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Element composition of Chinese river water analyzed by neutron activation

W. Gu(1,2) and J. Lu(1)

(1)Nanjing Institute of Hydrology and Water Resources, Nanjing, China,

(2)Hohai University, Nanjing, China.

The hydrochemical signatures of river water are the integration of both the surface and subsurface contributions with different annual/seasonal compositions during different stages. It is resulted from the precipitation solutes of the river basin and, that from the rainfall-runoff process of surficial and subsurficial geochemical evolution towards the discharge outlet of a basin. For the baseflow in large catchments, its quantity, isotopic composition and water age address the subsurface mixing and groundwater discharge from regional aquifers, lakes, wetlands and human settlements. The element composition defined as the sorts of chemical elements and its concentration of river water characterizes the main information of its hydrochemical signature. The formation factories of element composition include not only that of precipitation but that resulted from water-soil/rock and biological reactions within the unsaturated and saturated zones, it is however strongly dependent on the basin scale.

In order to have a general picture and comparison of the element composition of Chinese river water, 15 rivers distributed in all climatic/hydrological zones of this country are sampled at nearly the same season during its flood stage and low level. It includes not only the main big rivers but the inland river, island river and, small representative/experimental catchments.

Neutron activation method is used for analyses due to its high accuracy and sensitivity, dozens of elements can be measured simultaneously, even though some elements can't be determined and low accuracy for few elements. The samples are pre-concentrated by freeze-drying, first frozen at -10°, then evaporated in vacuum chamber with 10^{-3} mm Hg. The dried samples, standard reference materials and blank container for dried samples, were irradiated in a heavy-water cooled nuclear reactor, at first it is irradiated

for 10 minutes with thermal neutron flux of 9×10^{11}n/cm^2/s, secondly, after one week, it is re-irradiated for 20 h with thermal neutron flux of 6×10^{13} n/cm^2/s. Activated elements and its concentrations were determined using spectrometer.

35 elements are detected from the river water at the hydrometric stations on rivers listed in Table 1. More elements of 31 have been found in rivers 1 and 13, the least of 21 are found in river 5. Nine sorts of rare earth elements are detected in the cold area, river 1, only one such element is found in the arid river 4 but in this river the most sorts of rare elements of 9 are detected.

Table 1 Sampling network

No	Climatic belt[3,4]	Climate zone[3,4]	River	Hydrometric st
1	Temperate: north-intermediate	Semi-humid	Nen- jiang	Qiqihaer/Fulae
2	Temperate: intermediate	Semi-arid/semi-humid	Wulumuqi River	Yaojinqiao
3		Semi-arid/semi-humid	Wulumuqi-he -Boerqing	Yaojinqiao
4		Arid – extreme arid	Talimu-he – Nuer-he	Hetian
5		Arid – extreme arid	Black River	Wolfheart Mt.
6	Temperate:south	Semi-humid	Hai-he	Tianjin
7		Semi-arid to arid	Yellow River	Yinchuan
8	Sub-tropical : north	humid	Chu-he - Xijian	Chuzhou Hy Lab.
9		humid	Chu-he – Xijian - E	Chuzhou Hy Lab.
10		humid	Chu-he – Xijian - W	Chuzhou Hy Lab.
11	Sub-tropical:intermediae	humid	Yangtze Jiang – Xiang Jiang	Changsha
12		humid	Yangtze Jiang	Nanjing
13	Sub- tropical :sourth	humid	Min Jiang	Fuzhou
14	Tropical	humid	Island, Nandu Jiang	Haikou**
15	Tibetian-Qinghai Plateau	Semi-humid	Lahsa-he	Lhasa**

The element composition of the sampled river water can be compared with that of world fresh water reported by Bowen (WFW). It shows that the concentration of 16 elements is within that of WFW, i.e., Ca, K, Al, Fe, As, Ba, Mn, V, Mo, Co, Sb, Ag, Se, Yb, Hf and Hg. There are 19 elements especially the rare earth elements with its concentration ranged higher than that of WFW, they are: Cl, Na, Mg, Sr, Zn, Br, Rb, Cr, U, Cs, La, Nd, Ce, Sm, Th, Sc, Eu, Lu and Tb.

The element composition of river water at different water stages varies irregularly depending on the water composition of runoff components from different source areas. Three cases are identified: (a) The composition during base flow is lower than that of the flood stage, typically on river 11, the concentration of most elements of base flow except Au, Hg is higher than that of flood stage; (b) On the contrary to it, most elements have higher concentration during its flood stage and (c) Sometimes higher but sometimes lower, e.g., the Yantgtze at Nanjing, within two years with two stages of base flow and flood, on first year only Co, Cr, Cs, Fe, La, Th, Zn, Hg of base flow have higher concentration than that of flood stage, in addition to these elements the other 14 elements join in the higher group during the second year. However, some elements e.g., Br, Mg, Se, Sm, Sr, U, Mo have higher concentration during flood stages.

The co-relationship of element composition between rainfall, river water and groundwater depends on many factories including the basin scale, physical geographical parameters, the element composition of the soil/rock and aquifer itself, rainfall-runoff process, source area of river water components and groundwater and, anthropogenic activities, etc. In our study, for the concentration of rainfall (P), river water (R) and groundwater (G) of individual elements, three cases are identified as: (a) $G>R>P$; (b)$G<R<P$ and (c)R is higher than both P and G and on the contrary.