BARC/1999/E/023

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BHABHA ATOMIC RESEARCH CENTRE

REPORT ON THE PRE-OPERATIONAL ENVIRONMENTAL RADIOLOGICAL AND MICROMETEOROLOGICAL STUDIES AROUND KAIGA ATOMIC POWER PROJECT SITE

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1999

BIBLIOGRAPHIC DESCRIPTION SHEET FOR TECHNICAL REPORT
(as per IS : 9400 - 1980)

01	*Security classification :*	Unclassified
02	*Distribution :*	External
03	*Report status :*	New
04	*Series :*	BARC External
05	*Report type :*	Technical Report
06	*Report No. :*	BARC/1999/E/023
07	*Part No. or Volume No. :*	
08	*Contract No. :*	
10	*Title and subtitle :*	Report on the pre-operational environmental radiological and micrometeorological studies around Kaiga Atomic Power Project site
11	*Collation :*	29 p., 2 figs., 26 tabs.
13	*Project No. :*	
20	*Personal author(s) :*	
21	*Affiliation of author(s) :*	
22	*Corporate author(s) :*	Bhabha Atomic Research Centre, Mumbai - 400 085
23	*Originating unit :*	Health Physics Division, BARC, Mumbai
24	*Sponsor(s) Name :*	Department of Atomic Energy
	Type :	Government

Contd... (ii)

30	*Date of submission :*	August 1999
31	*Publication/Issue date :*	August 1999
40	*Publisher/Distributor :*	Head, Library and Information Services Division, Bhabha Atomic Research Centre, Mumbai
42	*Form of distribution :*	Hard copy
50	*Language of text :*	English
51	*Language of summary :*	English
52	*No. of references :*	4 refs.
53	*Gives data on :*	
60	*Abstract :* This report presents a summary of the results of preoperational environmental radiological and micrometeorological studies carried out during the year 1992, 1993, 1995, 1998 and 1999. Baseline radioactivity levels in Kaiga environment originating from ^{137}Cs, ^{90}Sr and natural radionuclides are given. Micro-meteorological data includes that from SODAR, tower and surface instruments. The data is compared with that observed at other NPP sites in the country.	
70	*Keywords/Descriptors :* CESIUM 137; STRONTIUM 90; KAIGA-1 REACTOR; KAIGA-2 REACTOR; SITE CHARACTERIZATION; ENVIRONMENT; ENVIRONMENTAL IMPACTS; BACKGROUND RADIATION; RADIUM 226; THORIUM 232; POTASSIUM 40; NATURAL RADIOACTIVITY; BASELINE ECOLOGY; METEOROLOGY; SOILS	
71	*INIS Subject Category*: B3140	
99	*Supplementary elements :*	

SUMMARY

This report presents a summary of the results of preoperational environmental radiological and micro-meteorological studies carried out during the year 1992, 1993, 1995, 1998 & 1999. Baseline radioactivity levels in Kaiga environment originating from Cs-137, Sr-90 and natural radionuclides are given. Micro-meteorological data includes that from SODAR, tower and surface instruments. The data is compared with that observed at other NPP Sites in the country.

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REPORT ON THE PRE-OPERATIONAL ENVIRONMENTAL RADIOLOGICAL AND MICROMETEOROLOGICAL STUDIES AROUND KAIGA ATOMIC POWER PROJECT SITE

1.0 INTRODUCTION

In all industrial development programs in the country, environmental monitoring has now assumed importance and statutory regulations have been established. Department of Atomic Energy has played a leading role in environmental monitoring and has set examples to other industries. Environmental Radiological Laboratories are set up near all major nuclear sites across the country under Health Physics Division, Bhabha Atomic Research Centre (BARC). An Environmental Radiological Laboratory (ERL) is established near Kaiga Atomic Power Project site also to carry out the environmental surveillance of this area.

