Kar-Tso: A HIGH ALTITUDE NATURAL SALT- PAN IN THE HIMALAYAS

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ABSTRACT

The saline lake, Kar-Tso, is located in a basin covering an area of 136 sq km at an altitude of 4535m above mean sea level in the Ladakh district of Jammu and Kashmir, India. This lake covers an area of 12.5 sq km and is the remnant of a large ancient lake. The slopes of the basin depict the story of the desiccation in the form of wave cut terraces, and receding water marks. This basin also has a freshwater lake, the Startspuk Tso, located at the southern part of the basin to which most of the freshwater inflow takes place. This lake finally drains into the Kar-Tso through a narrow meandering channel.
The passage of water from the freshwater streams to the Startspuk Tso and from there through the connecting channel to Kar-Tso was traced through sampling. The gradual transformation of freshwater to saline water was observed with final precipitation of salt. The variations in sodium, potassium, calcium and magnesium amongst the basic radicals and Cl, and SO_4 amongst the acid radicals were analyzed and traced. In the freshwater samples, the value (in ppm) are Na- 10 to 75; K-3 to 10; Ca-18 to 76; Mg-2 to 20; Cl-5 to 50; SO_4 - 60 to 200 with a pH of 8.2. The variation in chemical composition in the Kar-Tso, as analyzed along the east - west trending traverse line from east show the values (in percentage) Na - 0.24 to 9.9; K -0.09 to 4.8; Ca - 0.02 to 0.16; Mg - 0.01 to 2.25; Cl-0.3 to 10.15; SO_4-0.5 to 9.10.
Meteorological studies including diurnal temperature variation, wind velocity and direction, and relative humidity were undertaken for the months of August to October. Saline water evaporation studies in pan were also undertaken to determine net evaporation of water per sq. m. to determine approximate water budget of the lake system. It was found that there is a negative water budget in the order of $34x10^6$ liter/day. It is surviving as a lake only because of the extreme winter and accompanying snow fall extending for almost nine months of the year.
The analysis of salt budget reveals an addition of 1.5 tonnes of NaCl and 0.5 tonnes of KCl per day in to the Kar-Tso.
Chemically this is a Cl-SO_4-CO_3 lake system where NaCl, and KCl are the major chlorides, $CaCO_3$ deposits as the mud in the eastern part of Kar-Tso represents carbonate mineral and extensive efflorescence of $Na_2SO_4.10H_2O$ (mirabilite) and Na_2SO_4 (thenardite) are the sulphates.
This lake system thus presents a complete picture of a natural salt pan located at cold, high altitude locale in the Himalayas.

KEYWORDS: Ladakh, Saline Lake, Himalayas, High Altitude.

1. INTRODUCTION

In Ladakh district of Jammu and Kashmir state of India lie a large number of tectonic basins which presently support lakes. Such lakes are Pangong Tso, Tso Morari, Kiagar Tso and Kar-Tso. Besides, completely dry sedimentary sequences with large thickness of laccustrine sediments are also exposed such as at Lamayuru and Leh basin. These

basins depict a history of past wet conditions which gradually changed into dry cold arctic conditions of present day leading to drying out of lakes.
The history of Kar Tso is no different. It is located in the tectonic basin covering an area of 136 sq km lying 170 km south east of Leh at an altitude of 4535 m. (Fig-1). This basin once housed a large water body which was at least 66 m. deep as indicated by a wave cut terrace, about two meter wide, at that level. At present the basin has two water bodies, the Kar Tso, a dumb-bell shaped saline lake at the center of the basin, trending almost E-W, and a pear shaped freshwater lake, the Startspuk Tso at the southern end. These two lakes are connected through a narrow, meandering channel. Through this channel, the Startspuk Tso drains in to the Kar- Tso. A number of strand lines on its slope show a history of decreasing water level through time. Cunningham (1853) and Drew (1875) described this lake and gave details about its salinity and described the lake about 14 sq. km. in area which was almost 1.5 m. deep. However, at present the area of the lake has decreased to 12.5 sq. km. and its depth is only 0.8 m. at its deepest.
This basin received attention through scientific studies by Stoliczka (1866), Drew (1875) and Cunningham (1853) who considered this lake to have come up through damming of the outlet by glacial fill and alluvium. Mazari (2000), tried to correlate the desiccation of the lake recorded in the strand lines on the slopes of the basin to the climato - tectonic evolution during the Late Cenozoic. During 1975 and 1976 detailed exploration was undertaken through sending a large contingent of geologists to study its geological and geochemical evolution besides assessment of its mineral resources. The present paper is the outcome of the results of studies undertaken during that period.

