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An integrated analysis of subsurface environment in Asian coastal cities

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In order to evaluate the subsurface environment problems, such as land subsidence, groundwater pollution, and subsurface thermal anomaly, integrated analyses have been made beyond the boundaries between surface/subsurface and land/ocean in Asian coastal cities. Numerical modeling of the subsurface environment was established for Tokyo, Osaka, Bangkok, and Jakarta to evaluate the groundwater recharge rate/area, residence time, exchange of fresh/salt water. Using updated GRACE data, we have succeeded to reveal not only seasonal variations but also a secular trend of the mass variations in the Chao Phraya river basin. The result showed that the total mass change after 2002 was decreasing in the downstream section of the Chao Phraya (Bangkok) while it was increasing in the upstream portions. We have also developed groundwater aging methods using CFCs and 85Kr. The groundwater flow system in the urban aquifer has highly disturbed by human pumping. A dominant vertical downward flux was revealed in the urban area using CFCs and C-14, which originated from anthropogenic activity in the urban area. 3D groundwater simulation (MODFLOW) showed spatial change of the groundwater recharge area, the major recharge area of the pumped aquifer. This spatial change of the groundwater potential was strongly affected by regional groundwater pumping regulations, and the success or failure of those regulations are mostly affected by the availability of alternative water resources for the city area and the legal aspect of the groundwater resources. Accumulations of trace metals and dissolved nitrogen in groundwater were found especially in Jakarta and Manila. Various N sources and areas of denitrification were found by using N isotope distributions in groundwater. Groundwater salinization was found in Osaka, Bangkok and Jakarta. The difference of marine alluvium volume (same as topographic gradient), natural recharge and intensive pumping period controlled the degree of salinization. Organic and metal pollution histories were reconstructed in Asian cities using marine sediment cores. Minor amounts of terrestrial submarine groundwater discharge (SGD) were measured but huge material fluxes were seen by total SGD in some Asian coastal cities. The spatial variation of SGD was estimated around each city, using a topographic model and radon measurements. Based on the accumulation and transport of pollutants, we evaluated the vulnerability risk for all cities. For example, a relatively higher risk of nitrate contamination was found in Jakarta and Manila, and arsenic pollution was found in other cities, depending upon the redox conditions. The pollution accumulation and transport were controlled by natural factors such as topography, climate and geology as well as human impacts including pumping rate and pollution load. Core sampling in the coastal zone and groundwater sampling have been made to reconstruct the history of contamination in each study areas. Interpretations of chemical components and stable isotopes from the groundwater in Bangkok, Jakarta and Manila revealed the origin of the groundwater and degree of nitrogen/ammonium contaminations. Analysis of temperature profiles measured in boreholes provided information on the history of past ground surface temperature (GST). Increased subsurface thermal storage showed the starting time and degree of surface warming due to the combined effects of global warming and urbanization. In the Bangkok area, the amount of the GST increase is larger in the city center than that in the suburban and rural areas, reflecting the degree of urbanization. Subsurface heat

storage, the amount of heat accumulated under the ground as a result of surface warming, is a useful indicator of the subsurface thermal environment. For example, we can compare the heat storage values at different times in the past with other parameters representing urban subsurface environment obtained through various approaches.

Keywords: subsurface environment, land subsidence, groundwater pollution,
subsurfae thermal anomaly, integrated model, natural capacity