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Hydrogen and oxygen isotopic analysis of Antarctic lake waters

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New data on the stable oxygen and hydrogen isotopic composition of freshwater lakes of Schirmacher oasis, east Antarctica are presented. Spatial variation of tritium, deuterium and oxygen-18 isotopes in lake waters has been interpreted in terms of their environmental significance. Low levels of tritium indicate no significant input from station activities. Variation in $\delta^{18}O$ and $\delta^{2}H$ values is attributed to difference in relative contribution from glacial cover and fresh snow precipitation.

LAKES are as complex as other natural systems but are often well suited for environmental isotope studies. The only prerequisite is that isotopic variations occur, as a consequence of natural processes, between the various parts of the lake water and/or between the lake water and other waters in the environment. The environmental isotopes which are normally studied for lake water include ^{3}H, ^{2}H, and ^{18}O. With respect to other tracers, isotopes are often more conservative (apart from radioactive decay, which is easy to correct for), and therefore, enable us to separate physical processes from chemical and biological activities which provide sources or sinks for various substances. In particular, the isotopes incorporated into water molecules, i.e. ^{3}H, ^{2}H and ^{18}O are almost ideal tracers to investigate certain lake parameters[1].

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Lake Priyadarshini is one of the larger lakes in the Schirmacher Oasis, east Antarctica (Figure 1) with a total water spread area of about 0.75 sq km. This lake undergoes alternate cycles of seasonal melting (November–February) and freezing (March–October). The lake receives a major inflow from very shallow lakes at the south-western side, namely L3, L4 and L5 (Figure 1). Some minor inflow from the southern end through partially melted lakes was also noticed and so was through melting of fresh ice on valley slopes. After the Lake Priyadarshini is full, it outflows into smaller lakes (F1, F2), which in turn feed the ice shelf. The other important lakes are on the western edge of the Schirmacher oasis (Figure 1), namely Lake 91, Lake 55, Epsilon lake (El) and Epishelf Lake (Ep). The present investigation has involved analysis of tritium, deuterium and oxygen-18 isotopes of water samples collected from freshwater lakes during the XVI Indian Antarctic Expedition (December 1996–March 1997) using Hydrobias depth water sampler. The samples were brought to the Indian Institute of Technology (IIT) Kanpur and were stored in double-valve, air-tight plastic bottles at a cool place. The results of the isotopic analysis carried out at BARC, Mumbai during June–July 1998 have been compared with earlier analyses[2] and interpreted in terms of their environmental significance.

Tritium, a radioactive β-emitter with a half-life of 12.42 years is present in the atmosphere both due to natural (mainly the action of cosmic radiation on the upper layers of the atmosphere) and artificial (thermonuclear explosions) activities. In both the cases, tritium produced is introduced into the stratosphere. From there, it passes to the troposphere. It then takes part in the atmospheric water cycle in the form of HTO molecules and, through precipitation and molecular exchanges at interfaces, enters various reservoirs, oceans, lakes, soil water, groundwater, glaciers, polar ice sheets, etc.[3]. The tritium input to the southern hemisphere is considerably straightforward (through global deposition) and is of lower magnitude (almost one-fourth) with indications of delayed response, which results due to inter-hemispheric transfer time and dilution of tropospheric moisture by oceanic water vapour of significantly lower tritium content[4,5].

Deuterium and oxygen-18 occur in the oceans in concentrations of about 310 ppm and 1990 ppm for the molecular species HDO and $H_2{}^{18}O$, respectively. The universally adopted standard for deuterium and oxygen-18 is V-SMOW (Vienna Standard Mean Ocean Water)[6]. This refers to a hypothetical water whose hydrogen and oxygen isotope ratios are close to the mean isotope ratio of ocean water. When water changes state through condensation or vaporization, an isotopic fractionation occurs because of the difference in vapour pressures and diffusion velocities in air of the different isotopic species of water. Water vapour in equilibrium with liquid

