Re-searching the Land of Penguins: Antarctica
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This article is a narrative describing the activities and valuable experiences of the authors during their 35° Antarctic Expedition. The interest and dedication of Indian scientists who participate in these expeditions every year for the quest of science and excellence is undeterred by the extreme living conditions and hardships faced on the icy continent. In this expedition, the authors conducted extensive surveys for radiation mapping in and around the 'Bharati' station, Antarctica and have collected several samples of water, soil and rock for analysis. These are being probed for their radioactivity content using various analytical techniques. A scientific report based on the outcomes and observations will be published in the near future.

The journey to the southernmost continent
It was a clear sunny morning on November 29, 2015 at Cape Town, South Africa. We were already on cloud nine as we sat inside Ilusion-17 ALCI flight ready to take off for Novo airport in the Schirmarcher Oasis in Antarctica. It was a matter of pride to be among the 150 scientists from different countries across the world, who were off to the Land of Penguins for a purpose. Three hours of flying, and having crossed the 60°S latitude, it was made to dawn on us by the pilot that we were now at the point of no return as we were swiftly heading towards the bottom of the globe!! Leaving all uncertainties behind, geared up in our polar suits, we were about to step on the pristine icy continent, untouched by civilization. Although the landing on the stark white icy runway without a radar system was very smooth, the fear and excitement made us skip our heart beats. The first step on the glistening white ice felt like stepping on the moon!! The landscape looked exceptionally beautiful, the azure sky above and various shades of ice and snow everywhere (Fig.1). The summer here was freezing cold with temperatures of about -10°C. After the initial exuberance of trying to capture the first glimpse of the barren, icy and uninhabited planet in our cameras receded, we had cold feet, literally, thinking of our survival for the next three – four months in this hostile environment of the land beyond this earth.

Indeed, about 98% of the continent is covered with thick ice sheets which were formed 25 million years ago and holds about 75% percent of all fresh water on the Earth. The average thickness of the ice sheet is about 1.9 km with highest being 3.6 km at the poles. If all the ice on this icy continent melts, the sea level will rise by about 60 m! The inner regions of the continent receive an average of 5 cm of precipitation each year, primarily in the form of snow. The piling up of the snow for a million years has made Antarctica a cold desert.

Antarctica, although a 'no man's land', is governed by the Antarctic Treaty adopted in 1961 by twelve countries, which inducted India in 1983 as its fifteenth consultative member. The treaty requires that information among countries be shared openly, the research carried out here is for peaceful, non-commercial purposes, and that no development/testing of weapons takes place. As per Antarctic treaty, the station needs to be manned throughout the year. It has several policies laid out towards conserving the Antarctic environment. Almost 30 countries have constructed about 69 research stations in different parts of Antarctica. The first Indian expedition was led by Dr. S. Z. Qazim in 1982. It was a proud moment when our tricolour was first hoisted in the continent and India established a permanent station in Antarctica. This was a wooden hutment called 'Dakshin Gangotri' established in 1984, which was built on a glacier, which later submerged in

Fig.1: Glistening Antarctic Landscapes
ice. The second Indian station 'Maitri' was commissioned in 1989 and the third 'Bharati' in 2012.

In the past, scientists from BARC have participated in the 8th, 9th and 10th and 29th expeditions for generating baseline data on natural radioactivity in soil and water near the 'Maitri' base. In this 35th expedition, efforts were made to extend these surveys and measurements to the regions around new Indian station named 'Bharati' and various islands around the Larsemann hill region which houses the station. Also, with recent developments in online detectors and communication facilities, it was planned to install Indian environmental Radiation Monitoring System (IERMON) for online gamma radiation monitoring along with other instruments. It is well known that, cosmic radiation is higher at the poles with the neutron fluence being 4-5 times more at the poles than at the equator as reported by UNSCEAR 2000. Therefore, cosmic ray dosimetry was introduced in this expedition.

We were fortunate to be deputed from BARC in this expedition to Bharati station for carrying measurements towards the following objectives:

(i) Gamma and neutron radiation dose measurements at different locations around Bharati station using passive dosimeters,
(ii) Collection of soil and ice samples from different locations around Bharati
(iii) Collection of water samples for Tritium analysis
(iv) Measurement of natural radioactivity levels in the atmosphere due to Radon and Thoron
(v) On-site background gamma spectrometry using portable gamma spectrometer
(vi) Continuous measurement of gamma and neutron dose rate by installing on-line instruments. Training to NCAOR members stationed at Bharati for the day-to-day operation of the instruments and periodic transfer of data to BARC.