2. GEOHYDROLOGY OF THE AREA

The basin has centripetal drainage with Kar-Tso as the deepest part of the basin. Nalabokhar and Shingbuk nalas in the northern part and Polokong Ka Phu and Nuruchan Lungpa in the southern part are the perennial streams in the basin. The northern streams contribute directly to the Kar Tso but the southern streams debouch in to the Startspuk Tso. The Kar Tso and the Startspuk Tso are separated through the development of the delta lobes of the Polokongka Phu and the Nuruchan Lungpa. A number of springs occur around the Kar Tso viz. Thugje, Niyanda, Riyul, Chewar, Pongunagu contribute to the Kar Tso. Lenak spring, however, contributes to the Startspuk Tso.

3. HYDROGEOCHEMISTRY OF THE LAKE SYSTEM

Detailed sampling of the fresh water sources in the basin and the saline lake body was undertaken. Fresh water samples were collected from the inflowing streams viz. Nuruchan Lungpa, (Nala) and Polokongka Phu, and springs viz. Riyul spring zone, Chewur spring, Thugje spring zone, Lenak spring zone besides an artesian well that came into existence in the course of drilling. Samples were also collected from around the Srartspuk Tso and the channel connecting the Startspuk Tso to Kar-Tso. Brine samples were also collected form the Kar-Tso along an E-W trending traverse N-3 at an interval of 500 m. Bottom sediment samples from the same locations were also collected.
Water was sampled by slowly immersing the polythene bottle in undisturbed water. At locations with water depth greater than 50cm, two samples were collected, one from the surface and the other close to the bottom. The bottles were immediately sealed and analyzed within one to two days.
The analyses were made by rapid field methods and the samples were analyzed for, Na, K, Ca, Mg, SO_4, and Cl besides pH and specific gravity. Sodium and potassium were analyzed flame photometrically with solutions diluted to below 10mg/litre. Ca and Mg were determined by standard EDTA method, chloride was determined titrio metrically using potassium chromate as indicator and standard silver nitrate as titrant (0.0141N) and standardizing against 0.0141N NaCl. Sulphate was determined by ion- exchange method (Bhat, 1967) using Zeo Karb Resin-225 cation exchange. (Chowdhary 1977).

