Ambient air quality studies at different Islands of Larsemann Hills in East Antarctica

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Abstract

Air quality monitoring and impact assessment studies were carried out in Antarctica during the Austral summer season of the 30th Indian Scientific Expedition to Antarctica. Ambient air samples were collected from Bharati Island, Fisher Island, Mcleod Island, Stornes peninsula, and Broknes peninsula to evaluate the quality characteristics. Ambient air was not found to be significantly polluted as per the analytical results at any Island or peninsula during the study period.

Keywords: Air pollution, AAQ, SPM, RSPM, SO_2, NOx, CO

INTRODUCTION

The Larsemann Hills is an ice-free area of approximately 50 km2, located between the Vestfold Hills and the Amery Ice Shelf on the south-eastern coast of Prydz Bay, Princess Elizabeth Land, East Antarctica (69o30'S, 76o19'58" E). It consists of two significant peninsulas (Stornes and Broken), four little peninsulas, and approximately 130 near-shore islands (Stüwe *et al.* 1989). The closest important ice-free areas are the Bølingen Islands (69o31'58" S, 75o42'E) 25 km to the south-west and the Rauer Islands (68 o50'59" S, 77o49'58" E) 60 km to the north-east. A major climatic feature of the Larsemann Hills is the strong katabatic winds that blow from the northeast in summer days. The mean monthly temperature is a little above 0˚C, while winter temperatures are between –15˚C to –40˚C. Precipitation occurs as snow and is unlikely to exceed 200-250 mm water equivalent annually (Verleyen *et al.* 2004). The lakes are susceptible to the physical, chemical, and biological modification within their catchment boundaries. The comparatively benign microclimate and the occurrence of freshwater in summer provide a relatively hospitable environment to support Antarctic life forms. Few bird species like snow petrels, Skuas, Tern, and penguins are present. Seals are the most significant and dominant marine organisms in the vicinity. Mosses and lichens are widely distributed at different islands and peninsulas of Larsemann Hills.

Larsemann hills provide a unique opportunity for studying the environmental impacts of anthropogenic activities near research stations (Gasparon and

Burgess, 2000) of three nations (Australia, China, and Russia) and the new Indian Scientific Base at Bharati Island.

India is presently carrying out scientific research programs on Bharati Island, which lies between Quilty bay and Thala Fjord. This Island is the area separated to its west by Quilty bay and Fisher Island and to its east by Thala Fjord and the Stornes peninsula. Mcleod Island is situated about 2 km north of the Bharati Island.

Problems during Air Monitoring

Antarctica is not an ordinary place to monitor ambient air quality. An observer faces a few severe problems during air quality monitoring. These natural problems are given here:

1. Electricity supply and battery efficiency:

Since there is not any source of electricity in Antarctica, Generators are used to produce electricity during the ambient air quality assessment in the various remote islands/peninsulas. Besides this, batteries (DC) power is permanently reduced while working in Antarctica due to the extreme cold conditions. So, extra batteries and backup generators are required during the air quality assessment in Antarctica.

2. Freezing of Manometer:

Distilled water is generally used in a manometer tube of Respirable Dust Sampler (RDS) during air quality monitoring in everyday workplaces. The level of water should be zero at the start. But in Antarctica, the water level in the manometer tube posed a problem due to freezing. So, an anti-freezing agent (coolant) was used to avoid this problem during the ambient air quality monitoring.

3. Disturbance by wind speed:

Antarctica is a cradle of blizzards and the windiest place in the world. The katabatic winds having high speeds are harmful to Air quality monitoring stations, including RDS. Wind speed can uproot the RDS and disturb the monitoring program. Even filter paper may be damaged due to the wind if not handled with extreme care. Therefore, the RDS was anchored by solid cords with the stone boulders.

4. Freezing of Absorbing solutions:

NaOH and TCM solutions were used in impingers during the ambient air quality monitoring to absorb the NOx and SOx, respectively. However, in

Antarctica, solutions were frozen and bubbling was stopped due to the low temperature. A different method was adopted during the ambient air monitoring to avoid this problem. An ordinary electric bulb was placed inside the LVS near the impingers so that the bubbling in the solutions was not stopped.

