The chemistry of three 'holy' waters: a hydrologist's pilgrimage

The placid lake water of Manasarowar is known for its holy legend. Located in the Tibetan Plateau of Himalayas at a height of 6715 m amsl, the lake has an area of 320 km^2 with a cool and crystal-clear water mass. The lake is close to Mount Kailas, another holy place in Hindu legend. Historical Indian rivers like Ganges, Brahmaputra and Indus originate from the glaciers of the Himalayan peaks, just 100 km southwest of Manasarowar. The Tibetan Plateau is formed due to the tectonics of Himalayan ranges. The southwest or northeast monsoon rains do not reach Manasarowar, as the Tibetan Plateau is located on the northern slopes in the 'monsoon shadow'[1] zone. As such, only the 'snow line' is responsible for feeding the Manasarowar. The dry conditions are responsible for deposition of salts in the lakes. The lake water of Manasarowar (and Rakhas, Yandrok and Gunchun lakes close by) has no tendency to dry up, which might result[2] in an increase in salinity. The glaciers of the Kailas hill range are the sources of water for major rivers like Bhagirathi and Alaknanda, which are called Ganges further down. The rise of Himalayas has led to the formation of the Tibetan Plateau. The plateau is covered by alluvium and loess. In the western part of the plateau, Kailas conglomerate occurs. Alluvial soils are responsible for the leaching of ions like chloride, sulphate and sodium into Manasarowar waters. Another theory is that[3] the moisture-bearing winds from the Indian Ocean have been cut-off and drier conditions prevail in Tibet. This dryness lifts the saline particulates into the air and deposits them on glaciers, which eventually carry them to lakes. Biocarbonates, calcium and magnesium are due to the leaching of alluvium during snow melt and movement. However, even the 'still' water in a lake would result in concentration of salts with time. It is postulated[3] with observations from small stream beds in the area that a buried stream periodically flows, connecting Manasarowar and Rakhas lakes. While the snowmelt of Kailas range recharges the lake water, the above stream might be discharging the water to maintain the sustained freshness of the lake and glory to the waters of the Manasarowar. One of the authors (A.V.S.) had undertaken a pilgrimage to the holy lake during 1–3 March 2006 and brought the water sample out of curiosity. Another water sample was collected from Muktinath temple lake (5 March) from Nepal. During the return journey, another sample was collected from the groundwater well located in Rameswaram temple, Tamil Nadu (10 March). The sample was collected at a depth of 55 ft from the ground surface. Hydrochemical analysis of the three samples is given in Table 1. The higher salinity of groundwater (seven times higher than the two lake waters) due to dissolution[4] of the aquifer is clearly observed in the analysis of Rameshwaram temple well-water. The geology of the depth section of this area is alluvial sandy-clay. The conductivity of the sample increased due to clayey particles dissolved into the groundwater. Samples from Manasarowar and Muktinath are surface waters and are influenced heavily by glacier melt. The geology of the area also plays a minor role in influencing the conductivity of the two samples.

Table 1. Hydrochemical analysis of water samples

Element	Manasarowar lake	Muktinath temple lake	Rameswaram temple well (groundwater)
Chloride (mg/l)	8.0	7.0	528
Nitrate (mg/l)	0.2	0.2	133
Bicarbonate (mg/l)	120.0	74.0	230
Sulphate (mg/l)	34.0	113.0	212
Sodium (mg/l)	25.0	4.0	400
Potassium (mg/l)	2.5	0.6	44
Calcium (mg/l)	24.0	40.0	64
Magnesium (mg/l)	15.0	24.0	58
Hardness as $CaCO_3$ (mg/l)	120.0	200.0	400
Total dissolved salts (mg/l)	224.0	268.0	1690
Sp. conductance (μs/cm)	350.0	419.0	2640
pH at 31°C	7.67	7.65	7.2

1. Mathur, S. M., *Physical Geology of India*, NBT, New Delhi, 1991, p. 180.
2. Mathur, U. B., *Quaternary Geology Memoir 63*, Geological Society of India, Bangalore, 2005, p. 344.
3. Krishnan, M. S., *Geology of India and Burma*, Higginbothams Ltd, Madras, 1960, p. 604.
4. Singanan, M. and Somasekhara Rao, K., *Indian J. Environ. Prot.*, 1996, **16**.

ACKNOWLEDGEMENTS. We thank Prof. T. Ramamohana Rao, Emeritus Professor, Department of Geology, Andhra University for useful discussions.

C. SUBBA RAO*
A. VACHASPATHI SARMA
Y. SOMU NAIDU

Department of Geophysics,
Andhra University
Visakhapatnam 530 003, India
**e-mail: ahivisakha@hotmail.com*