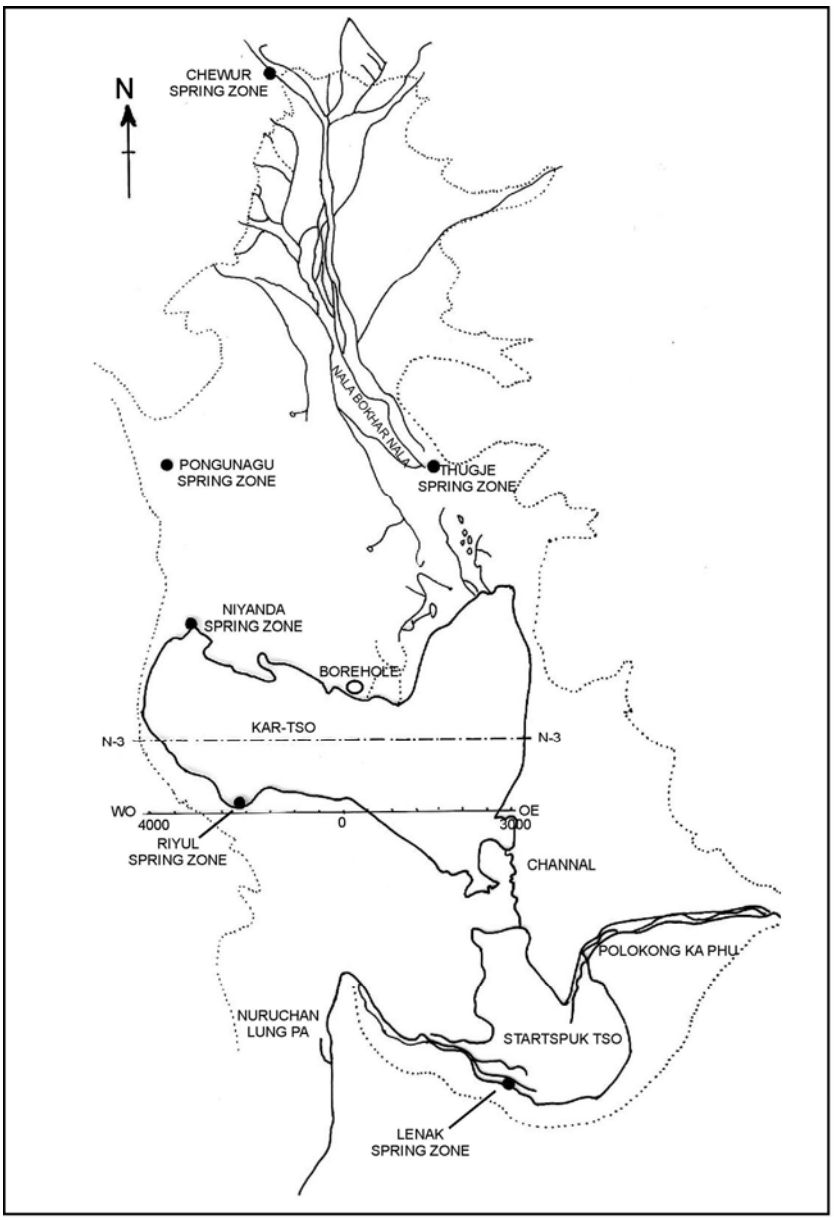

Figure 1: Sketch map of Kar-Tso basin showing sampling plan ang water bodies

3.1 Chemical variation in fresh water

Fresh water samples on analysis (Table-1) show ph of 8.0 to 8.2. and Sp. Gr. of 1.005. The content of Na varies between .0004 ppm to 0.0025 ppm, except in the sample from the borehole which shows a value of 0.04 ppm. Similarly, K values range between 0.0003 to 0.001 ppm. Ca values 0.0004 to 0.006 ppm, Mg 0.0002 to 0.004 ppm. Amongst the cations Cl varies between 0.001 to 0.006 ppm and SO_4 from 0.0012 to 0.008 ppm. The sample from the borehole, however, does show comparatively higher concentration i.e. Na-.0.04, K- 0.006, Ca 0.022, Mg 0.01, Cl.0.061, and SO_4 .0.065, The chemical analysis of water samples from Startspuk Tso do not show appreciable concentration of salts, the values being Na 0.002 ppm, K-0.005 ppm. Ca-0.004ppm, Mg 0.002 ppm Cl- 0.006 ppm, and SO_4 0.04 ppm.

The water samples from the meandering channel connecting the Startspuk Tso to the Kar-Tso, however, show gradual rise in the concentration of salts. At its proximal end the values are Na-0.001, K-0.005, Ca 0.003, Mg 0.006, Ca 0.04, SO_4 0.05 ppm, but at its distal end the values are Na-0.31, K-0.65, Ca 0.018, Mg 1.34, Cl-1.05 and SO_4 0.38 ppm.

This rise in concentration seems to be due to evaporative loss of water as well as due to mixing of brackish water of the Kar Tso.

Table 1: Chemical analysis of fresh water samples inflowing into Kar Tso from springs and channels.