Study Area

Monitoring was carried out at various Islands/peninsulas of Larsemann Hills in the summer season during 30th ISEA between November to December in 2010. Parameters like Suspended Particulate Matter (SPM), Respirable Suspended Particulate Matter (RSPM), Sulphur dioxide (SO_2), Oxide of Nitrogen (NO_x) and Carbon Monoxide (CO) were measured. Ambient air quality was monitored at location - latitude 69 24 43.4 S and longitude 76 11 45.0 E at Bharati Island. Total 15 numbers of air sampling were conducted during this period. Monitoring of ambient air quality has been carried out at eight locations simultaneously for SPM, RSPM, SO_2, NO_x and CO for 24 hours for whole study period. Maximum 3 monitoring and minimum 1 monitoring was conducted for air quality at each sampling location. The duration, frequency and parameters to be analyzed are given below:

Table –1: AAQ Monitoring Schedule at Larsemann Hills

S.N.	Parameter	No. of Location	Weeks of Study
1	Suspended Particulate Matter (SPM)	8	5
2	Respirable Suspended Particulate Matter (RSPM)	8	5
3	Sulphur dioxide	8	5
4	Oxides of Nitrogen	8	5
5	Carbon monoxide	8	5
6	VOCs	8	5

METHODOLOGY

Standard procedures (IS: 5182) were adopted for ambient air quality monitoring. Its relevant parts were followed for Respirable Particulate Matter (Part-XXIII), Suspended Particulate Matter (Part-IV), Sulphur dioxide (Part-II), Nitrogen dioxide (Part-VI), and Carbon Monoxide (Part-X) (SIIR, 2010).

RESULT AND DISCUSSION

The air environment is influenced by natural factors as well as anthropogenic activities from continuous scientific work carried out at Larsemann hills by many countries (Burgess *et al.* 1992).

The observed concentration of pollutants has been compared with the latest National Ambient Air Quality Standards notified by MOEF, Govt. of India. The site details of different AAQ sampling locations are given in Table 2.

Table-2: Details of Ambient air quality monitoring Sites at Larsemann Hills (East Antarctica)

Sampling Location	Sampling No.	Latitude	Longitude	Altitude	Date of Monitoring
AAQ-1					
U/S Bharati	1	69°24'26.2"S	76°11'35.0"E	46 m	18-19/12/2010
Island	2	69°24'26.2"S	76°11'35.0"E	46 m	19-20/12/2010
AAQ-2	3	69°24'21.5"S	76°11'24.5"E	35 m	27-28/12/2010
AAQ-3	4	69°24'16.6"S	76°11'42.2"E	22 m	06-07/12/2010
D/S Bharati	5	69°24'16.6"S	76°11'42.2"E	22 m	09-10/12/2010
Island	6	69°24'16.6"S	76°11'42.2"E	22 m	10-11/12/2010
AAQ-4	7	69°22'41.8"S	76°17'59.5"E	62 m	15-16/12/2010
Broknes	8	69°22'41.8"S	76°17'59.5"E	62 m	16-17/12/2010
Peninsula	9	69°22'41.8"S	76°17'59.5"E	62 m	17-18/12/2010
AAQ-5	10	69°23'39.2"S	76°16'16.8"E	97 m	21-22/12/2010
AAQ-6	11	69°25'02.6"S	76°03'35.1"E	103 m	11-12/12/2010
Stornes	12	69°25'02.6"S	76°03'35.1"E	103 m	12-13/12/2010
Peninsula	13	69°25'02.6"S	76°03'35.1"E	103 m	13-14/12/2010
AAQ-7	14	69°21'41.9"S	76°08'05.8"E	51 m	23-24/12/2010
AAQ-8	15	69°24'11.1"S	76°12'01.2"E	10 m	29-30/11/2010

Suspended Particulate Matter in ambient air is the dust retained on glass micro filter paper and in the cyclone. As per the regulatory requirements (NAAQS), the 24-hourly average value of SPM in residential, rural and other areas should not exceed 200 $\mu g/m^3$, while the same for the sensitive area should not exceed 100 $\mu g/m^3$. In 2009 notification SPM was excluded from the list of pollutants to be monitored.

Analytical data (Depicted in Table 3, Table 4, Table 5, Table 6, and Table 7) shows the level of SPM in ambient air at all the eight locations at Bharati Island and adjacent Islands/Peninsulas of Larsemann Hills during the monitoring period. The minimum value of SPM was found as 5 $\mu g/m^3$ at Fisher Island during the monitoring period, while the maximum value was found as 26 $\mu g/m^3$ at the downstream location of Bharati Island. The higher values were found due to the construction and operational activities at Bharati Island. All the values during the entire monitoring period of XXX ISEA were below the prescribed limit of standard for NAAQS.

