Journal Homepage: -www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
Article DOI:10.21474/IJAR01/8484
DOI URL: http://dx.doi.org/10.21474/IJAR01/8484
ISSN NO. 2320-5407

RESEARCH ARTICLE

CHEMICAL CHARACTERIZATION OF ICE AND MELTWATER OF GLACIERS IN MIYAR VALLEY, LAHAUL & SPITI DISTRICT, HIMACHAL PRADESH, INDIA.

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Manuscript Info

Manuscript History
Received: 02 December 2018
Final Accepted: 04 January 2019
Published: February 2019

Key words: -
Glacier, anions, cations, Miyar, Takdung, Uldhampu.

Abstract

The study of chemical characteristics of the glacier including ice and meltwater streams originating from the glaciers play a significant role in classifying and assessing overall downstream water quality. In this study, chemical analysis and interpretation of three glacier's ice and meltwater streams originating from Miyar, Takdung and Uldhampu glaciers, were carried out to understand major ion chemistry, ascertain the ionic variation in ice and meltwater, source rock characteristics and potability of water. Analytical results are represented by using Piper Trilinear, Stiff and Pie diagrams. The result represents the concentration of both cations and anions values are relatively higher in meltwater. The individual sample wise interpretation of Piper and Stiff diagrams shows Ca^{++} and Mg^{++} are dominant cation and HCO_3^- and CO_3^{--} are dominant anion in both Ice and meltwater samples of Miyar and Takdung Glaciers. Whereas ionic values in Ice and meltwater samples of Uldhampu glacier varied as $Cl^- > SO_4^{--} > HCO_3^- + CO_3^{--}$ and $SO_4^{--} > Cl^- > HCO_3^- + CO_3^{--}$ respectively. Comparative study of analytical results with permissible range defined in Bureau of Indian Standard (BIS, 2012) for potable water, shows ionic concentrations in samples of Miyar and Tukdung glaciers are within the permissible range and ice and meltwater of Uldhampu glacier reveals its acidic nature with pH 5.64 and 4.00.

Introduction: -

The glacial form one of the components of the hydrological budget playing an important role in buffering stream flow (Barry, R. and Seimon, A. 2000), acting as water storage over a range of temporal and spatial scales (Jansson, P., Hock, R. and Schneider, T. 2003) and provides water to downstream users and communities during periods of low precipitation as well. The Himalayan region, encompassing the Hindu Kush mountains and Tibetan Plateau, spanning Afghanistan, Bhutan, China, India, Myanmar, Nepal, and Pakistan are rich in glaciers (ICIMOD 2011). Melt water from mountain glaciers of the Himalaya are one of the dominant water resources for North India along with rainfall and ground water on which the country depends for its drinking water, irrigational and hydropower needs. The anthropogenically induced climate changes causing glacial retreats making a serious impact on hydrological cycles resulted decreasing water resources, quality and quantity (IPCC 2007). The chemical characteristic of melt waters from the glaciers is extremely important to find out weathering reactions, anthropogenic and climate change impacts on fresh water resources. During the glaciology expedition in

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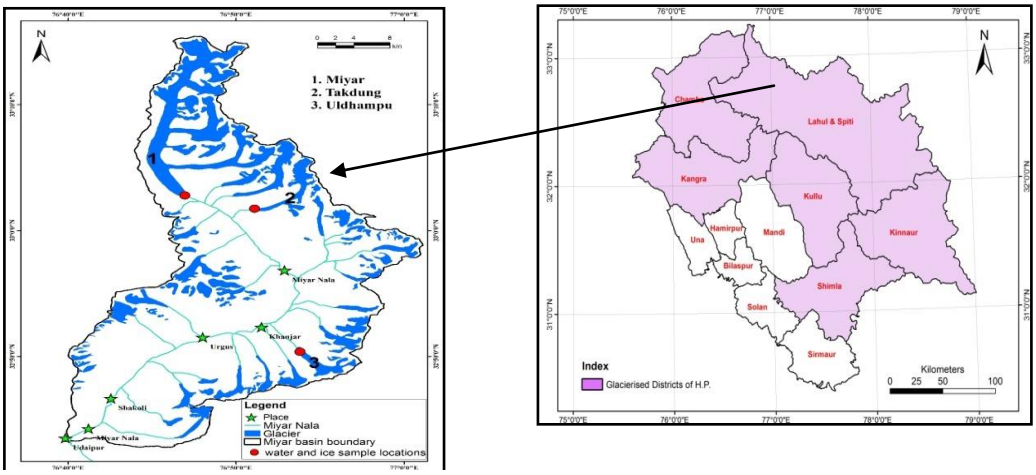
Miyarvalley, Himachal Pradesh, total 6 numbers of glacier's ice (from snout of Glacier) and meltwater (from glacial stream) samples were collected from Miyar, Takdung and Uldhampu glaciers to ascertain chemical variations in glacier ice and meltwater, role of lithology and quality of water for drinking purpose.