The journey to the icy continent begins at National Centre for Antarctic and Oceanic Research (NCAOR), Goa under Ministry of Earth Sciences which organizes these expeditions to Antarctica each year. More than 20 institutes from all over India, participate in the Indian Antarctic Program. The research includes topics ranging from atmospheric, biological, environmental and earth sciences, glaciology to human physiology and medicine. Prior to the expedition, the proposed projects were evaluated by a panel of judges and were shortlisted at NCAOR, Goa. From BARC, project proposal was defended by Dr. A.K. Bakshi, Principal Investigator of the project. Selected candidates undergo stringent medical test at AIIMS and high altitude acclimatization and mountaineering training provided at Auli, Uttarakhand under the guidance of Indo Tibetan Boarder Police (ITBP).

Our batch was warmly welcomed by the Station leader of ‘Maitri’ station at the Novo airport and we boarded the huge tanker-like snow vehicle called “PistenBully” (Fig.2). After a journey of 10 km from the Novo runway, covered in an hour, we were at the Indian station ‘Maitri’. This is situated on the rocky mountainous region in Antarctica called Schirmacher Oasis with Priyadarshini lake, a freshwater lake, as a landmark. The stay at ‘Maitri’ for a few days was a mid-way halt on the way to our final destination ‘Bharati’ station, which is about 3000 km away from “Maitri”. A chartered Basseler plane, with a capacity to carry about 1500 kg load (persons + cargo inclusive) (Fig.3), took about 10 hours to reach Progress runway, built by Russians, near the ‘Bharati’ station. The ride further on snow vehicles and snow scooters, smooth and exuberant, brought us to ‘Bharati’ which looked similar to a space station with the scientists draped in polar clothing weighing 7 kg, almost looking like astronauts!

**Life at Bharati Station**

BARC had participated in the previous Antarctica expeditions with the base station at ‘Maitri’. During this 35th expedition (November, 2015 – February, 2016), we got the opportunity to be stationed at ‘Bharati’ for the first time. Built with a German architecture base, the station comprises of 33 steel containers housing quite a few fully automated systems; most importantly, it can boast of a ‘zero waste discharge’. There is a stark difference between the two Indian stations; while Maitri has the warmth of Indian culture, Bharati is an upgraded version - modern and technologically superior (Fig.4).
Abiding by the mandates of the Antarctica Treaty, Bharati station has an efficient non-polluting waste treatment protocol. The solid waste, including the kitchen waste, is segregated into glass, plastic, paper (duly compacted) and tins. It is packed, sealed in drums and sent back to South Africa via the ship for disposal. The waste water from the kitchen and toilet goes through the waste water treatment process in huge tanks. The sludge is separated, packed and sealed into drums for disposal at South Africa, while the treated water is purified to drinking water quality and discharged into the sea. For drinking and other household purposes, sea water is pumped in for desalination followed by reverse osmosis. Water usage is optimally restricted owing to the high cost of operation of the plant which uses generators running on Aviation Turbine Fuel (ATF).

Discipline and camaraderie are the essential attributes required for harmony at this isolated station and hence a strict code of conduct is to be observed. It is made very clear to the participants during the training sessions at NCAOR, Goa prior to the expedition that there are only two ranks in Antarctica, members and the station leader who is in command of the station. The technical activities started on each day with a mandatory meeting with the station leader sharp at 0900 h. This served a dual purpose, firstly to ensure that all the station members were fine and healthy and secondly, to arrange the logistic support for the scientists to perform their tasks and to discuss routine tasks related to the station operation and maintenance.

The experience at the station was enriching in terms of interpersonal relation-building as well. The fortnightly ‘Galley Duty’ roster would be displayed on the board assigning the daily responsibility for the upkeep and maintenance of the station to a team of two persons. The 24 hours galley duty began at 0600 h by helping the chef prepare breakfast for 50 station members. After breakfast, the daily chores like cleaning of the station, including toilets and bathroom, as well as utensils had to be performed. It was then again time to help the chef for lunch and dinner preparations. The Galley duty ended with two hourly patrolling of the station in the night to monitor and note the readings of station emergency systems such as fire alarms, air circulation control, the generator and other installed automatic systems. In the morning at 0600 h, the charge was then relayed to the next two members listed on the roster. This hectic, energy sapping duty was performed by one and all, irrespective of the rank, including the station leader. Another important activity jointly executed by all was the ‘Shramdaan’ which entailed offloading of cargo/food rations from the ship and uploading the huge drums of waste generated over the year.