Table-3: Results of Ambient air quality at Bharati Island (East Antarctica)

Sampling Location	Sampling No.	SPM	RSPM	SOx	NOx	CO	VOCs*	SPM/ RPM (%)
Unit	**-**	**µg/m^3**	**µg/m^3**	**µg/m^3**	**µg/m^3**	**mg/m^3**	**ppm**	**-**
AAQ-1	1	15	7	2.9	13.2	0.7	ND	46
U/S Bharati Island	2	17	8	1.8	9.8	0.9	ND	49
AAQ-2	3	26	12	3.9	15.7	1.2	ND	45
Near Apple Hut	Minimum	15.0	7.0	1.8	9.8	0.7	-	45.0
	Average	19.3	9.0	2.9	12.9	0.9	-	46.7
	Maximum	26.0	12.0	3.9	15.7	1.2	-	49.0
	98th percentile	25.6	11.8	3.9	15.6	1.2	-	48.9
	95th percentile	25.1	11.6	3.8	15.5	1.2	-	48.7
	50th percentile	17.0	8.0	2.9	13.2	0.9	-	46.0
	Std. Deviation	5.9	2.6	1.1	3.0	0.3	-	2.1

Table-4: Results of Ambient air quality at Bharati Island (East Antarctica)

Sampling Location	Sampling No.	SPM	RSPM	SOx	NOx	CO	VOCs*	SPM/ RPM (%)
Unit	**-**	**µg/m^3**	**µg/m^3**	**µg/m^3**	**µg/m^3**	**mg/m^3**	**ppm**	**-**
AAQ-3	4	27	11	4.9	16.5	0.9	ND	40
D/S Bharati Island	5	23	9	4.0	20.3	1.1	ND	41
	6	28	12	5.4	18.9	1.3	ND	42
	Minimum	23.0	9.0	4.0	16.5	0.9	-	40.0
	Average	26.0	10.7	4.8	18.6	1.1	-	41.0
	Maximum	28.0	12.0	5.4	20.3	1.3	-	42.0
	98th percentile	28.0	12.0	5.4	20.3	1.3	-	42.0
	95th percentile	27.9	11.9	5.3	20.2	1.3	-	41.9
	50th percentile	27.0	11.0	4.9	18.9	1.1	-	41.0
	Std. Deviation	2.6	1.5	0.7	1.9	0.2	-	1.0

Table-5: Results of Ambient air quality at Broknes Peninsula at Larsemann Hills.

Sampling Location	Sampling No.	SPM	RSPM	SOx	NOx	CO	VOCs*	SPM/ RPM (%)
Unit	**-**	**µg/m^3**	**µg/m^3**	**µg/m^3**	**µg/m^3**	**mg/m^3**	**ppm**	**-**
AAQ-4	7	9	5	2.1	12.9	1.2	ND	49
Broknes	8	8	5	4.5	10.2	0.9	ND	57
Peninsula	9	8	4	3.6	10.9	1.1	ND	53
	Minimum	8.0	4.0	2.1	10.2	0.9	-	53.0
	Average	8.3	4.7	3.4	11.3	1.1	-	55.0
	Maximum	9.0	5.0	4.5	12.9	1.2	-	57.0
	98th percentile	9.0	5.0	4.4	12.8	1.2	-	56.9
	95th percentile	8.9	5.0	4.4	12.7	1.2	-	56.8
	50th percentile	8.0	5.0	3.6	10.9	1.1	-	55.0
	Std. Deviation	0.6	0.6	1.2	1.4	0.2	-	2.8

Table-6: Results of Ambient air quality at different locations at Larsemann Hills.

Sampling Location	Sampling No.	SPM	RSPM	SOx	NOx	CO	VOCs*	SPM/ RPM (%)
Unit	**-**	**µg/m^3**	**µg/m^3**	**µg/m^3**	**µg/m^3**	**mg/m^3**	**ppm**	**-**
AAQ-5 Fisher	10	5	3	1.9	7.8	0.8	ND	51
AAQ-7 Mcleod	14	8	4	1.6	6.2	0.7	ND	52
AAQ-8 Papanin	15	9	5	4.5	11.1	1.2	ND	56
	Minimum	5.0	3.0	1.6	6.2	0.7	-	51.0
	Average	7.3	4.0	2.7	8.4	0.9	-	53.0
	Maximum	9.0	5.0	4.5	11.1	1.2	-	56.0
	98th percentile	9.0	5.0	4.4	11.0	1.2	-	55.8
	95th percentile	8.9	4.9	4.2	10.8	1.2	-	55.6
	50th percentile	8.0	4.0	1.9	7.8	0.8	-	52.0
	Std. Deviation	2.1	1.0	1.6	2.5	0.3	-	2.6

Table-7: Results of Ambient air quality at Stornes Peninsula at Larsemann Hills.