2.0 SITE DESCRIPTION

2.1 Location

The Kaiga Project site (Latitude :14.86° and Longitude:74.44°), located about 58 km (by road) east of the coastal town Karwar in the state of Karnataka, is in the valley of Kali river which originates from the Western Ghats and joins Arabian sea at Karwar **(Fig-1)** . The site is on the left bank of fresh water Kadra Reservoir formed on Kali River, constructed recently, about 11 km down stream of the site.

2.2 Land and water use

In general, the area is hilly. Evergreen reserved forests cover most of the area around the site. A small fraction of the land is used for agricultural purpose. In view of the evergreen forest surrounding this area ecological study pertaining to this area is very important.

Major water bodies present in this area are Kadra reservoir and Kali River. Presently there is no major fishing activity in the Kadra reservoir recently formed and reservoir and fisheries have not stabilized. Major source of drinking water to the villages is well water. Drinking water for Project Township is taken from River Kali, downstream of Kadra reservoir. Down stream of the reservoir, Kali River waters are used for small-scale fishing.

2.3 Population Distribution

The site is sparsely populated. The power station complex has an exclusion zone of 2.3 km, under its full administrative control, where no public habitation exists. The population data of 15 km radius zone, based on 1991 census data, is shown in **Table-1**. However, consequent to the formation of Kadra dam, submergence of some villages has taken place resulting in the redistribution of population.

3.0 PLANT DESCRIPTION AND EFFLUENT MANAGEMENT

Six units of 220 MW(e), Pressurised Heavy Water (PHWR) type power plants are proposed to be built up at Kaiga site. The first two units are in advance stage of construction and commissioning. Once through cooling system is adopted for the condenser cooling of the power plant. The water after passing through the condenser is carried through an open channel and released back into Kadra reservoir at a location 2 km down stream of the intake through an out fall structure. Sufficient precaution is taken to minimize the release of radioactivity through the effluents. Liquid effluents are treated and activity is estimated and ensured to be within the limits prescribed by regulatory authorities. Most likely radionuclide that may get released is tritium.

Gaseous effluents from the plant are filtered through High Efficiency Particulate (HEPA) filters and released through a 100 m high stack. Radioactivity release through stack is also continuously monitored to ensure the compliance of regulatory release limit requirements.

4.0 OBJECTIVES OF ENVIRONMENTAL SURVEY PROGRAMME

The primary aim of the Environmental Radiological Laboratory (ERL) is to demonstrate that radiation exposure received by the members of the public due to the operations at nuclear plant is well within the limits prescribed by national regulatory body. First step involved in this process is a detailed pre-operational survey:

1. To establish the baseline radioactivity levels of this environment
2. To collect data related to the characteristics of atmospheric, aquatic and terrestrial environment.
3. To collect data related to the population distribution and public utilisation of aquatic, terrestrial and atmospheric environment.

Vast data of meteorological parameters of the site is collected at this stage to understand the dilution and dispersion characteristics of the atmosphere. Levels of natural and fallout radioactivity in environment are established. The data from the pre-operational survey is utilised to identify the potential pathways of exposure and to identify the places and the type and frequency of samples to be collected during the operational stage. During operational stage, environmental samples are collected and analysed from pre-determined locations at predecided frequencies. The annual intake of radioactivity is assessed and its associated internal radiological exposure to the members of the public is calculated as per the standard procedures.

5.0 PRE-OPERATIONAL SURVEY AT KAIGA

Pre-operational survey for the baseline radioactivity levels in aquatic and terrestrial environment of Kaiga site have been undertaken since 1992 by Health Physics Division, BARC, Mumbai.[1] Samples of water, soil, vegetation and crops from Kaiga site were collected and analysed at BARC, Mumbai. This forms the preliminary pre-operational survey. In 1993, a Met. Station was commissioned at Kaiga site to study the atmospheric dispersion characteristics. In 1998, a full-fledged Environmental Radiological Laboratory (ERL) was established at Kaiga. Consequent to

this, a detailed pre-operational baseline radioactivity measurement covering an area of 30 km around the site in Kaiga environment was carried out at ERL, Kaiga.