Study Area

The study area located in Miyar valley which comes under Lahaul& Spiti district of Himachal Pradesh (Fig-1), covering an area of 960 km^2, containing 93 glaciers which occupies 211 sq. km as glacierized area of the total basin. Miyar is the largest glacier having 22 km length. MiyarNala is originating from the Miyar glacier and merges into Chenab river at Udaipur. The basin extends between $32^0$43'13.93" N to $33^0$15'15.55" N and $76^0$39'54.32" E to $77^0$00'47.94" E within Greater Himalayan range with altitude ranging from 2634 m to 6022 m asl. For approaching Miyar Valley, nearest rail head is Chandigarh and from Chandigarh to Udaipur via Manali is well maintained metallic road. Khanjar is a small village situated in last road head in the valley. Miyar glacier is situated at 35 km distance from Khanjar village on famous track route going to Ugrus Pass (5017 m) and Tarsalamu Pass (5358 m). Geologically, the study area having Proterozoic rocks of the Vaikrita Group (Kharo and Chamba Formations). Phyllite, Biotite gneiss, granite gneiss, porphyroblastic and augen gneiss, migmatite, granite, aplite, pegmatite, vein quartz and minor schist are dominant rock type on study area(Tangri, S.K., 2006).

Fig. 1: -Map of the study area showing location of sampling sites in Miyar Valley, Himachal Pradesh.



Materials and Methods: -

The quality of water depends on its dominant ionic composition dissolved in form of cation and anion. Total 06 samples (Table-1 & 2) in which three Ice and three meltwaters collected from glaciers snout and meltwater streams of Miyar, Takdung and Uldhampu glaciers during July to September, 2017. All the samples were collected in high density polyethylene bottle in order to minimize container's pollution and better sample preservation. All the samples were analysed in Geological Survey of India (GSI), Chemical Lab, Lucknow to get the concentrations of major cations like potassium (K^+), sodium (Na^+), magnesium (Mg^{2+}) and calcium (Ca^{2+}) and some major anions like bicarbonate (HCO^{3-}), chloride (Cl^-), nitrate (NO^{3-}), phosphate (PO_4^{3-}) and sulphate (SO_4^{2-}) and other important parameters like temperature (Temp), pH, electrical conductivity (EC), total dissolved solids (TDS), and total hardness (TH). Samples were analyzed as per the American Public Health Association (APHA) Standard Methods defined for the examination of water and wastewater. For determination of major cations (Ca^{2+}, Mg^{2+} and $CaCO_3$) and anions (HCO_3^- and CO_3^{--}) concentrations the Complexometric Titration and Acid Base Titration analysis methods were used. Gravimetric, Argentometric Titration and UV Visible Spectroscopy methods were used to determine SO_4^{2-}, Cl^- and NO_3^- ions. K^+ and Na^+ ions were determined by Flame Photometer (Systronics-125).

Table 1: -Details of Ice samples collected for major ions study.

Sr. No.	Sample No.	Latitude	Longitude	Source Glacier
1	MI/I/01	33^0 02' 47.3'' N	76^0 46' 56.5'' E	Miyar
2	TUK/I/02	33^0 01' 44.7'' N	76^0 51' 05.5'' E	Takdung
3	ULD/I/03	32^0 50' 22.7'' N	76^0 53' 47.6'' E	Uldhampu

Table 2: -Details of meltwater samples collected for major ions study.

Sr. No.	Sample No.	Latitude	Longitude	Source Stream
1	MI/W/01	33^0 02' 43.9'' N	76^0 46' 58.3'' E	Miyar
2	TUK/W/02	33^0 01' 43.5'' N	76^0 51' 03.1'' E	Takdung
3	ULD/W/03	32^0 50' 24.2'' N	76^0 53' 49.6'' E	Uldhampu

Results and Discussion: -

Analytical results of Ice and meltwater samples are given in table-3. As per the interpretation of results, pH value varies from 4.00 to 7.14 shows acidic to slightly alkaline nature. Among cations, the concentration of Ca shows 2-4 ppm and Mg, Na and K shows same value from <1 to 1 ppm. Whereas values of Cl^-, HCO_3^-, NO_3- and SO_4^{--} anions ranges 1-9, 2-7, <1-5 and <5-20 ppm respectively. The comparative study of analysis result with the permissible ranges of ions determined in Bureau of Indian Standard (BIS 10500, 2012) given in table-4. The total dissolve solids (TDS) and ionic concentrations value in all the samples are within permissible range for drinking purpose, but the Ice and meltwater (ULD/I/03 and ULD/W/03) which were collected from Uldhampu glacier shows acidic nature of water with low pH values of 5.6 and 4.0 that is not within the acceptable range determined for potable water. This type of anomalous low pH values in snow was alsorecorded in different part of J&K and Indian Himalayas by other workers.