SAMPLE LOCATION	pH	Sp.Gr.	Na gm/ 100cc	Ka gm/ 100cc	Ca gm/ 100cc	Mg gm/ 100cc	Cl gm/ 100cc	SO_4 gm/ 100cc
RIYUL SPRING ZONE	8.2	1.005	.0012	.0006	.005	.002	.0035	.0012
NIYANDA SPRING ZONE	8.2	1.005	.0013	.001	.006	.002	.0035	.009
PONGUNAGU SPRING	8.3	1.005	.0004	.0005	.006	.0014	.003	.016
CHEWUR SPRING	8.2	1.005	.0002	.0004	.004	.001	.003	.02
POLOGONKLA PHU	8.0	1.0004	n.t.	n.t.	.001	.0002	.001	n.t.
NURUCHAN NALA	8.0	1.0004	.001	.0003	.002	.002	.003	.006
THUGJE SPRING ZONE	8.2	1.005	.0015	.0009	.004	.004	.006	.008
LENAK SPRING ZONE	8.2	1.004	0.0025	.0008	.0004	.003	.002	.003
BORE HOLE		1.005	.04	.006	.022	.01	.061	.065
STARTSPUK TSO (MEAN OF 6 SAMPLES)	8.8	1.005	.002	.005	.004	.002	.006	.04
CHANNEL FROM 1	8.7	1.05	.001	.005	.003	.006	.04	.05
2	8.8	1.05	.004	.008	.001	.001	.21	.016
3	8.8	1.05	.02	.05	.006	.007	.32	.4
4	8.4	1.15	1.6	4.75	n.d.	n.d.	n.d.	n.d.
5	8.0	1.10	0.31	0.65	0.18	1.34	1.05	0.38

3.2 Chemical variation in brine samples in the Kar- Tso.

Brine samples were collected along the traverse N-3 running E-W almost at the central part of the Kar-Tso. Samples were collected at a distance of 500m. From east towards west gradual increase in the concentration of salts has been noticed. The results of the chemical analyses are presented in Table-2 (Fig-2) the values at the eastern end show Na – 4.95 gm/lt, K-2.15 gm/lt, Ca –0.04 gm/lt, Mg 1.29 gm/lt Cl 5.77 gm/lt, and SO_4 5.14 gm/lt. These values indicate already high level of concentration of salts in the lake, almost unaffected by the mixing of inflowing water from the Startspuk Tso. Ca and Mg values do not show similar change in their concentration as shown by the Na and K values or Cl and SO_4 values, most likely due to their precipitation as carbonate or bi- carbonate due to sudden change in the concentration of the brine. The Na and K show sharp lowering in their values at times, near the points of entry of fresh water from the springs close to its boundary viz. Niyanda and Riyul spring zones, and in the central part of the lake close to the borehole with artesian flow of water. The composition of brine at the distal end of the Kar Tso show values of Na-rising up to 9 gm/lt, K-5.75 gm/lt, Ca-0.06 gm/lt. Mg-2.12 gm/lt, Cl, 5.25 gm/lt and SO_4 as 6.65 gm/lt.