5.1 Results of Preliminary Survey

The preliminary survey was carried out in winter season of 1992 and summer season of 1993[2]. The survey covered mostly locations within 15 km and a few locations upto 30 km from the plant site. In addition to background radiation survey, limited number of environmental samples such as air particulates (12), fresh water (10), seawater (2), soil (21), vegetation/crops/fruits (10) and aquatic organisms (6) were analysed. The samples were analysed for Gross α, Gross β, ^{137}Cs, ^{90}Sr, ^{226}Ra, ^{232}Th, ^{40}K, etc as the case may be. Some water samples were analysed for ^{3}H also. The results of the preliminary survey carried out during the period from 1992-93 are shown in **Tables 2 to 10.** Some more water samples were collected during 1995 and 1999 and analysed for ^{3}H, the results are shown in **Table 11(A) & 11(B).**

5.2 Results of Meteorological measurements

Meteorological measurement programme to study the atmospheric dispersion characteristics at Kaiga site was initiated in the year 1993. A Doppler **SODAR** (Sound Detection and Ranging), a remote sensing device, was commissioned and is being continuously operated at the site since 1993. The SODAR output consists of vertical profiles of wind speed, wind direction and status of atmospheric stability. In addition to the SODAR, five numbers of 16 m high meteorological towers equipped with wind measuring systems were used to record meteorological measurements at different locations within the site.

Presently, Micro-meteorological Laboratory (MML) have a 16 m tower (A), and SODAR at Kaiga village which is about 2 km away from the site and a 21 m tower (C) is located within the plant site boundary.

Figure- 2 shows typical annual wind roses based on the data from SODAR and Met. Towers A and C. A characteristic feature of this site is the very high frequencies of calm conditions at lower heights due to hilly terrain surrounding the site. It is very clear that, upto 100 m height, prominent wind directions are WSW, WNW and W and other winds are considerably cut off due to high hills around. However at and above 200 m, other winds such as ENE and E were also observed. The Tower C, located within the site boundary, also shows a wind pattern comparable with that of 200 m and above SODAR data, though the tower height is only 21 m. This leads to the conclusion that the wind pattern in plant site boundary differ, particularly at lower heights, from that observed in the present MMLab Hence wind data from present MMLab location would not be a fully representative data for the assessment of atmospheric distribution of gaseous effluent released from the stack, which is located within the site boundary. This effect may be resulting from the differences in the topography of the two locations. In order to get the wind data representative to the site, it is proposed to shift the SODAR facility and MM Lab to an appropriate place within the site boundary. In addition to SODAR, it is proposed to have a 60 m tower also at this site. However, representative data from 21 m Tower was used for the preliminary calculation of atmospheric dispersion factors.

The data of temperature, atmospheric pressure and humidity measured at Met. Lab are shown in **Table-12-14.** Average monthly rainfall data for the period 1996 -98 are given in **Table -15.**

5.3 Results Of Detailed Survey by ERL, Kaiga

Consequent to the establishment of the Environmental Radiological Laboratory, at Kaiga Township, in 1998, a detailed pre-operational survey of this area was initiated at the site. The villages covered in this survey are indicated in **Figure.1.** The results of this survey are described below.

5.3.1 Natural Radiation Background

From 1989 onwards, Thermo-luminiscent dosimeters (TLD) supplied by EAD, BARC were used to assess external radiation levels due to natural radioactivity. Average radiation background observed during the period 1987 to 1997 is shown in **Table- 16.** During this period a limited number of TLDs covering the exclusion zone and the Township were only put. From 1998 onwards, an extensive background measurement using environmental TLDs covering an area up to 30 km around the site was carried out. The results observed are shown in **Table-17.** Background dose rate measurements in these locations were also carried out with the highly sensitive radiation survey meters. Exposure rates observed are also shown in Table –17.

5.3.2 Measurement of baseline activity levels

The baseline activity levels of fallout radionuclides in the aquatic and terrestrial environmental components were estimated.

Following types of samples were collected from the environment.