Table 3: -Analytical result of Ice and Meltwater.

Sample Id	OH^-	SO_4^{--}	Cl^-	NO_3^{--}	CO_3^-	HCO_3^-	T.H as $CaCO_3$	Mg^+	Ca^+	K^+	Na^+	H^+	TDS	E.C.	pH
MI/I/01	Nil	<5	1	<1	Nil	5	5	<1	2	<1	<1	Nil	5	9	6.62
MI/W/01	Nil	<5	4	1	Nil	7	10	<1	4	1	<1	Nil	15	24	7.14
TUK/I/02	Nil	<5	2	<1	Nil	5	5	<1	2	<1	<1	Nil	5	10	6.87
TUK/W/02	Nil	<5	4	2	Nil	7	10	<1	4	<1	1	Nil	20	34	6.81
ULD/I/03	Nil	<5	7	1	Nil	2	10	1	2	<1	<1	Nil	10	17	5.64
ULD/W/03	Nil	20	9	5	Nil	Nil	15	1	4	<1	<1	0.6	55	83	4.00

Table 4: -Physical Parameters for drinking water given by Bureau of Indian Standard, 2012 (IS 10500-2012).

S.No.	Characteristic	Requirement (Acceptable Limit) Mg/l	Permissible limit in the absence of alternate source
1.	pH value	6.5-8.5	No relaxation
2.	Chloride (as Cl)	250	1000
3.	Iron (as Fe)	0.3	No relaxation
4.	Nitrate (as NO_3)	45	No relaxation
5.	Sulphate (as SO_4)	200	400
6.	$CaCO_3$	200	600
7.	Calcium (as Ca)	75	200
8.	Magnesium (as Mg)	0.1	0.3
9.	Mercury (as Hg)	0.001	No relaxation

Graphical Representation of Major Ions concentration

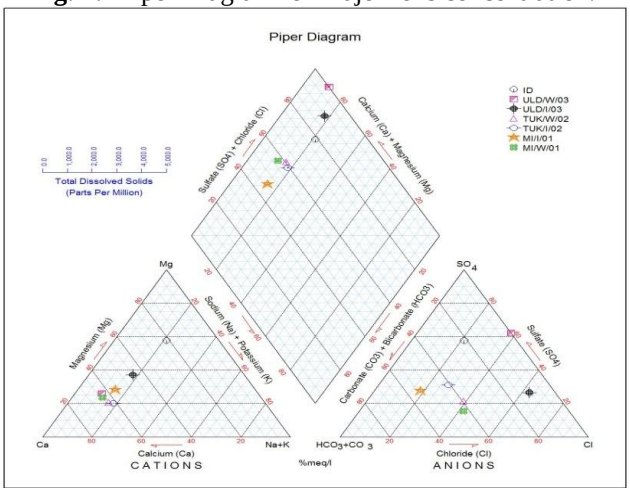
The graphical representation of chemical analysis data makes it simpler and quicker to clarify, interpret and facilitate to find out correlation between two or more data on single platform. The concentration of major ions (anions and cations) in samples of the study area have been displayed in form of tables as well as different types of diagrams. In present study Piper, Stiff, and Pie diagrams are used for representation and interpretation of major ions chemistry of

Ice and meltwater by plotting the cations and anions. The Rockwork software 16 version was used for preparing Piper, Stiff and Pie diagrams.

