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Evaluation of Shallow Groundwater Discharge Fluxes and Nutrient Fluxes in the West of Qinghai Lake Using Radium Isotopes

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We collected 14 samples and 9 samples for surface water in Quan bay and the north bay of Qinglai Lake respectively, as well as 11 samples for groundwater and 3 samples for river water. First the water samples were filtered through a column of Mn-fiber to absorb radium isotopes; then we immediately placed the column with Mn-fiber in the Radium Delayed Coincidence Counter (RaDeCC) to measure the short-lived isotope 223Ra and 224Ra, after that the radium was separated by BaSO4 coprecipitation method from Mn-fiber and was dried, finally the precipitation ware put in the instrument to measure the long -lived isotope 226Ra and 228Ra, Which has been sealed 20 days.

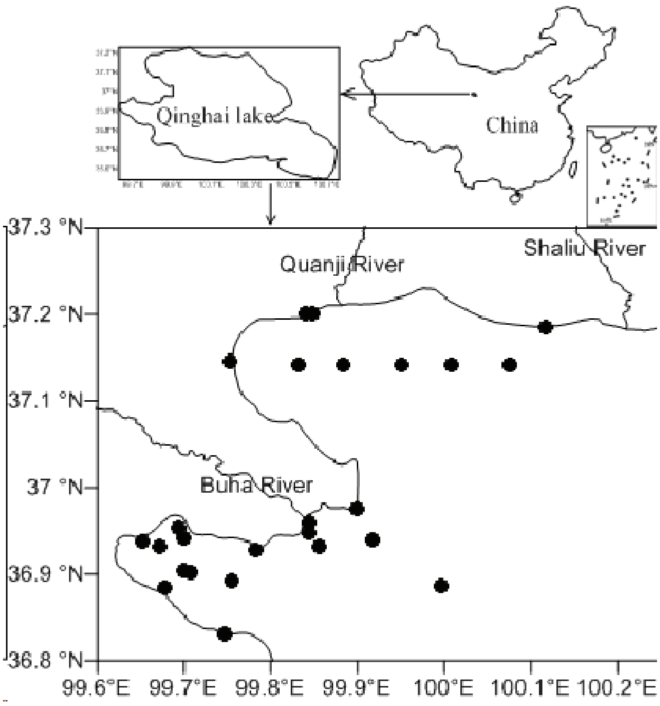

Fig. 1. Study area and sampling stations

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The ^{223}Ra activities in surface water ranged from0.02 to2.41dpm100L^{-1} in the study region, with^{224}Ra activities ranged between 1.70 and 83.06dpm100L^{-1}, ^{226}Ra activities ranged from 43.88 to 88.65dpm100L^{-1}, and ^{228}Ra activities ranged from 38.31 to 120.69 dpm100L^{-1}.From figer2, it is observed that the radium activities is very high, while salinity is lower relatively in the coast that near the estuarine, far away from the offshore ,the radium activities is reduced ,that because excess Ra was the desorption of Ra from river borne suspended particles (Su et al., 2011) or from the strong coastal groundwater possibly (Hussain et al., 1999; Ji et al., 2012; Krest and Moore, 1999; Miller et al., 1990; Moore, 1999; Yang et al., 2002).The radium activities in surface water of the coast where far away from estuarine (the station 20130618QH-04，20130618QH-06，120731QH-03 and 120801QH-01) is less than that in lake ,Which is caused by the dilution effect of lake. In the lake, the radium activities in the south bay reduced with the increase of salinity, that because the dilution of lake water possibly; while the radium activities in the north bay increased with the increase of salinity, what Some research concluded that the origin of this excess Ra was the desorption of Ra from river borne suspended particles and diffusion from the bottom sediments (Elsinger and Moore, 1980; Key et al., 1985; Li et al., 1977; Moore, 1981).

