

Water supply system and environmental impacts of chemical release accidents caused by the major earthquake

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Natural hazard triggering technological disasters (Natech) cause pronounced impacts on both society and the environment. In Japan, the Great East Japan Earthquake is an example of such event, when radioactive cesium-137 spread to the air and soil and finally to the river, which raised concerns on environmental and human health impacts (Takahashi et al., 2017). Caused by unexpected earthquakes or other extreme natural events, Natech is a rising concern given the increasing number of handled chemicals. Under these situations, measures to prevent serious accidents involving such toxic chemicals are highly important. However, after the accident, both impacts for the environment and urban infrastructure, such as the water purification system, have not been clarified quantitatively, especially under unstable situations such as major earthquakes. In addition, the effectiveness of each measure against the accidents has not been clarified systematically and comprehensively. Therefore, this study aims to clarify the behavior of toxic chemicals that are accidentally released into the river due to the seismic motion, and to evaluate countermeasures in terms of their efficiency to prevent the release itself or the removability of chemicals from the water after the release accident.

As the research target area, Yodo River basin in Osaka is selected for its large density of chemical facilities and high risks of liquefaction because of the sandy sediment. Yodo River is also an essential water resource that supports urban infrastructure in the Kansai area. Therefore, significant social impacts are expected in the case of an accident. Pollutant Release and Transfer Register (PRTR) chemicals, which could possibly grasp the actual handling amount, are selected for the simulation. Specifically, PRTR registered chemicals (e.g., acrylonitrile and formaldehyde, among others) with high toxicity and difficult to remove at water treatment plants were selected for the worst-case simulation. The model based on AIST-SHANEL (Standardized hydrology-based assessment tool for chemical exposure load) with improved time resolution and flow rate calculation was used. As the risk evaluation endpoints of this study, we set two standards, (i) subacute toxicity to humans in purified water and (ii) acute toxicity to aquatic organisms in river water. Both emergency shut-off valves set in the chemical facilities and activated carbon treatments in the water purification plant are the countermeasures of (i), and only the former is that of (ii). As a result, out of target substances such as formaldehyde, three chemicals exceeded the standard of subacute toxicity to humans in purified water, which would cause the suspension of water supply. We found that the activated carbon adsorption treatment effectively removes the chemicals with high organicity value that is related to the carbon structure (Fujita and Akatsuka, 1984) or the ones with octanol/water partition greater than 1.5. Otherwise, released chemicals are difficult to remove using the water purification treatment; therefore, precautionary measures such as the emergency shut-off valve are necessary. In terms of protecting aquatic organisms in the river, six chemicals such as acrylic acid presented risks and exceeded the standard of acute toxicity to such organisms. An emergency shut-off valve installed in advance can reduce the amount of released chemicals to 1 to 2%, which decreases the possibility of affecting the most vulnerable aquatic organisms even at the water-intake point that is closest to the accident site.

From these analyses, we conclude that precautionary measures at industrial facilities effectively protect both aquatic organisms and water supply system, given that they can be applied to the chemicals that are difficult to remove using the absorption treatment.

Keywords: Chemical contamination, Water supply system, Earthquake, Environmental dynamic analysis,
Environmental impacts