs dynamics in dam lakes. We also assessed the cost-benefit by the entire dredging the dam lakebed.

The numerical model used in this study consists of two modules: lake water part and sediment part. The study site is a dam lake located about 20 km from the Fukushima Daiichi Nuclear Power Plant. The input parameters of the model were the monthly observed data of ^{137}Cs concentrations and water quality in inflow/outflow water observed since 2014 (Tsuji et al., under review), ^{137}Cs and water quality in lake water observed data of observed each quarter of the year in 2014-2017 (Tsuji et al., 2020), ^{137}Cs profile in the lake sediment (Funaki et al., 2022), and the parameters of ^{137}Cs desorption obtained from the sediment incubation experiment (Tsuji et al., 2022). In addition, hydrological data provided by the dam management office, meteorological data recorded by the local meteorological weather station, and the parameters related to the diffusion and generation of ^{137}Cs and its relevant components in the literatures were input. The simulated period was 2014-2023. Two countermeasure scenarios were assumed, 1) dredging scenario: the ^{137}Cs concentration in the sediment at the start of the simulation was set to one-thousandth of the observed value. 2) aeration scenario, the concentration of dissolved oxygen in the lake bottom was fixed at the saturation value, to avoid the retention of NH_4^+ which can promote ^{137}Cs desorption from sediment. In each scenario, decontamination of ^{137}Cs in the catchment area of the dam lake was not assumed, and the inflow load of ^{137}Cs into the dam lake was unified among the three simulations. The cost of dredging was estimated based on the actual cost of decontamination work of small-scale reservoirs by a construction company. The benefit per year was estimated as the maximum value supposing that the net profit of agriculture and fishing in the dam beneficiary area completely recovered to that before the nuclear disaster.

As a result, the numerical simulation predicted that the dredging scenario would reduce the discharge load of dissolved ^{137}Cs by up to 23% per year, and the aeration scenario would reduce the discharge load of dissolved ^{137}Cs by up to 15% per year. Both scenarios decreased only the concentration of ^{137}Cs in the lake bottom water, so the effect of the decrease in ^{137}Cs in discharge water emerged during the lake circulation period (in winter season). However, because the particles which contain ^{137}Cs continuously carried from the catchment area and deposited on the lake bed, the effect of reducing the ^{137}Cs load was estimated to be limited unless conducting the decontamination of the hinterland forest area.

The cost of full-scale dredging of the dam lake was estimated to be approximately 260 million dollars, and the maximum benefit was estimated to be 4 million dollars per year. Considering that decontamination of the forest would also be necessary to completely eliminate the risk of contamination by ^{137}Cs, it would take as long as several hundred years to generate benefits that match the cost of decontamination work.

References

Tsuji, H. et al. Env. Pollut. under review; Funaki, H. et al. (2022) Sci. Total Environ., 812, 152534; Tsuji, H. et al. (2022) Applied Geochem., 140, 105303. Tsuji, H. et al. (2020) Global Environ. Res., 24, 115-127.