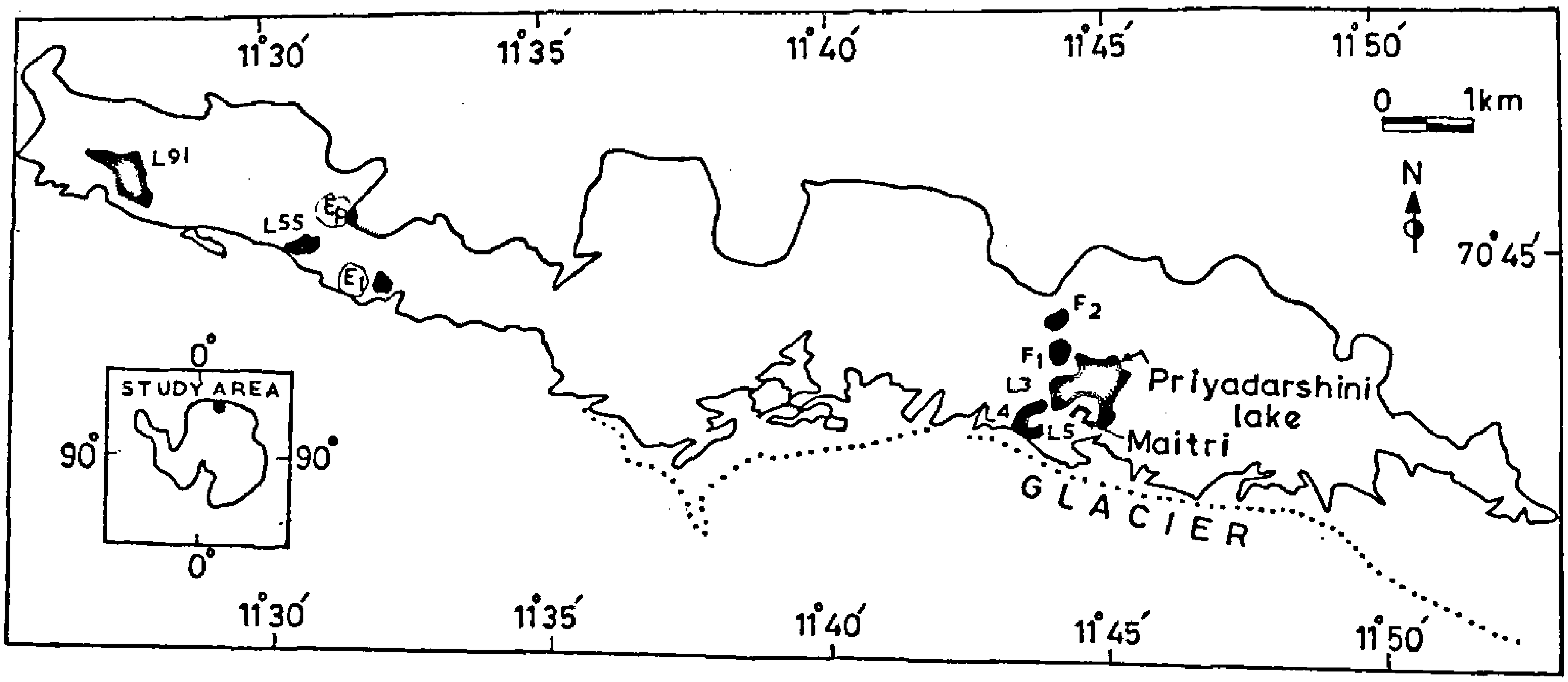

Figure 1. Sampling locations of freshwater lakes in Schirmacher oasis, east Antarctica.

water is depleted in the heavy isotopic species with respect to the liquid phase. The degree of isotopic fractionation is inversely related to temperature. Lakes and open systems have δD and $\delta^{18}O$ values that deviate from the Global Meteoric Water Line (GMWL) because they are subjected to evaporation[7]. Repeated evaporation and condensation lead to progressively lighter isotopic values in the vapour phase.

Antarctica, which occupies the southern polar region, is the natural laboratory and observatory for scientific study of natural phenomena. However, due to a great deal of scientific activities in different stations in Antarctica for the last two decades, there is concern about man-made impact on its environment. Information regarding the present level of tritium is useful in this context. Keeping this objective in mind, freshwater samples from lakes collected during the XVI Indian Antarctic Expedition were analysed for their tritium content using ultra-low level liquid scintillation counting counter (Wallac 1220 Quantulus) with the minimum detection limit of 0.5 TU at sigma level. One sample of snow precipitation was also analysed to compare its tritium level with that in the lake water.