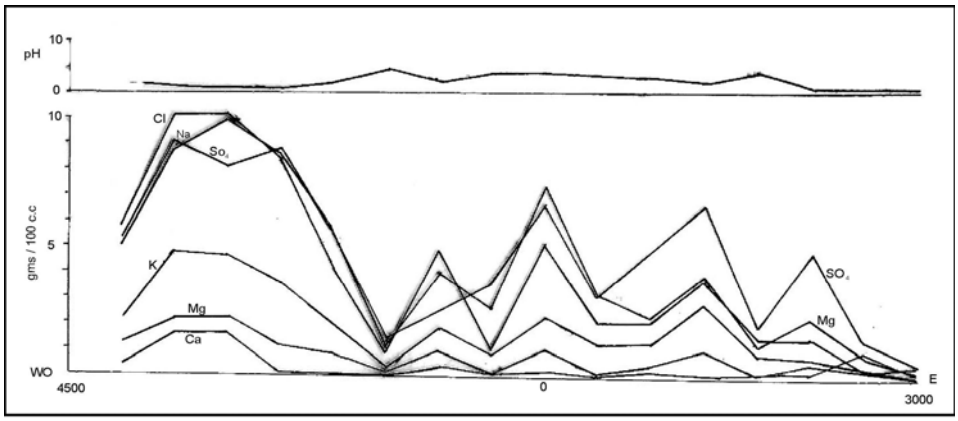

Figure 2: Sketch showing chemical variations in brine along E-W traverse at N-3

Table 2: Chemical analysis of brine samples along traverse n-3

SAMPLE NO.	pH.	Sp.Gr	Na gm/ 100cc	K gm/ 100cc	Ca gm/ 100cc	Mg gm/ 100cc	Cl gm/ 100cc	SO_4 gm/ 100cc
E/3500	8.4	1.166	4.95	2.15	0.04	1.29	5.77	5.14
E/3000	8.2	1.25	8.8	4.8	0.16	2.20	10.15	9.10
E/2500	8.2	1.26	9.9	4.65	0.16	2.25	10.15	8.08
E/2000	8.3	1.208	9.55	4.05	0.013	1.83	9.10	8.11
E/1500	8.4	1.12	5.6	2.0	0.01	0.916	4.20	5.37
E/1000	8.6	1.06	2.65	1.1	0.011	0.535	1.92	1.16
E/500	8.8	1.145	4.0	1.90	0.04	1.03	4.90	n.d
0/0	8.8	1.15	2.65	0.90	0.021	0.14	1.05	3.51
W/500	8.8	1.16	7.30	2.3	0.024	1.11	5.17	6.60
W/1000	8.8	1.005	0.016	0.01	0.008	0.001	0.035	0.12
W/1500	8.6	1.146	9.0	5.75	0.06	2.12	5.25	n.d.
W/2000	8.4	1.156	3.9	2.85	0.01	1.19	3.72	6.65
W/2500	8.6	1.08	2.1	1.40	0.048	0.487	2.80	n.d.
W/3000	8.2	1.14	2.25	0.75	0.019	0.54	1.53	4.80
W/3500	8.2	1.06	0.08	0.3	0.1	0.2	0.3	1.47

Variation in the concentration of Na, K, Ca, and Mg seems to be only through evaporative loss of water from the system. Even in the eastern part where the lake has a winder spread, allowing greater evaporation loss of water, high concentration of salt in the brine has been recorded.

3.3 Chemical analysis of solid grab samples from the lake bottom.

Chemical analysis of solid grab samples collected from the same locations as the brine samples, i.e. along the N-3 east - west trending traverse with in the Kar- Tso (Table-3 Fig-3) faithfully represent the gradual concentration of brine in the lake from east to west as well gradual differential precipitation of consequent minerals. At its eastern end, the grab samples show. Na-5.0 gm/%, K-2.2 gm/%, Ca 3-2 gm% ,Mg 11.9 gm%, Cl 9.4 gm%, SO_4 0.49 gm% indicating precipitation of whatever Ca and Mg was present in the system at this locale. Compared to this, the values at the distal end of the lake show Na-38.0gm%, K.0.54 gm%, Ca 1.1 gm%, Mg o.54 gm%, Cl - 1.75 gm% and SO_4 - 62.38 gm%

The curves depict changes in the values similar to those exhibited by the variation in the brine concentration.

This description indicates that the lake Kar Tso presents a typical saltpan under natural conditions. The flowing fresh water changes to brackish water and finally results in precipitation of salt in the course of its movement from the east to west in the lake.

The curve showing the thickness of the precipitated salt at the lake bottom (Fig 3) closely corresponds to the rising concentration of salts in the brine. The maximum thickness of the salt layer recorded was 0.80m at the distal end, similar small zones of precipitation of salts were also noticed in the different locales in the lake