It was not all work, though there were ample resources for entertainment. NCAOR has provided sports and fitness facilities like gymnasium, table tennis and chess. There were
special memories of cricket and volleyball played on the concrete helipad, especially of the match when we were unofficial volleyball champions in Antarctica, having beaten both the Chinese and the Russians in the volleyball tournament conducted on the airfield! Yoga sessions were conducted in the mornings along with regular health checkups by the medical doctor. The ‘Entertainment Room’ houses huge LED TV and recliners with a bank of CDs (movies and informative). One could try a hand on the various instruments available such as tabla, harmonium, guitar and drums. An all-religion prayer room resonated with the chant of bhajans and pujas on every Tuesdays. No opportunity of having festivities was missed, with birthdays and wedding anniversaries being celebrated with the ceremonious cake cutting leading to a small entertainment program. It was a special patriotic moment to be celebrating the Republic Day, thousands of miles away from our homeland, by chorus singing of patriotic songs (Fig.5). The warmth and aroma of the Indian station was shared with 150 guests from different stations and countries by way of a lavish meal. The venue for these celebrations was a beautiful lounge overlooking the blue southern ocean, large drifting icebergs and the never setting sun.

We also visited a few nearby stations such as Russian station Novo near Maitri, Chinese station ‘Zongshan’ and Russian station ‘Progress’ near Bharati (Fig.6). The Australian station Davis is as large as a town with over 200 people during summer. It is overwhelming to see the strong feeling of camaraderie among the Antarcitcans, with no differentiation in terms of nationality, culture, colour, caste, creed etc. The Chinese were the friendliest.

Though stationed at the bottom of the earth, we were well connected to the other parts of the globe, thanks to the installed communication systems. Wi-Fi and high speed net connectivity, WhatsApp and Skype ensured that we stayed connected with our near and dear ones by means of voice calling and video chatting, albeit with disturbances. Satellite phones were available with a 20 min time slot per month made available to each member. This was a boon to alleviate the feeling of loneliness and isolation that slowly sets in as the days pass.

Work beyond hardships is worship

Working in Antarctica is a milestone in itself as it requires tremendous determination and grit to work against the odds with limited means and tools. The true spirit of research surfaces, as innovations with available resources are needed at every step to perform the tasks at hand in the very harsh environment.

The unpredictable weather further adds to the hardships. Our instruments, which were to be sent by air cargo to ‘Bharati’ before our arrival, were unfortunately still lying at Maitri Air base. This meant we had to tow them along, making our official cargo weigh a whooping 250 kg! To add to it, one of the two Basseler flights got cancelled causing panic among members to reach Bharati as this was the last flight to Bharati for the season. Now, we had the daunting task of accommodating 10 persons along with instruments such that, restricting the total weight to 1500 kg. As the official instruments could not be compromised on, the Maitri station leader came up with the plan of shifting the instruments from heavy wooden boxes to polystyrene boxes to reduce the weight. We left the spare parts of the instruments at Maitri. The personal suitcases were also done away with by transferring all our belongings to travelling bags provided at Maitri.

After reaching the Bharati station, our most important job was to unpack and install the instruments successfully. Although we had undergone training in Mumbai, we were really anxious, particularly with the installation of online instruments (Fig.7). We installed and linked two environmental radiation monitors (ERM) and started acquiring data. However, thanks to our mentors in BARC, there were no major hurdles and we soon had all the instruments operational. The field work was further made enjoyable and revitalizing, owing to the pristine environment with visibility up to a few kilometers on a sunny day, a resultant of negligible anthropogenic activities.

With very scarce flora and fauna, the place is nearly lifeless giving an eerie feeling. Strong winds and drifting snow greatly
affect visibility. The strong sun and the reflection from white ice causes a white-out condition wherein the objects are devoid of shadows and contrast, at times giving a sense of disorientation. There also looms the danger of getting trapped in the deep crevasses. These perils are well recognized and hence moving out alone is strictly prohibited. It was unfortunate that during our stay, one experienced helicopter pilot from the Australian station fell into a crevasse and succumbed to death as he could not be rescued on time. Therefore, all surveys for collection of radiation data, rock, soil and water samples were carried out in groups. Additionally, members always donned the UV protective glasses, applied protective cream and carried a wireless radio with communication accessibility up to 6-8 km.