1. Air,
2. Soil and Sediment,
3. Lake water, River water, Well water and Sea water.
4. Leaves, Vegetables, Fruits.
5. Fish, Meat and Egg.
6. Cereals, Pulses and Nuts.

The type and number of samples collected and analysed for pre-operational survey are shown in **Table-18.**

5.3.2.1 Air samples

Air samples from ERL premises were collected using high volume air sampler. After allowing one-week decay, long lived gross α and gross β activities of air particulates were measured by ZnS scintillation counting system and Low Background Beta counting system respectively. The results are shown in **Table-19.**

5.3.2.2 Aquatic environment

The liquid effluents from plant, after passing through a 2 km long open channel will be discharged into Kadra reservoir. Kadra reservoir and down stream waters are of main concern for aquatic monitoring. Well water is the major source of drinking water in the villages. Downstream of Kali River up to and including Karwar Sea is used for fishing. The results of estimation fallout levels of ^{137}Cs and ^{90}Sr in water samples are shown in **Table-20.** In the case of water samples, ^{137}Cs and ^{90}Sr baseline activity levels are comparable with that reported at other sites.[2,3]

Sediment and fish samples collected from different water bodies were analysed for ^{137}Cs and ^{90}Sr and the results are shown in **Table- 21.** Some typical water samples were also analysed for the water quality parameters such as Total Dissolved Solids (TDS) and Alkalinity. The results are shown in **Table-22.**

5.3.2.3 Terrestrial environment

Soil and vegetation (mainly leaves) samples were analysed for 137Cs and ^{90}Sr. Other edible samples such as vegetables, milk, cereals, meat and composite diet etc. were also analysed. The results are shown in **Table-23.** Geometric Mean values for ^{137}Cs and ^{90}Sr observed in terrestrial samples of Kaiga are comparable with that reported for similar samples at Narora. However ^{137}Cs values for soil and vegetation from Kaiga environment is slightly higher than that reported at Narora[3]. Wild variety of non-edible type vegetation locally known as congress leaves (local name) was found to be picking up maximum ^{137}Cs. Higher values of ^{137}Cs in the soil was observed in coastal Karnataka by other workers also [4].

5.3.2.4 Natural radioactivity levels in terrestrial samples

Some terrestrial samples were analysed for ^{40}K activity. A well type NaI (Tl) detector coupled to a Multi-channel Analyser was used for this purpose. The results are shown in **Table- 24.**

5.3.3 Indicator organism

From the study of Table-23 and 24, it is very clear that leaves are picking up more ^{40}K as well as ^{137}Cs compared to other terrestrial samples. In general wild plants are found to contain more fallout activity as compared to those grown in controlled soil. Amongst the leaf samples analysed in the present survey, one wild plant namely Congress leaf (common name) was found to contain maximum ^{137}Cs activity. Investigation on the other parameters affecting the ^{137}Cs pick up from the soil by the plants is in progress. This will help in the identification of an indicator organism.

5.4 Internal Body Radioactivity Measurement

A shadow shield Whole Body Counting system was commissioned at ERL, Kaiga. 330 staff members of Operation & Maintenance Section of the Project were subjected to Whole Body Counting to assess their pre-operational levels of internal contamination at Kaiga Atomic Power Station. The results of the measurements for ^{137}Cs and ^{60}Co are shown in **Table 25.**

6.0 SAMPLING PROGRAM FOR THE OPERATIONAL PHASE

The following factors were considered while reaching a suitable sampling program during operational phase.

1. In the case of atmospheric discharge, the most affected sectors are D, E, F, L and M. Some of the villages in these sectors are not easily accessible and some villages are sparsely populated, in such cases, samples from nearest accessible areas are proposed to be collected. With respect to land use, the main population centres, on both sides of Kali River (M and N sectors) are selected for sampling the different environmental matrices.
2. The main aquatic discharge is to the Kadra Lake. The drinking water source to the Kaiga Township is from Kali River very near to the outfall of the reservoir. In general, wells are the major source of drinking water for surrounding villages.

