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Assessing tsunami-induced groundwater salinization and its temporal change: a numerical modelling study on the Niijima Island, Japan

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Groundwater is vulnerable to many natural hazards, including tsunami. As reported after the 2004 Indian Ocean earthquake and the 2011 Great East Japan earthquake, the generated massive tsunami inundations resulted in unexpected groundwater salinization in coastal areas. Water supply was strongly disturbed due to the significantly elevated salinity in groundwater. Supplying fresh water is one of the prioritized concerns in the immediate aftermath of disaster, and during long-term post-disaster reconstruction as well. The aim of this study is to assess the impact of tsunami on coastal groundwater system and provide guidelines on managing water resources in post-tsunami period. We selected the study area as the Niijima Island, a tsunami-prone area in Japan, which is under the risk of being attacked by a devastated tsunami with its wave height up to 30 m. A three-dimension (3-D) numerical model of the groundwater system on the Niijima Island was developed by using the simulation code FEFLOW which can handle both density- dependent groundwater flow and saturated-unsaturated flow processes. The model was justified by the measured water table data obtained from the field work in July, 2015. By using this model, we investigated saltwater intrusion and aquifer recovery process under different tsunami scenarios. Modelling results showed that saltwater could fully saturate the vadose zone and come into contact with groundwater table in just 10 mins. The 0.6 km^2 of inundation area introduced salt mass equivalent to approximately 9×10^4 t of NaCl into the vadose zone. After the retreat of tsunami waves, the remained saltwater in vadose zone continuously intruded into the groundwater and dramatically salinized the aquifer up to about 10,000 mg/L. In the worst tsunami scenario, it took more than 10 years for the polluted aquifer to be entirely recovered by natural rainfall. Given that the groundwater is the only freshwater source on the Niijima Island, we can provide suggestions on preparedness of tsunami disasters and guidelines of supplying water resource in post-tsunami period based on these numerical modelling results. This approach has implications for the disaster prevention and the better preparation with respect to tsunami and tsunami-like events such as storm surges on other coastal areas.