Initially, we scanned the area around Bharati station and observed that the gamma radiation levels were about 20 μR/h. However, there was a surge in our excitement when we observed radiation levels of about 50 μR/h on "Bharati Top".

![Fig. 7: Installation of various online instruments in the Laboratory at 'Bharati' station.](image1)

![Fig. 8: Bharati Top having gamma radiation level of about 50 μR/h](image2)

![Fig. 9: Radiation survey showing hotspots with radiation levels of about 200 μR/h](image3)

![Fig. 10: Radiation survey of Bharati Island](image4)
(Fig. 8). Subsequently, as it got unfolded, there were many “hot spots” around the station with radiation levels as high as 200 μR/h (Fig.9) and the survey results were mapped on the Google map as displayed below (Fig.10). We carried instruments such as Neutron REM counter, Tissue Equivalent Proportional Counter (TEPC) for LET measurements, gamma tracer, gamma spectrometer, and indigenous Compact Ariel Radiation Monitoring System (CARMS) for measuring cosmic gamma and neutrons doses. As a part of radiation survey, we went along the frozen southern ocean on snow scooters called “skidoo” with our instruments on the sledge and generator (Fig.11). We surveyed many islands and collected rock, soil and water samples.

Fig.11: Instruments on sledge on sea ice

It was disappointing that even after a month the penguins were elusive, although skuas, snow petrels and seals were commonly spotted. It was quite a disheartening thought to return from the Land Of Penguins without seeing the penguins. As luck would have it, on one sunny day, near Mcleod Island, we spotted four Adelie penguins. These small penguins, were much more charming than the ones generally seen in photographs. They were equally curious but not scared, may be because there are no predators on the land of Antarctica!

In mid-December, the hard sea ice starts melting as the temperatures soar above 0°C. On a less fortunate day, as we were returning back from a survey, our skidoo got stuck in the ice which had thinned down (Fig.12). Since, it was just the beginning of the melting season, only a part of our skidoo got submerged, although our shoes and socks were wet as we vacated the vehicle. We were not very far from the station and could communicate to get help from the logistic team quickly. Thus, a major mishap was averted. From that day onwards, going to the islands along the frozen ocean on skidoo was forbidden. Now, everybody was looking forward for the ship to arrive which would bring helicopters for commuting.

During the initial few days at Bharati station, there were no fresh vegetables and fruits and the chef cooked with frozen vegetables, ready to cook food and pulses. The monotonous food made the members eagerly wait for the Russian ship “Evan Papanin”, hired by NCAOR (Fig.13). The arrival of the ship brings in hope for wintering people and is celebrated with great joy. The ship is the lifeline of our Antarctic stations as it brings gallons of fuel for running the station, and it carries rations for the two stations to enable them to survive the cold months. The ship also brought in two helicopters, one of which was a large KAMOV helicopter used for transporting heavy loads such as huge containers (Fig.14). The helicopters are the means of transport in the summer months and used for providing pick up and drop for the surveying teams based on the GPS locations.

Fig.12: Skidoo mishap caused by onset of melting of snow

Fig.13: The Russian ship “Evan Papanin” - lifeline to our Antarctic stations.

Fig.14: KAMOV helicopter on a helipad in front of 'Bharati' station.
The two Environmental Radiation monitors (ERM), one kept inside the laboratory and the other installed outside the station, developed under Indian Environmental Radiation Monitoring Network (IERMON) was able to send data to BARC through NCAOR server with the help of networking team from NCAOR (arrived by ship) and BARC scientists stationed in Mumbai (Fig.15). It was one of the highlights of our work as the environmental radiation data could be transmitted directly to BARC without any manual intervention. For measurement of radon/thoron concentration, indigenously developed portable Radon monitor, SMART RnDuo was installed inside the lab.