Based on the above observations, an annual sampling programme for operational phase is drawn and details are shown in **TABLE-26.**

7.0 CONCLUSION

Pre-operational survey of Radiological and Meteorological aspects of Kaiga site was carried out. Results of detailed radiological survey indicates that baseline activity levels due to ^{137}Cs and ^{90}Sr in edible samples are comparable with that elsewhere. Baseline activity of ^{137}Cs in soil and wild non-edible varieties of vegetation was found to be slightly higher than that reported in other NPP sites. Meteorological survey with SODAR and Tower instruments indicates high frequencies of calm conditions and major wind flow is through the channel made by river valley.

8. ACKNOWLEDGEMENT

Guidance from Dr.U.C.Mishra, Director, H. S. & E Group, in completion of the work is gratefully acknowledged. The continuous encouragement and constant support from Shri S.Krishnamony, Ex.Head, HPD, Shri V.K.Gupta, Head, HPD and Shri M. Sundaram, Head, PPSS, HPD, were the driving force for the completion of this work. Valuable suggestions and constant support received from Shri.V.K.Sharma, Project Director and Shri.N.Rajasabai, Station Director, Kaiga Project are gratefully acknowledged.

9.0 REFERENCES

1. Preliminary Pre-operational Environmental Radioactivity and Radiation Measurements around Kaiga Atomic Power Station site., Kamala Rudran et al., BARC, 1994.
2. Environmental Radiation Measurements around Madras Atomic Power Station (MAPS) Site, BARC/1995/I/009
3. Environmental Radiation Measurements around Narora Atomic Power Station (NAPS) Site, BARC/1995/I/010
4. Distribution of Natural and Artificial Radioactivity Components in the Environs Coastal Karnataka, Kaiga. K. Siddappa, K.M Balakrishna, A.P Radhakrishna, H.M Somashekarappa and Y. Narayana, Mangalore University-1994.

Table -1

Population Distribution Around Kaiga Site (Within 15 km - 1991 Census)

PLACE	SECTOR	POPULATION
AMBAGAON	E	183
ANSHI	P	615
BALEMANE	A	221
BARBALLI	C	84
BARE -SOUTH	F	645
BARE-NORTH	F	90
BENADAGALLI	G	130
BIRKOL	C	1,211
BIGAR	D	221
DEVKAR	D	831
GOTEGALLI	N	556
GULE	L	121
HARTUGA	L	1,162
HEGARNIKOTEBAVI	K	23
HONNAGUDDE	E	207
JOGLEPAL	E	24
KATTINAHAKKAL	H	315
KANNUR	E	78
KALACHE	D	1,422
KODTHALLI	C	84
KODASALLI	D	305
KODLAGGADE	E	847
KUCHEGAR	M	145
KAIGA	H	216
KADRA	N	2,877
MALLAPUR	M	1,497
MALLANI	J	28
MARUGADDE	I	129
MAVINAMANE-I	E	865
MAVINAMANE-II	F	115
MAVINAMANE-III	G	489
MARAHALLI	H	166
SHIRVE	M	329
SHKALITURLI	K	17
SHEVEGALLI	J	59
SUNKSAL	G	848
TARGAR	D	187
TULSAGERI	B	6
VARJARALLI	E	558
VIRJE	N	1,747

Table-2

Results of External Radiation Background Measurements Around Kaiga Atomic Power Project Site using Scintillometer.