Piper's Trilinear Diagram

The Piper trilinear diagram (Piper, A. M. 1953) is one of the most useful tools for graphical representation in water quality studies and understanding the geochemistry of water. This diagram consists of two lower triangles that show the percentage distribution on the equivalents per million basis of major cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) and the major anions ($SO4^{--}$, Cl^{-}, CO_3^{--} and HCO_3^{-}), a diamond shaped part above that summarizes the dominant cations and anions to indicate the final water type from which inference is drawn on the basis of hydro-geochemical facies concept. The analytical result (Table-3) of major ions of all six samples are plotted in Piper diagram which is shown in Fig-2. The graphical plots of ionic concentration on Piper's diagram represent that most of the samples lies in Ca^{++} and HCO_3^{-}, Cl^{-} and SO_4^{2-} facies in cation and anion trilinear diagram. The Diamond diagram exhibits one ice sample (MI/I/01) collected from Miyar glacier shows dominance of Ca^{2+}-HCO_3^{-} and falling in Ca^{2+}-Mg^{2+}-HCO_3^{-} facies. Three samples (MI/W/01, TUK/W/02 and TUK/I/02) collected from Miyar and Tukdung glaciers are dominant with mixed Ca^{2+}, Mg^{2+} and Cl^{-} ions falling in Ca^{2+}-Mg^{2+}-Cl^{-}-SO_4^{2-} facies. The ice and water samples of Uldhampu glacier are dominant with Ca^{2+}-Cl^{-} ions falling in Ca^{2+}-Mg^{2+}-Cl^{-}-SO_4^{2-} facies in piper diagram. The Phyllite, Biotite gneiss and granite gneiss are dominant rocks types of the area. The presence of dominant Ca^{++}, Cl^{-} and SO_4^{--} ions in glacier ice and their higher values in meltwater confirms dissolution of ions by chemical weathering of plagioclase feldspar bearing Granitic gneiss, Chlorite bearing Phyllitic rock. The higher values of $CaCO_3$may be linked with calcite bearing rock of the study areas.

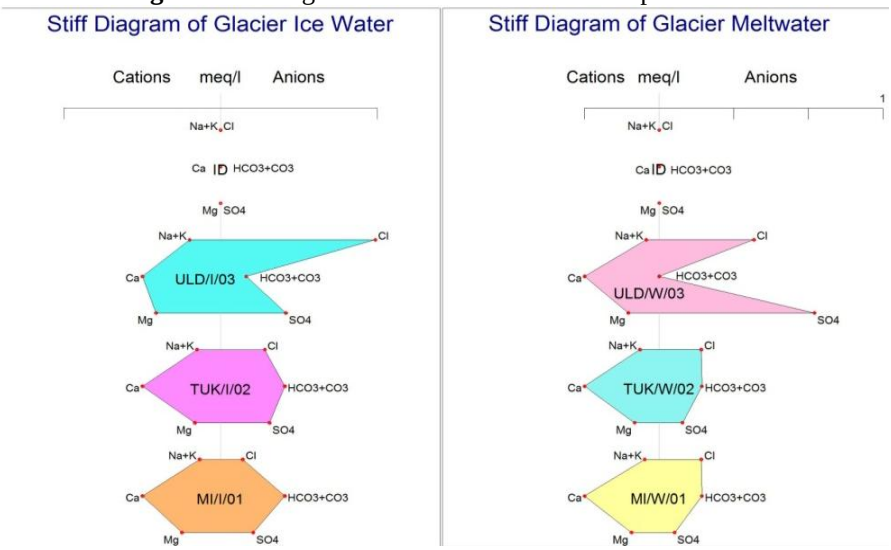
Fig. 2: -Piper Diagram for Major Ions concentration.



Stiff Diagram

Stiff (1951), proposed another technique for presenting chemical analysis data in form of four parallel axis and one vertical axis for representing the chemical analysis data. The procedure proposed by stiff (1951) is such that four cation concentrations are plotted to the left of the vertical axis and four anions to the right, all values are in milli equivalent per liter. Each ion is plotted as a point and the points are connected to form a polygonal shape. The resulting points when connected, form an irregular polygonal pattern. It is relatively simple method of ionic data representation. For better representation of ionic concentrations and distribution of individual ions in samples, all the samples analytical data were plotted in stiff diagram (Fig. 3) with the help of Rockwork software 16version. In this diagram, center vertical axis shows zero value in meq/l and beyond this axis values of cations and anions increases in horizontal axis. This diagram provides a clear representation about ionic concentration values in individual sample. As per the stiff diagram interpretations for Ice and meltwater of Miyar and Tukdung glaciers, the abundance order of cations and anions varies as Ca^{++}> Mg^{++}> Na^{+} + K^{+}, HCO_3^{-} + CO_3^{--}> SO_4^{--}> Cl^{-} in ice and HCO_3^{-} + CO_3^{--}> Cl^{-}> SO_4^{--} in meltwater respectively. The cations distribution in ice and meltwater of Uldhampu glacier is similar like Miyar and Tukdung glaciers but the anionic chemistry of Ice and meltwater varies as Cl^{-}> SO_4^{--}> HCO_3^{-} + CO_3^{--} and SO_4^{--} > Cl^{-} > HCO_3^{-} + CO_3^{--} respectively. In all samples, Calcium and magnesium are dominant cations while bicarbonate, Chloride and sulphate are dominant anions, the dissolution of dominant ions found in ice and meltwater samples confirms possibility of leaching from source rocks (Phyllite, Granite, Gneiss and Phyllite) exposed in the vicinity of streams.