As the sea had melted, venturing to far-off islands was impossible. Once, we got the pick and drop support from the helicopter, we carried out field work on various islands e.g. Fisher, Broknes, Manning and Betts (Fig.16). Betts Island was by far the most beautiful island near Bharati station and the farthest island we had ventured. The southern ocean near Bharati station had by now melted and we could see penguins enjoying on small floating icebergs making loud sounds in the otherwise quiet and serene landscapes. On this very island, we came across a rock with highest gamma exposure rate of more than 700 μR/h (Fig.17). The analysis of the rock samples at BARC has shown that uranium, potassium and considerable amount of thorium got incorporated during the rock formation. According to the plate tectonic theory, over 200 million years ago, Antarctica and India were attached together as a part of the Gondwana and further a part of the supercontinent Pangaea; later the continents split and drifted away. A landmass broke away from Antarctica and joined Asia which we now call India. In that sense, Antarctica is the mother of our motherland. The eastern sea shore of India, which was connected to Antarctica, also possesses higher
Thorium concentration. Is it a mere coincidence that the east coast of India and the area around Bharati station has more thorium deposits or there is something more subtle hidden? Only thorough analysis of rock and soil samples using various analytical techniques will solve the mystery.

We tried to survey as many islands as possible because, with the departure of the ship, the facility of helicopter transport would also be gone. It was an amazing experience to have a breathtaking bird’s eye view of the stunning landscape of Antarctica from a helicopter. We could see the big icebergs with turquoise blue water, seals lazily lying on the ice, raft of penguins drifting slowly and of course, the beautiful majestic Bharati station (Fig. 18 & 19).

There was snowfall and snow drift with strong scary winds. We could barely see up to 5 m. When we contacted the station, the communication section bluntly refused to rescue us by helicopter citing the bad weather conditions and suggested us to “enjoy the Antarctica weather” in jest. Fortunately, the weather improved quickly and everybody was rescued by the helicopter. In fact, India Meteorological Department (IMD) had forewarned about the storm and snowfall but as the sun shone bright, nobody expected such a turn of weather. That day, for sure, all of us realized the importance of IMD in Antarctica and the correctness of their predictions. The weather forecast data for the two Antarctic stations is also available on their official website. Antarctica is called as the land of “Blizzards” during which speeds of the wind can be more than 300 km/h. Even today, we shudder at the thought of being stranded in the bitterly cold and windy conditions. A similar situation is a snow drift with strong winds as shown in a photograph in front of the station (Fig. 20).

It was soon time for our expedition to end. In India, we are accustomed to seeing the sun rising from the east and setting in the west. But here, it revolves around us, just above the horizon! During this stay, we saw sunlight throughout the day except during blizzards and snow fall. Gradually towards mid February, it used to get dark for 2-3 hours. We would see the
sunset and sunrise within a few hours, with the sky turning from orange to crimson and the sun would vanish leaving the Bharatians in the dark. On one particular night, we saw Aurora Australis! It is the flashing of colorful lights in the southern hemisphere. It was a beautiful aurora of green lights (Fig. 21). It was really a magical experience to observe this phenomenon and an apt culmination to our wonderful stay at Bharati.

**BARC’s quest for science**

During the expedition, we set up a radiation monitoring laboratory at Bharati station. Two environmental radiation monitors (ERM), developed under Indian Environmental Radiation Monitoring Network (IERMON) were installed successfully for online gamma monitoring. The detectors are transferring data to BARC server on hourly basis all the way from Antarctica since more than a year now. A REM counter was also installed for continuous cosmic neutron monitoring. The laboratory is still well maintained and more systems were installed during the 36th Antarctica Expedition. An extensive radiation survey was carried out around the Bharati station and on various islands in the 35th and 36th expedition. Quite high exposure rates were observed in some places. A large area of 50 m² in Broknes region recorded exposure rates in the range of 100-150 µR /h due to the presence of rocks called “Progress Granite” as per the geological map of the area. It represents a small high background radiation area. The rocks and soil samples were brought back and are being analyzed to figure out the reason behind the higher exposure rates. Most samples indicate higher thorium than Uranium concentration. This has also been confirmed by radon and thoron emanation studies of these samples carried out in the laboratory. On-line monitoring of radon/ thoron using Smart RnDuo has also shown atmospheric thoron gas concentration to be slightly more than the radon gas concentration though both are less than the world/Indian average. Detailed analysis of the samples is continued.

Antarctica is an out of the world experience! The ice sheets and huge icebergs give you a feeling of being in heaven. Mankind should strive towards saving the continent, its icebergs, penguins and the white landscape. We stayed in Antarctica for only about three and half months and to describe our experience in Antarctica is like, to quote from William Blake,

*To see a World in a Grain of Sand*
*And a Heaven in a Wild Flower,*
*Hold Infinity in the palm of your hand*
*And Eternity in an hour*

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