We have constructed conserved quantity model based on the water, ^{226}Ra and ^{228}Ra to estimate the fractions of river, lake water and groundwater according to 3-end-member mixing model of Moore (2003), this model has discerned the different source radium, and which has a well response with salinity (Dulaiova et al., 2006; Moore, 2003).showing as:

$$f_R+f_L+f_{GW}=1.00 \quad (1)$$

$$226Ra_Rf_R+226Ra_Lf_L+226Ra_{GW}f_{GW}=226Ra_M \quad (2)$$

$$228Ra_Rf_R+228Ra_Lf_L+228Ra_{GW}f_{GW}=228Ra_M \quad (3)$$

Where f is the fraction of the lake water (L), groundwater

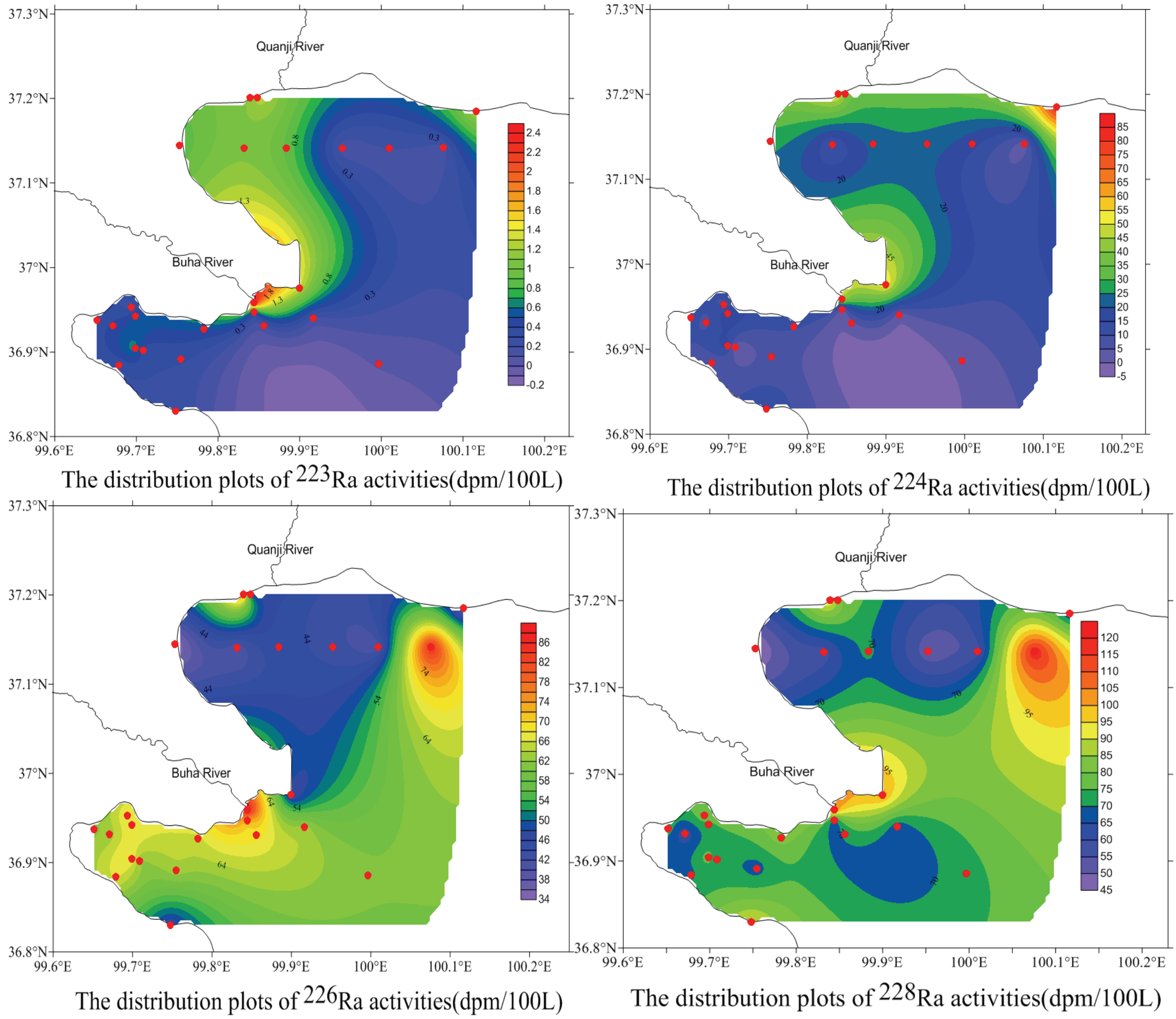


Fig. 2. The radium isotope activities distribution

(GW) and river (R) end-members; $226Ra_{GW}$ is the 226Ra activity and $228Ra_{GW}$ is the 228Ra activity in the groundwater end-member; $226Ra_L$ and 228RaL are respectively the 226Ra and 228Ra activities in the lake water end-member; $226Ra_R$ is the 226Ra activity and $228Ra_R$ is the 228Ra activity in the river water end-member; $226Ra_M$ and $228Ra_M$ are respectively the 226Ra and 228Ra activities measured in the sample. We get the average fractions in the North Bay were f_L =0.54, f_{GW}=0.14 and f_R=0.32, and the average fractions in the south bay were f_L =0.61, f_{GW}=0.21 and f_R=0.18, what is similar to that of coastal lagoons.

