Evaluation of subsurface warming in the Tokyo metropolitan area: characteristics of long-term change in subsurface temperature beneath Yokohama and Kawasaki areas

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Recent research investigations have provided insights regarding the subsurface warming in the Tokyo metropolitan area that widely spreads not only over the urban center but also the suburbs (e.g., Miyakoshi et al., 2019). Based on the results of repeated measurements of temperature–depth profiles (since 2000) and subsurface temperature monitoring (since 2009) at observation wells in Tokyo and Saitama areas, it is found that the long-term warming trend of subsurface temperature mainly changes at shallow depths. Distinct regional differences in the subsurface temperature distribution and secular changes are observed, and the warming trend in the urban center is noted to be considerably larger than that in suburban areas. Subsurface warming is also observed at the deep parts of areas with large groundwater development (e.g., Musashino Upland) because of the effects of anthropogenic groundwater flow. Subsurface warming has been generated by the complex combination of effects of temperature increases at the ground surface and shallow subsurface induced by urbanization and groundwater flow changes caused by pumping and global warming.

The temperature–depth profiles were observed from November 2018 to March 2019 at 20 observation wells in Yokohama and Kawasaki areas, which are located in the southern Tokyo metropolitan area. Observations at the same wells were also conducted; 14 of these were measured in 2001 or 2004. The evaluation of subsurface temperature distribution and the calculation of gradients of long-term subsurface temperature changes for the past 14–17 years are based on the datasets derived from the foregoing observations.

By comparing the past and present datasets, the occurrence of subsurface warming is detected in all 14 wells. Regional differences in warming trend are also noted, and particularly high increases are observed at four wells located inland. Except for these four, the subsurface warming trends are estimated to be approximately 1.6×10^{-2}–2.9×10^{-2} ℃/year and 1.0×10^{-2}–2.0×10^{-2} ℃/year at depths of 30 and 40 m, respectively. These warming trends decrease with depth, and a higher warming trend is observed at the wells in or around the urban center located in the coastal area. A particularly high warming trend of 3.0×10^{-2} ℃/year at a depth of 30–40 m is found at the four wells in the inland area. The subsurface warming trend at these wells indicates the maximum value at a certain depth. It is assumed that the temperature variations are caused by the effects of groundwater pumping in comparison with the geological structure.

The spatial scale of the groundwater flow system in or around this area is smaller than that in the central part of Kanto Plain. It is observed, however, that subsurface warming widely spreads, and the probable factor for such a spread is presumed to be the combined effects of urbanization, changes in groundwater flow, and global warming. The characteristics of subsurface temperature changes in the Yokohama and Kawasaki areas will be compared with those of the other Tokyo bay areas.

The use of observation wells to measure temperature-depth profiles in this study was supported by Environmental Science Research Institute, Environmental Planning Bureau, City of Yokohama, and Water

Quality Section, Environmental Policy Department, Environmental Protection Bureau, Kawasaki City.

Keywords: temperature-depth profile, subsurface warming, groundwater flow, groundwater development, urbanization, Tokyo metropolitan area