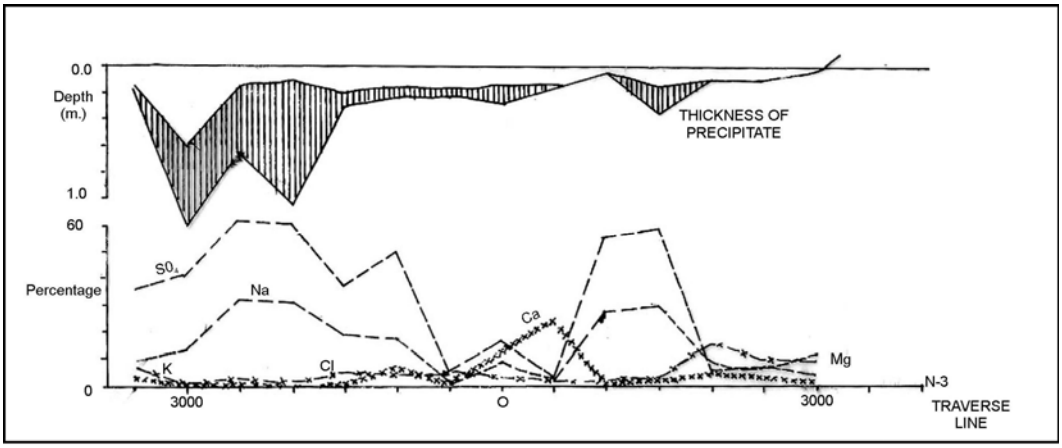

Figure 3: Sketch showing of water, thickness of precipitate, shemicalvariations in the precipitated salt layer in the lake

Table 3: Chemical analysis of solid grab samples from lake along traverse n-3

SAMPLE NO.	Na gm/5%	K gm/%	Ca gm%	Mg gm/%	Cl gm%	SO_4 gm/%
W/3000	38.0	0.54	1.1	0.54	1.75	62.38
W/2500	32.0	0.54	0.43	0.26	2.8	62.91
W/2000	31.0	0.14	0.21	0.1	1.77	61.10
W/1500	19.0	1.4	1.7	1.34	5.6	37.24
W/1000	18.0	5.6	6.6	1.3	4.9	50.96
W/500	2.0	0.7	1.3	6.6	5.78	6.62
0/0	8.3	0.84	12.6	4.8	3.5	17.76
E/500	1.8	0.6	24.6	4.6	1.75	2.45
E/1000	1.4	0.5	25.5	1.4	1.98	1.39
E/1500	30.0	0.32	0.3	0.05	2.45	59.41
E/2000	8.6	3.2	5.3	6.0	16.1	3.43
E/2500	4.8	2.1	7.9	6.1	9.45	2.45
E/3000	5.0	2.2	3.2	11.9	9.4	0.49

4. EVAPORATION TEST AND WATER BUDGET

Evaporation tests were undertaken to determine the rate of evaporation per day (Rastogi et al., 1977) adopting pan evaporation experiments (Reeves, 1968), Pans, aligned N.S and E-W, lined with polythene, were filled with brine of 1.16 sp.gr. and reduction in water level was observed for only 2 days so as to avoid inconsistency in evaporation rate due to increase in the concentration of brine (Langbein, 1961) the data so obtained was extrapolated for the total area of the water body of the Kar-Tso with a factor of 25% reduction for an open large water body (Langbein, 1961).

The observations revealed an evaporation loss of 8 lt per day in the pans and on extrapolation for the lake it was calculated to be 6lt/day after reducing it by 25%. For a total area of 12.5 sq. km. for the main water body of the lake and surrounding small detached water bodies therein, at 6lt/day/sq.m., the evaporation loss was computed to be $82x10^6$ lt/day. Compared to the volume of in flowing water in to the lake i.e. $48x10^6$ lt./day, the evaporation loss provided a negative water budget of $34x10^6$ lt./day, contributing 1.5 tonnes of NaCl and 0.5 tonnes of KCl per day to the lake. It is natural as Cunningham (1853) and Drew (1875) besides Hutchinson (1937) have recorded decreasing levels of water in recent times.

Under static conditions, with discounting the yearly inflow and evaporative loss of water from the system, the volume reduction from the lake maxima to the present day volume of the lake, is of the order of 2500 times.

5. CONCLUSION

The lakes in the Tibetan region have shown decrease in the water level through time and consequent increase in salinity, leading even to development of playas (Zheng Mianping, 1997) Similarly, the Kar -Tso shows development of a salt pan which shows continuous rise in the salinity from its eastern end to the western part, The western part shows development of a precipitated crystalline salt layer below the brine. The concentration level in the brine also reacts to the inflow of freshwater from the springs located near its border.

Evaporation loss of water in the lake indicates a negative water budget of the order of $34x10^6$ ltr./day. The total salt input in to the lake computed in terms of contribution out of the water lost through evaporation is of the order of 1.5 tonnes of NaCl and 0.5 tonnes of KCl.