The apparent ages of coastal water masses can be calculated by the different of the initial activity ratio of the radium（Ar_i）and the measured activity ratio of the sample (Moore, 2000):

$$t=Ln(Ar_i/AR_{obs})/(\lambda_{224}-\lambda_{226}) \quad (4)$$

of which λ_{224} and λ_{226} and are the decay constants for 224Ra and 226Ra (λ_{224} = 0.189 day^{-1}), in the search, we usually choose the highest AR of the samples as the initial activity ratio (Peterson et al., 2008).The average apparent ages of coastal water masses has been calculated according to the formula, the south bay of that is 14.26 d, while the average apparent ages of the north bay water is 6.18 d. The apparent ages of coastal water is increasing with the increase of offshore distance, this explain that the water masses update rate near the estuarine is faster than that in the lake, which is consistent with the other research results. (Dulaiova et al., 2006; Moore et al., 2006; Moore and Krest, 2004; Peterson et al., 2008).

To quantify the SGD (submarine groundwater discharge) into the Qinghai Lake, we follow the theory of Moore et al. (2006) and construct a radium mass balance model in Qinghai lake system. The formula is showing as: the

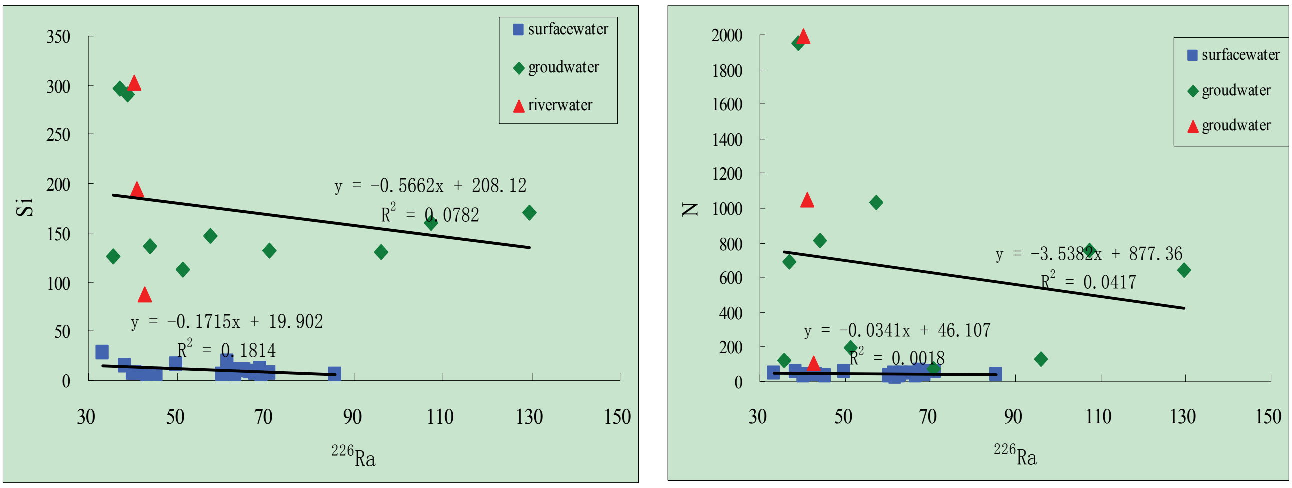


Fig. 3. Plots of activities of Ra isotopes vs. nutrient

radium fluxes (Flux，dpm/d)