Location	Radial distance (km)	Directional detail	Radiation levels (μSv/h)	
			1993	1992
Kaiga site	0-5	-	0.045	0.045
Hartuga	0-5	W	0.045	0.055
Kaiga village (Sodar Lab)	0-5	WSW	0.035	-
Balemane	5-8	N	0.045	0.045
Devkar	5-8	ENE	0.035	0.040
Bare	5-8	ESE	0.035	0.055
Harur	5-8	SE	0.045	-
Dasanalli	5-8	WNW	0.035	-
Kadra	8-16	WNW	0.035	0.055
Kuchegar	8-16	W	0.045	0.060
Mallapur	8-16	WNW	0.035	0.050
Sulgeri	8-16	NE	0.035	0.055
Ulvi	8-16	NNE	0.055	0.085
Anshi	8-16	NNW	0.055	0.055
Kodasalli	8-16	ENE	0.045	0.045
Basal	8-16	E	0.035	-
Ankola	16-32	SSW	0.045	0.050
Agsur	16-32	SSW	0.035	-
Hebbul	16-32	SSE	0.035	-
Kinnar	16-32	W	0.045	-
Asnotti	16-32	W	0.045	-
Arbail(Plane)	16-32	E	0.055	-
Arabail(Hills)	16-32	E	0.130	0.120
Telangeri	16-32	ENE	0.075	-
Vajrahalli	16-32	E	0.060	-
Idugundi	16-32	ENE	0.055	-
Yellapur	16-32	ENE	0.060	-

Table-3

Radiation Level in Karwar beach and Town Area
(Survey conducted during the 17-21 May 1993)

Sr. no	Location	Radiation Level (μSv/h)
1	Outside NPC guest house	0.035
2	Near sea, Opposite Guesthouse	0.045
3	Outside Marine Biological Lab	0.035
4	Near sea, opposite MB Lab	0.035
5	Kodibag ferry point	0.055
6	Middle of Karwar Beach	0.030
7	Near Children's Park (beach)	0.025
8	Beach near Sadashivgad	0.030
9	Near sea at Sadashivgad	0.060
10	Rocky areas at Sadashivgad	0.060
11	Near temple at Sadashivgad	0.035
12	Shirwad Railway station, Karwar.	0.045
13	Near NPC ware-house at Shirwad.	0.070

Table-4

Long-lived Air Particulate Radioactivity Level in Kaiga Environment

Location	Gross α activity (mBq/m³)		Gross β activity (mBq/m³)	
	1993	1992	1993	1992
Kodibag	0.7±0.4(2)	-	18±5(2)	
Kaiga site	0.6±0.4(2)	0.13±0.07(2)	12±6.5(2)	5.6±0.8(2)

Figures in bracket indicate number of samples. Air volume for each sample =4.8m^3

Table-5

Radioactivity Content of Water Samples

Location	Gross Alpha mBq/l		Gross Beta mBq/l		Cs-137 mBq/l		Sr-90 mBq/l
	1993	1992	1993	1992	1993	1992	1993
Kodibag, Sea water	-	-	-	-	59±19	<12	<19.5
Sukeri Backwaters	-	-	-	-	69±11	<12	<19.5
Kaiga River water	<1.7	<3.29	69±31	19±6	25±6	<12	<19.5
Kodasalli river water	<1.7	<3.29	<35	39±8	16±6	<12	<19.5
Kadra River water	<1.7	<3.29	<35	14.6±5	27±6	<12	-
Virje Bore-well water	<1.7	<3.29	-	45 ±32	19±6	<12	<19.5
Ulvi Bore-well water	-	<3.29	<35	13±5	19±6	<12	<19.5
Bare Bore-well water	<1.7	<3.29	<35	17±7	13±6	<12	<19.5
Kaiga Bore-well water	<1.7	<3.29	<35	-	<10	<12	<19.5

Table-6

Radioactivity in Soils from Kaiga Environment (Bq/kg dry wt)