Table 1 shows the tritium concentration of the freshwater samples collected during the expedition from different lakes in the Schirmacher oasis region. In general, the tritium levels of all freshwater lakes measured during the present expedition are extremely low, ranging between 1.9 and 4.2 TU with an average of 3.1 ± 0.5 TU. Minor spatial variations in tritium levels in different lake water samples could also be due to mixing of waters from different sources, i.e. glacier melt, fresh precipitation, etc. Tritium concentration of local fresh snow precipitation near Epsilon lake (5.8 ± 0.6 TU) is slightly higher than the lake waters.

The general range of values of tritium content in lake water corroborates with the expected low range of tritium concentration in the southern hemisphere. Higher tritium concentration in fresh precipitation may be due to the polar effect since the tritium values are known to increase from low to high latitudes. This is clearly seen in the latitudinal distribution of tritium content in monthly precipitation for oceanic (coastal and island) stations of the IAEA/WMO global network[5]. The lakes in the Schirmacher oasis receive waters from glacial melt (old ice) with low tritium values (< 5 TU) and from snow precipitation with high tritium values (5.8 TU). Therefore, the tritium concentration of the lake waters in this region averages around 3.1 TU. It is also confirmed that there is no significant impact on the spatial distribution of tritium levels due to tritium influx or station activities around.

For ^{18}O and ^{2}H analysis, an online prep system (ISOPREP18) and 602 E Auto Mass Spectrometer supplied by VGISOGAS, UK were used. ^{18}O in the samples was measured using the standard procedure[8]. Calibration and reproducibility studies were carried out using IAEA standards. The earlier procedure for ^{2}H analysis was by reduction of water by uranium at 800°C and by measurement of hydrogen gas mass spectrometrically[9]. The procedure used in the present study was the zinc method[10] which is simple and avoids the memory effect inherent in the uranium method. Calibration and reproducibility of ^{2}H measurements were carried out using IAEA standards SMOW, GISP and SLAP[11]. All measurements were expressed with respect to SMOW. The standard deviation of measurement (1 sigma) was 0.1 per mil for oxygen-18 and 0.5 per mil for deuterium.

The results of $\delta^{18}O$ and $\delta^{2}H$ values are listed in Table 1 and plotted as X–Y plot with reference to GMWL in Figure 2. Three clusters of values are clearly distinguished in the

Table 1. ^3H, $\delta^{18}O$ and δ^2H values for lake water samples collected from Schirmacher Range area, east Antarctica

Sample number	Location	Location details	Sampling depth	^3H	$\delta^{18}O$	δ^2H
1	Priyadarshini	Site S1 close to the eastern shore	Surface	–	–26.7	–203.1
2	Priyadarshini	shore	2.5 m	–	–25.68	–201.9
3	Priyadarshini		4.5 m	–	–26.00	–196.3
4	Priyadarshini	Site S3 close to the southern shore	2.5 m	–	–26.18	–202.8
5	Priyadarshini		4.5 m	–	–25.73	–200.7
6	L91	Westernmost edge of Schirmacher oasis	Surface	3.2 ± 0.5	–23.46	–184.4
7	L91	in direct contact with the Continental	2 m	–	–22.2	–175.3
8	L91	shelf	4 m	–	–23.54	–177.2
9	L91		6 m	–	–23.7	–178.0
10			8.5 m	–	–23.76	–176.4
11	L3	Lakes flowing into Priyadarshini;	Surface	2.6 ± 0.5	–29.5	–216.2
12	L4	closer to polar ice cap	Surface	1.9 ± 0.5	–28.32	–208.2
13	L5		Surface	2.9 ± 0.5	–30.75	–222.8
14	L55	Inland lake in western Schirmacher	Surface	3.3 ± 0.5	–30.34	–218.9
15	El	Epsilon-shaped inland lake in western Schirmacher	Surface	3.9 ± 0.5	–28.07	–210.9
16	Ep	Epishelf lake in western Schirmacher fed by Lake 55	Surface	2.5 ± 0.5	–30.1	–217.3
17	F0	Outflow from Lake Priyadarshini	Surface	3.9 ± 0.5	–27.4	–199.2
18	F1	First lake receiving outflow from Lake Priyadarshini	Surface	–	–27.6	–207.3
19	F2	Second lake receiving outflow from Lake Priyadarshini	Surface	4.2 ± 0.5	–27.03	–198.5
20	Snow ppt	Western Schirmacher close to El	–	5.8 ± 0.5	–	–

