CHEMISTRY OF MAJOR ELEMENTS AND URANIUM-THORIUM SERIES NUCLIDES IN INDIAN RIVERS

BY

M.M. SARIN

PHYSICAL RESEARCH LABORATORY

AHMEDABAD 380 009

INDIA

A THESIS

SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

OF THE

GUJARAT UNIVERSITY

DECEMBER 1983

CERTIFICATE

I hereby declare that the work presented in this thesis is original and has not formed the basis for the award of any degree or diploma by any University or Institution.

M.M. Sarin
(Author)

Certified by:

Dr. S. Krishnaswami
Thesis Supervisor

December 1983.

DEDICATION

TO MY BELOVED FATHER

ABSTRACT

Surface water samples from the Ganga main channel, its tributaries and from the Brahmaputra River are collected during March, September and December 1982 representing the lean, peak and moderate flows occurring in these rivers. These samples have been analysed for dissolved major ions (Na^+, K^+, Mg^{2+}, Ca^{2+}, HCO_3^-, Cl^-, SO_4^{2-} and SiO_2^o), D/H and $^{18}O/^{16}O$ isotopic ratios, dissolved ^{238}U and $^{234}U/^{238}U$ activity ratio. The suspended sediments have been analysed for major and trace elements (Na, K, Mg, Ca, Al, Fe, Mn, Cr, Ni and Cu) and for U-Th isotopes (^{238}U, ^{234}U, ^{232}Th, ^{230}Th and ^{228}Th).

The rivers within the Ganga and Brahmaputra Basins have been broadly classified as 'highland rivers' , viz., Bhagirathi, Ganga (upto Hardwar), Yamuna (upto Saharanpur), Ghaghara, Gandak, Brahmaputra and Manas and 'lowland rivers', viz., Yamuna (at Allahabad), Chambal, Betwa, Ken, Son and Gomti. The abundances of major ions have been used to evaluate the major ion chemistry of the highland and lowland rivers in terms of chemical weathering of the rocks and soils of their drainage basins. In these river basins, the marine contribution of cyclic salts is insignificant relative to chemical weathering. In the highland rivers, Ca^{2+}, Mg^{2+} and HCO_3^- are the most abundant ions, $(Ca+Mg)/TZ^+$ ratio is about 0.9 and

HCO_3^-/TZ^- ratio varies between 0.8 to 0.9. This suggest that the chemistry of the highland rivers is dominated by weathering of carbonate rocks, an observation consistent with the regional lithologies. Further, the relatively low silica, Na^+ and K^+ abundances in these rivers and high (Ca+Mg): (Na+K) equivalent ratios (range between 5.2 to 11.5) lead to the conclusion that the silicate weathering in these drainage basins is of minor importance.

The abundances of major ions in the Yamuna, Chambal and Gomti Rivers (lowland rivers) is influenced by the weathering of carbonates, silicates and soil salts in varying proportions. The relative proportions vary seasonally there by providing a unique opportunity to study the weathering processes regulating the abundances of major ions in these river waters. During lean flow (summer months), the contribution from alkaline and saline salt-affected soils is more pronounced. This is reflected upon the high abundances of Na^+, Cl^- and SO_4^{2-} in these river waters during lean flow. Thus, in summer months the major ion composition of these rivers is more of 'evaporitic' nature. During peak flow, the chemical composition of these rivers closely follow that of 'rock-dominated' type of waters. Hence the major ion composition of these rivers show large seasonal variation. In Ken and Son Rivers the carbonate weathering dominates the major ion composition. Of all the rivers studied, the silicate weathering appears to be more pronounced in Betwa River.

The TDS content of the highland rivers ranges between 93 to 233 mg/l where as in the lowland rivers the TDS content varies between 130 to 460 mg/l, the higher values occur during lean flow. The downstream and seasonal variations in the major ion chemistry of the Ganga main channel are controlled by the chemistry of the tributaries and their mixing volumes. Also, the chemical transport of dissolved constituents is conservative within the Ganga River basin. The average annual fluxes of dissolved salts transported by the Ganga and Brahmaputra Rivers are 67×10^6 and 50×10^6 tons/yr, respectively. These two rivers transport 3 % of the global supply of water and salts to the oceans.

The regional and seasonal variations of δD and $\delta^{18}O$ have been studied, for the first time, in these river waters to delineate the relative contributions (to the river flow) from different hydrologic regimes. In all the rivers, δD and $\delta^{18}O$ values are higher during lean flow period compared to that during peak flow conditions. However, this seasonal variation is more pronounced in the lowland rivers. The linear relationship ($\delta D = 6.1\ \delta^{18}O - 4.5$) between δD and $\delta^{18}O$ values yield a slope of 6.1, significantly lower than the slope of meteoric water line. This seem to suggest that the isotopic enrichment in these river waters occurs as a result of evaporation losses from rivers and dams.

The regional variations in $^{234}U/^{238}U$ activity ratio of the river waters within the Ganga and Brahmaputra River basins seem to be dominated by the lithology of the terrains which they drain. In lowland rivers, draining through relatively fresh granite and gneissic rocks, the $^{234}U/^{238}U$ activity ratio varies between 1.16 ± 0.03 to 1.84 ± 0.03 which are significantly higher than those of the highland rivers, 1.02 ± 0.02, consistent with the predominantly sedimentary geology of their drainage basins. The uranium concentration in these river waters show a linear relationship with ΣCations. The $^{238}U/\Sigma$Cations ratio in these river waters is very similar to that in the river suspended sediments suggesting congruent dissolution for major cations and uranium. The Ganga and Brahmaputra Rivers constitute the major source of dissolved uranium to the oceans. These two rivers transport annually 9.4×10^{8}g of uranium to the Bay of Bengal, about 10 % of the global river input to the oceans. The residence time of uranium in the Bay of Bengal relative to its supply via these rivers is only about 2×10^{4} years.

CONTENTS

CHAPTER

CHAPTER

LIST OF FIGURES

Figure No. Page

LIST OF TABLES