REFERENCES

Andotra B.S. and Verma N.K.R., (1967). Report on the geological mapping of parts of Rupshu area and the investigation of sulphur by drilling in Puga area, Ladakh district, *unpublished Geological survey of India, Report.*

Bhat G.D., (1967). Quick method for estimation of sulphate, *Salt Researeh Industry. Vol. 4.pp - 131.*

Burrard and Hayden. (1907). Desiccation of lakes in Geography and Geology of Himalayan Mountains and Tibet. *Gian Publications. pp 204-206.*

Chowdhuri R. and Rangachari N., (1976). Kar Tso project -1975, Exploration of the Kar Tso lake brines and deposits for possible exploitation of Potash and other Commercial salts. *Report on the work done by Planning and Development Division Fertilizer Corporation of India, Ltd. Sindri*.

Cunningham A., (1853). Ladakh- Physical, statistical and historical with notices of the surrounding countries *Reprinted by Sagar Publications New Delhi, 1970.*

Drew F., (1875). The Jammu and Kashmir Territories, A geographical account *Oriental Publications, New Delhi.*

Hutchinson G.E., (1937). Limnological studies in Indian Tibet, *Int. Rev. Hydrobiology. Vol. 35.*

Hutchinson G.E., (1939). A Treatise on Limnology Vol - 1 *John Wiley & Sons Inc*.

Kashkari R.L., (1973). Investigation of evaporite deposits around Kar Tso lake in Changthang area, Ladakh District .J&K *unpublished report of the Geological survey of India.*

Kashkari R.L., (1974), Borax and evaporate deposils of Puga valley and Tso - Kar lake area and geological prospecting in Puga valley ,Ladakh, J & K *unpublished report of the Geological Survey of India.*

Krishnaswamy V.S., Raslogi S.P., Padhi R.N., Shanker R., Das R.N., Kapoor S., Narayan S., Nawani P.C., Dimri D.,B., Hasan K., Ghatak T.K., Aich P.K., Kashkari R.L., Singh B., Pandit A., Shankarnarayanan Ram S., Murthy M.K., (1977). First project report on Integrated, Mnltidisciplinary Project for exploration of potash in Kar Tso, Ladakh District J&K, *unpublished Report of the Geological Survey of India.*

Langbein W.B., (1961). Salinity and hydrology of closed lakes, *U.S.G.S. Prof. Paper, 412.*

Livingston D.A., (1963). Data of Geochemistry, Sixth edition, chapter- G., Chemical Composition of Rivers and Lakes. *U.S.G.S Prof Paper, 440-G.*

Mazari R.K., (2000). Palaeoshorelines as indicators of Late Cenozoic Climo-Tectonic Changes in Ladakh Trans Himalaya An illustration from Kar Tso Lake. *Earth Science Frontiers.*

Raina B.N., Nanda M.M., Bhat M.L., Mehrotra P.C., Dhall B.N., (1962). Report on investigation of coal, limestone, broax and sulhpur deposits of Ladakh. J&K, *unpublished Report of the Geological Survey of India.*

Rastogi S.P., (1979). Geochemical Charactersties and evolution of Kar Tso Lake, in *Proceedings of the Himalayan Geology Seminar,1976 Geological Survey of India. Misc. Pub. No. 41,pp-259-277.*

Rastogi S.P., Kapoor S, Narayan S., (1987). Meteorological and evaporation test studies in Kar Tso area, Ladakh district J&K, *Records of the Geological Survey of India. Vol.117.*

Stoliczka F., (1866). Geological Sections across the Himalayan Mountains from water bridge on the river Sutlej to Sungdo on the Indus: with an account of the formations in Spiti accompanied by a revision of all known fossils from the district,*Memoir, Geological Survey of India, Vol-5, pt-I pp.1-154, plates 1-10.*

Verma N.K.R., (1967). Evaporites of Kar Tso, Ladakh, J&K., Indian Minerals, Vol,26 No.3.

Verma N.K.R., (1968-69), Investigation of evaporites in Kar Tso Lake area, Ladakh, J&K, *unpublished Progress Report of the Geological Survey of India.*

Zheng M., (1997). An Introduction to Saline Lakes on the Qinghai- Tibet Plateau *(Monographiae Biological) Kluwer Academic Publishers.*\