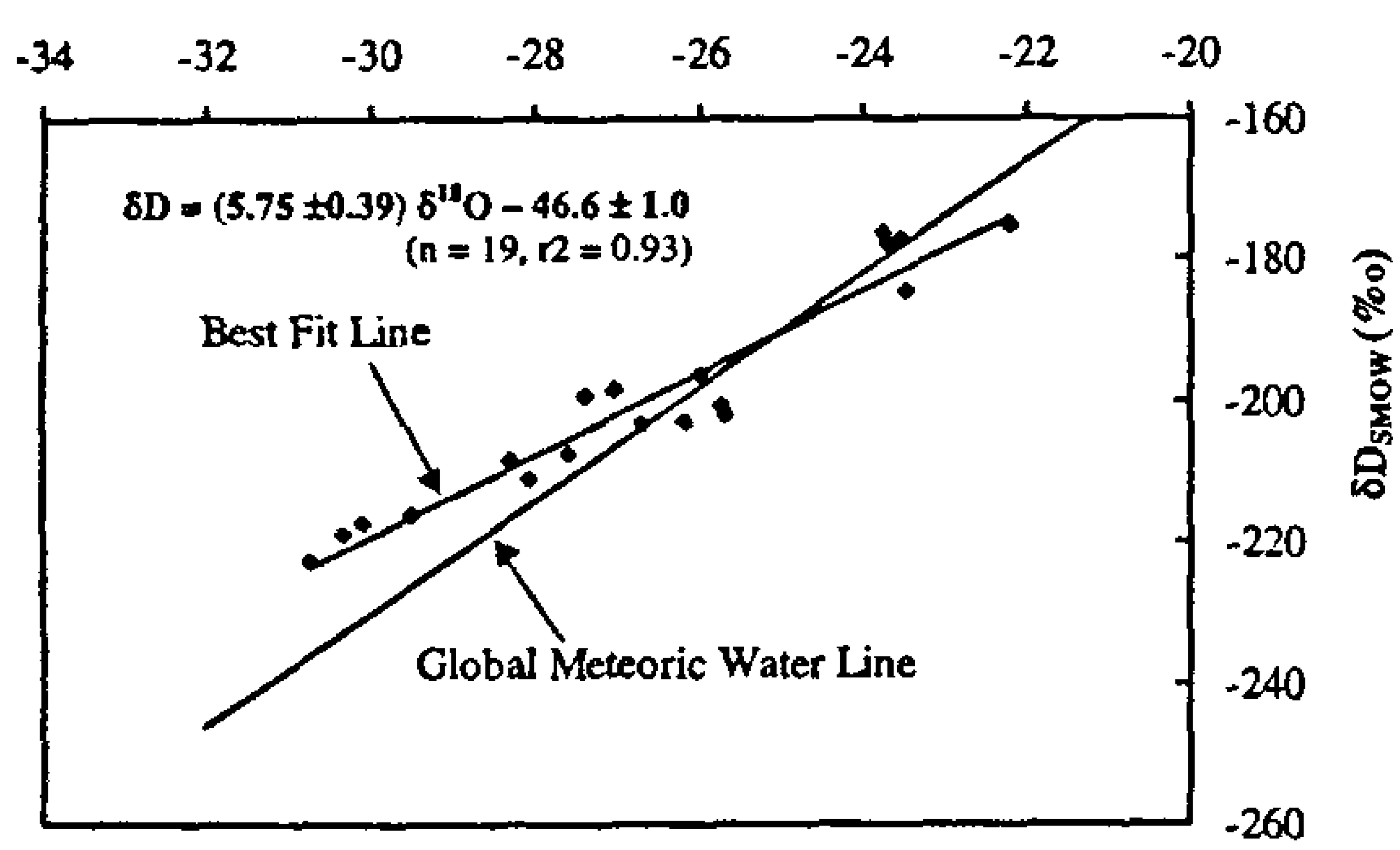

Figure 2. δD-$\delta^{18}O$ plot for freshwater lakes in Schirmacher oasis, east Antarctica.

plot which represent the spatial variation of $\delta^{18}O$ and δ^2H values in the region. These variations are essentially a function of relative contribution from glacier cover (old ice with depleted values) and fresh snow (with enriched values). In the present data set, L3, L5, L55, El show the most depleted values. As can be seen from Figure 1, they are very close to the glacial cover and hence receive glacial melt water. These values also plot above the GMWL and reflect the isotopic signatures of the air mass which was responsible for the formation of the glaciers. A similar trend is also observed in some of the Himalayan rivers, which receive glacial melt waters.