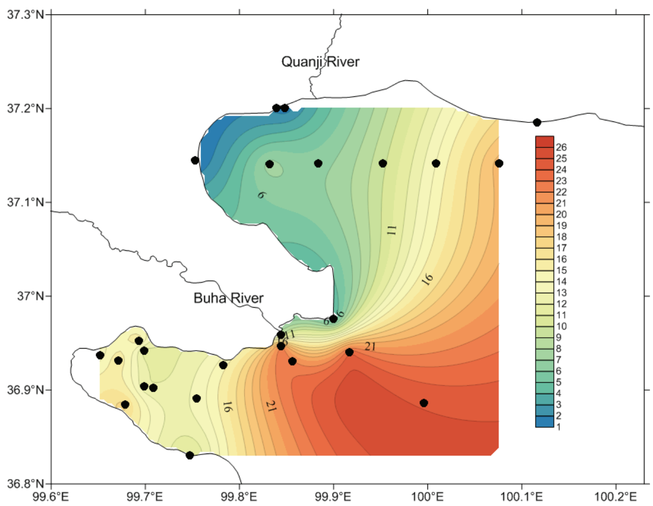
$$F（Ra_{GW}）+F（Ra_R）=F（Ra_M-Ra_L）+F（Ra）_{decay} \quad (5)$$

among，$F（Ra）_{decay}=V^*(Ra_M)\ \lambda$

$F（Ra_M-Ra_L）=I/T_f \quad I=V^*（Ra_M-Ra_L）$

$F（Ra_R）=M^*Ra_R \quad LGD=F（Ra_{GW}）/Ra_{GW}$

$F（Ra_{GW}）$ is the flux from groundwater,（Ra_R）is the flux from river water, Ra_{GW} is the Ra activity of the groundwater , Ra_R is the Ra activity of the river, Ra_L is the Ra activity of the bottom lake water, and Ra_M is the Ra activity measured in the surface water. V is the volume of the lake bay, λ is the decay constants for different radium, I is the radium inventory, T_f is the flushing time, and M is mean annual river runoff. The flux of SGD has been estimated according to the formula used by223Ra，224Ra ，226Ra and 228Ra,the result is that the average SGD of north bay is 1.11×10^8 m^3/d,and the south bay of that is 2.12×10^8 m^3/d. We can also calculate the flux of SGD using the results of the 3end-member mixing model



Ages and flushing times of surface water(^{224}Ra,^{226}Ra)

Fig. 4. Apparent ages of surface water in Qinghai Lake

(the equation is SGD= $(V^*f_{GW})/T_f$), the flux of SGD in south bay is $4.35\times10^7 m^3$/d and that is $6.4\times10^7 m^3$/d in north bay, which is somewhat smaller than the average value we calculated above (the same as the 226Ra and 228 Ra -mass balance model), but within the error.

We can use our estimated SGD flux by Ra-mass balance model ($2.12\times10^8 m^3$/d ，$1.11\times10^8 m^3$/d 2.6×106 m3/d) to estimate the SGD-derived nutrient inputs flux. In the North Bay, the SGD-derived nutrient loads were 2.75×10^4 mol/d and 2.62×10^4 mol/d for $NO3^-$ and SiO_2 respectively, in the south bay they were 9.95×10^4 mol/d and 2.15×10^4 mol/d respectively. the SGD-derived $NO3^-$ inputs flux is more than six times as many as that of Buha river ,and which is mostly ten thousand times as many as that of Quanji river, SGD-derived SiO_2 inputs flux is about 40 times as many as that of Buha river, and that is more than thousand times as many as that of Quanji river. From above we can see that SGD is important to nutrient inputs of Qinghai Lake, it is a problem that can not be ignored, what have significant impacts on the coastal ecosystems.

Key words: Qinghai Lake; Radium isotopes; shallow groundwater; SGD

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