Changing groundwater balance by leaking water mains and groundwater infiltration to the sewer system in major cities, Japan

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It is widely recognized that two artificial components, leakage from water mains and groundwater infiltration to the sewer system, may exert a large influence on groundwater balance in urban areas. In this paper, roles of these two components in groundwater balance will be quantified and discussed for major cities in Japan.

The water supply data of 1995, published by the Japan Water Works Association, were examined for 47 densely populated prefectural capitals with large imported water supplies. The total water supply across the country was 16*109 m3/yr and 9.7% of supply, that is 1.6*109 m3/yr, was lost through leakage. For respective capitals, leakage rate (% of total water supply) ranges from 2% in Niigata to 22% in Gifu. A simplifying assumption was made that all leakage became recharge, and dividing the leakage quantity by the areal extent of water supply for each capital gave recharge flux as 8 mm/yr (Niigata) -214 mm/yr (Osaka). This recharge flux was compared with net precipitation, which was obtained by subtracting annual evapotranspiration based on the Thornthwaite method from annual precipitation. The ratio of recharge flux to net precipitation is found to be low, being below 5% for 43 out of 47 capitals due mainly to high precipitation (900-2600 mm/yr) under the monsoon climate and relatively low leakage rate. However, the ratio is exceptionally as high as 16.1% for Osaka and 10.5% for Tokyo, the third largest and the largest city in Japan, respectively. For these highly urbanized cities with impermeable-surface ratio of more than 0.8, net groundwater recharge by precipitation, calculated by multiplying net precipitation by permeable-surface ratio, becomes less than one-fifth of the net precipitation. Therefore, despite high precipitation and low leakage rate, in Tokyo and Osaka, leakage must be comparable in size with recharge by precipitation or already be a predominant source of groundwater recharge.

The Japan Sewage Works Association data of 1996 indicate that 4% (Matsue) from 54% (Niigata) of total amount of sewage is accounted for by groundwater. Dividing the amount of groundwater in a sewer system by an areal extent of treatment for each capital gives groundwater influx as 22 mm/yr (Matsue) -1434 mm/yr (Wakayama). Niigata, Kyoto, and Osaka also show high groundwater influx of 1299 mm/y, 1134mm/y, and 1010mm/y, respectively. The net effect of these two man-made components is to deplete groundwater in 37 out of 47 capitals, with an especially high minus quantity of -1.4*108 m3/yr for Osaka and Kyoto, and -1.1*108 m3/yr for Nagoya. In contrast, the balance is an increase of groundwater amount of as much as 1.0*107 m3/yr for Tokyo, followed by Kagoshima (3.8*106 m3/yr) and Okayama (3.1*106 m3/yr).

In summary, leakage from water mains and groundwater infiltration to the sewer system are found to be the controlling factors on groundwater balance in some large cities in Japan. Such information can then be used as the basis for working out a sound groundwater management plan for these cities.