The second cluster of values corresponds to Lake Priyadarshini and its outflows (F0, F1, F2), L4, and Ep. All these lakes are very much inland and have no direct contact with the glacial cover. They are mostly fed by fresh snow precipitation or through melting of relatively younger snow along the valley slopes. Their influence is clearly manifested in slightly enriched values of $\delta^{18}O$.

The most enriched values are, however, shown by Lake 91 samples. This lake is located at the westernmost edge of the Schirmacher oasis and was observed to be in direct contact with the continental shelf area. The enriched values of samples from Lake 91 may be attributed to its hydraulic continuity with the shelf ice where the rate of snow accumulation is fairly high and $\delta^{18}O$ values have also been reported to be enriched (the top of the shallow cores in the shelf area has been reported to have values around –18 to –19 per mil[2]).

Variations are observed within these clusters also. For example, the surface samples from Lake Priyadarshini as well as the samples from Lake 91 are more depleted than the deeper samples. This probably indicates inverse stratification, which is typical of lakes in the Antarctic region. Temperature measurements during the same period in Lake Priyadarshini clearly show that the warmest layer in the lake occurs at around 3 m and not at the surface[12].

Further, although the lakes L3, L4 and L5 are shown as a single lake in the map, they were observed to occur as separate, small pools of water during the low flow period. This may have caused a horizontal stratification in the lake. Differences in $\delta^{18}O$ and δ^2H values may also be caused by variable glacial input into the lake. Similarly, the outflow lakes from Lake Priyadarshini are observed to be more depleted than Lake Priyadarshini, particularly in δ^2H.

The data set presented here establishes the current range of values of ^3H, δ^2H, and $\delta^{18}O$ in lake waters in the Schirmacher oasis region, east Antarctica. Low levels of tritium indicate no human impact and the variations in δ^2H and $\delta^{18}O$ are in close correspondence with the relative contribution of old glacial cover and fresh snow precipitation.

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Spatial and temporal variation in susceptibility of the American bollworm, *Helicoverpa armigera* (Hübner) to *Bacillus thuringiensis* var. *kurstaki* in India

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Studies were carried out to determine the baseline susceptibility of the American bollworm, *Helicoverpa armigera* to *Bacillus thuringiensis* var. *kurstaki* (*B.t.k.*) HD-1 and HD-73 strains for the populations collected from different places in India. The populations from Delhi (field), Raichur (F_1 and F_2) and Bangalore were least susceptible to the toxicity of *B.t.k.* HD-1. On the contrary, the Hyderabad and Madurai populations were most susceptible. *B.t.k.* HD-1 caused neonate mortality of 37.4% at 10 ppm and 68.6% mortality at 100 ppm after 96 h of treatment. Mehna and Nagpur populations were least susceptible to *B.t.k.* HD-73 whereas Guntur, Bapatla, Hyderabad, Madurai and Vijayawada populations were most susceptible. HD-73 caused mortality of 62.3% at 100 ppm and 91.7% at 500 ppm after 96 h of treatment. Temporal variations of insect mortality showed that LC_{50} (96 h) of *B.t.k.* HD-1 increased from 9.47 ppm in October 1998 to 51.04 ppm in December 1998 for the insect population on pigeonpea in Delhi. The baseline susceptibility studies show that there is a possibility of tolerance (resistance) in some populations. These studies are discussed in relation to their importance *vis-à-vis* growing use of *B.t.k.* and future cultivation of *B.t.* transgenic crops in the country.

AMERICAN bollworm, *Helicoverpa armigera* (Hübner) is an important polyphagous pest of cotton and many other crops of agricultural importance all over the world. It causes US $300 million worth of damage in legumes alone every year in India[1]. The total annual damage including all agricultural crops could be nearly US $1 billion. Dai and Guo[2] reported cotton yield loss of more than US $1 billion in China due to *H. armigera* alone during 1992. The pest has become serious with regular outbreaks and has developed resistance to almost all conventional insecticides including synthetic pyrethroids[3]. Therefore, it is natural that integrated pest management tactics including specific resistance management tactics have been advocated to control the pest[4–6]. Some of the management tactics recommend the

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