Sampling Location	Sampling No.	SPM	RSPM	SOx	NOx	CO	VOCs*	SPM/ RPM (%)
Unit	**-**	**µg/m^3**	**µg/m^3**	**µg/m^3**	**µg/m^3**	**mg/m^3**	**ppm**	**-**
AAQ-6	11	6	3	1.3	7.2	0.6	ND	8
Stornes peninsula	12	7	4	1.4	5.6	0.8	ND	55
	13	7	3	1.2	5.2	0.7	ND	48
	Minimum	6.0	3.0	1.2	5.2	0.6	-	48.0
	Average	6.7	3.3	1.3	6.0	0.7	-	50.3
	Maximum	7.0	4.0	1.4	7.2	0.8	-	55.0
	98th percentile	7.0	4.0	1.4	7.1	0.8	-	54.7
	95th percentile	7.0	3.9	1.4	7.0	0.8	-	54.3
	50th percentile	7.0	3.0	1.3	5.6	0.7	-	48.0
	Std. Deviation	0.6	0.6	0.1	1.1	0.1	-	4.0

*[ND- not detected, (*LoD - 0.01 ppm)]*

Respirable Suspended Particulate Matter (RSPM) in ambient air is a dust particle below 10-micron size. These particles were retained on glass micro filter paper after separating the total suspended particulate matter in the cyclone assembly. As per the regulatory requirements (NAAQS), the 24-hourly average value of RSPM in residential and ecologically sensitive areas should not exceed 60 µg/m^3. Analytical data (Depicted in Table 3, Table 4, Table 5, Table 6, and Table 7) shows the level of RSPM in ambient air at Bharati Island and adjacent Islands/Peninsulas of Larsemann Hills. The minimum value of RSPM was found as 3 µg/m^3 at Fisher Island during the monitoring period, while the maximum value was found as 12 µg/m^3 at the downstream location of Bharati Island and near Apple hut. All the values during the entire monitoring period of XXX ISEA were below the prescribed limit of standard for NAAQS.

RSPM is part of the total SPM monitored here. The ratio of RSPM Vs SPM was also tabulated. Data indicates that the RSPM (<10µm) is 40% - 49% of the SPM (<100µm) concentration at Bharati Island, while at other Islands/Peninsulas, the ratio of RPM Vs SPM was found in the range of 48% - 57%.

The presence of SO2 & NOx in the atmosphere indicates human activities. As per the regulatory requirements (NAAQS), the level of both the pollutants Sulfur dioxide as SO2 and Oxides of Nitrogen as NOx should not exceed 20µg/m^3 and 30µg/m^3, respectively (annual average) in case of ecologically sensitive areas. Values on 24 hours basis should not exceed 80µg/m^3 for SO2 & NOx. The 24 hourly average values are presented in Table 3, Table 4, Table 5, Table 6, and Table 7 for SO2 & NOx in the study area. The minimum value of SO2 was found as 1.2 µg/m^3 at Stornes Peninsula, while the maximum value was found as 5.4 µg/m^3 at the downstream location of Bharati Island during the monitoring period. All the results are well below the permissible limits during the monitoring period of 30th ISEA. The minimum value of NOx was found as 5.2 µg/m^3 at Stornes Peninsula during the monitoring period, while the maximum value was found as 20.3 µg/m^3 at the downstream location of Bharati Island. Jones (2001) also presented a similar NOx trend in Antarctica's atmosphere.

The presence of CO in the atmosphere is mainly due to partial combustion or incomplete combustion of fuels. The specified limit of CO in ambient air as per NAAQS-2009 is 2 mg/m^3 on an 8-hourly averaging period in the case of ecologically sensitive areas. Analytical data (Depicted in Table 3, Table 4, Table 5, Table 6, and Table 7) shows that the level of CO was around during the monitoring period. the level of CO was found around as 1.0 mg/m^3, below the prescribed limit of 2 mg/m^3 in NAAQS. Jain et al. (2008) and Kulkarni et al.(2010) observed a similar trend of CO in Antarctica. Volatile organic compounds (VOCs) were not detected at AAQ monitoring locations during the 30th Indian Scientific Expedition to Antarctica in the austral summer.

Conclusion

An environmental study at Larsemann Hills has been carried out to assess the air environment quality at various Islands. There are existing research bases in Australia, Russia, and China, and a skyway operated by Russia. India has also established a new research base in the Larsemann Hills area. The outcome of the analytical work can be concluded that ground-level air pollutants concentrations did not vary much in the monitored area.

Ambient air quality monitoring is continuously required to predict the impacts of any anthropogenic activity on the environment (Sharma et al. 2011). This available baseline data will help predict the particular area's effects and

consequences. The impacts of operations of the Indian Scientific Station in the Larsemann hills can be measured with the help of available data and further continuous study.

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