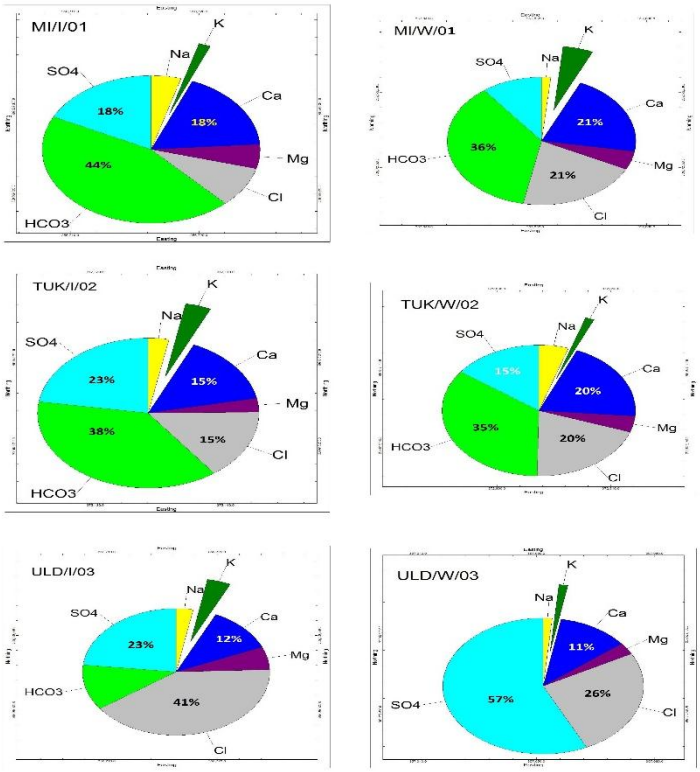
Fig. 3: -Stiff diagram of Ice and Meltwater Samples**.**



Pie Diagram

The Pie chart represent the total ionic concentration ratios of individual cations and anions in water by means of circle. The segments of the circle are indicative of percentage composition in degree (Mohammed Dauda and Garba Abba, 2015). For better schematic representation in form of percentage of ions in individual samples, all the six samples analytical result have been shown in form of pie diagrams in Fig. 5. The percentage wise illustration of ionic concentration by pie diagram shows that HCO_3^-, SO_4^{--}, Ca^{++} and Cl^- are dominant ions in both Ice and meltwater samples of Miyar and Tukdung glaciers. Whereas ionic values in samples of Uldhampu glacier varied as Cl^- (41%), SO_4^{--} (23%) and HCO_3^- (12%) in Ice and SO_4^{--} (57%) and Cl^- (26%) in meltwater.

Fig. 4: -Pie diagram of individual Ice and Meltwater Samples.



Conclusion: -

Hydro-chemistry of Ice and meltwaters of Miyar, Takdung and Uldhampu glaciers, located in Miyar Valley of Lahaul& Spiti district, Himachal Pradesh was studied to ascertain the chemical variation in glacier ice and meltwater, correlation with geology of the area and to determine quarter quality. The analytical result interpretation show that calcium and magnesium are the dominant cations, while bicarbonate is dominant anion followed by Chlorite and Sulphate in glacier Ice and meltwater of Miyar and Takdung glaciers. The Ice and meltwater collected from Uldhampu glacier shows variation in anions concentrations as Cl^-> SO_4^{--}> HCO_3^- + CO_3^{--} and SO_4^{--}> CL^-> HCO_3^-> CO_3^{--} respectively. The dominant ionic concentration in all samples and composition of rock of the study area is matching and confirms their dissolution by chemical weathering from predominant rocks of the area. The comparative study of individual ionic concentration with listed permissible range defined in Bureau of Indian standard (BIS, 2012) for drinking water revealed that Ice and meltwater ofMiyar and Tukdung glaciers are within the permissible range and can be used as potable water. Whereas Ice and meltwater samples of Uldhampu glacier shows acidic in nature (5.64 and 4.00 pH) and hence cannot be used for drinking purpose. The low pH values found in the samples of Uldhampu glacier is probably due toatmospheric contamination of snow with acidic particles may be likely causes of acidic nature of ice.

Acknowledgement: -

Authors are grateful to the ADG & HOD, Geological Survey of India, NR, Lucknow and DDG Mission-IV for their guidance and support throughout the research work and also indebted to Chemical Division, NR, Lucknow for chemical analysis of samples.

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