Location	Gross α*		Gross β		Cs -137	Sr-90
	1993	1992	1993	1992	1993	1993
Kodibag	-	-	1022±300	-	<1.2	4.8±1.6
Kinnar	11.8±0.9	-	1382±318	-	7.0±0.4	7.6±1.8
Kuchegar	11.1± 0.7	-	763±284	-	2.2±0.4	3±1
Devkar	12.7±0.9	14±2	753±290	630±90	2.4±0.4	3±1
SODAR Facility	10.1± 0.7	-	<360	-	<1.2	6.4±1.6
Sulgeri	14.9± 10	-	865±299	-	13.3±0.4	5.7±1.9
Balemane	8.6± 0.8	12±2	408±178	340±50	<1.2	2.4±1.6
ERL site	22.1± 1.4	-	578±302	-	6.3±0.4	5.4±1.6
Virje	9.4± 0.8	30±3	<360	610±80	11.1±0.4	-
Anshi	16± 1.0	-	1022±301	-	21.5±0.7	4.1±1.5
Ulvi	-	36±3.7	393±289	840±70	25.5±0.3	3.6±1.4
Bare	22±1.1	23±3	797±298	840±80	11.8±0.4	2.6±1.4
Arbail	23.7±1.6	-	<360	-	4.1±0.4	4.2±1.5
Hartuga	7.3±0.7	31±3	590± 274	420± 60	5.9± 0.4	3.4± 1.3

Notes:*Excluding Uranium and Radium.

Table-7
Natural Radioactivity in Soil (Bq/kg. dry wt) During 1993

Location	Ra-226	Th-232	K-40
1. Kodibag	<4.1	11.1±0.7	360±20
2. Kinnar	5.2±1.5	21.5±1.1	520±23
3. Kuchegar	7.4±0.8	19.6±0.7	394±23
4. Devkar	4.4±1.1	26.3±0.7	490±26
5. SODAR Facility	19.2±1.1	19.6±0.7	360±27
6. Sulgeri	<4.1	15.9±1.1	526±27
7. Balemane	8.5±1.5	15.9±1.1	360±20
8. ERL site	<4.1	21.8±1.1	370±22
9. Virje	22.0±0.7	10±0.4	240±22
10. Anshi	18.0±1.5	30.3±1.1	530±24
11. Ulvi	44.0±1.9	59.2±1.5	420±22
12. Bare	16.3±0.7	22.9±0.7	370±23
13. Arbail	1.8±1.1	30.3±0.7	470±23
14. Hartuga	22.2±0.7	21.5±0.7	280±21

Table-8
Radioactivity in Samples of Plant Origin During 1992 (Bq/kg. wet wt)

Sample Description	Location	Gross Beta	Cs-137
Dry grass	Virje	6.6±3.4	2.1±0.01
Dry grass	Balemane	11.2±0.24	4.02±0.01
Aerecanut (Tender)	Kuchegar	100±27	2±1.5
Aerecanut (Ripe)	Kuchegar	125±18	2±1.6

Table-9
Radioactivity Levels in Vegetables/ Fruits/ Crops During 1993 (Bq/kg wet wt)

Sample Description	Location	Gross α	Gross β	Cs-137	K-40	Sr-90
Cinnamon Leaves	Bare	0.14±0.1	<360	6.2±1.2	150±25	<2.0
Lemon leaves	Devkar	1.65±0.3	321±129	1.8±0.9	180±20	<2.0
Bamboo leaves	Balemane	0.48±0.2	341±103	12.5±1.3	300±32	<2.0
Cashew fruit	Harur	<0.05	<360	0.86±0.19	38±4	<2.0
Karavanda fruit	Kinnar	0.37±0.08	<360	0.96±0.4	87±8	<2.0
Nerala fruit	Kinnar	-	-	2.8±0.4	36±8	3.0±2.2
Brinjal	Mallapur	<0.05	110±26	<0.05	100±6.6	-
Rice Husk (Dry)	Sulgeri	-	-	13±6.6	333±132	-

Table-10
Radioactivity in Aquatic Organisms During 1993 (Bq/kg. wet wt)

Sample Type (Local Name)	Location	Gross α	Gross β	Sr-90	Cs-137	K-40
Sardinella Fimbriata (pedi) Marine fish	Kodibag	0.25±0.25	<50	1.8±0.5	<0.5	10.5±0.4
Mugil Cephalus (Shewate) Esturine fish	Sunkeri	0.5±0.3	<50	0.7±0.4	0.8±0.3	45.5±5.8
Scylla Serrata (kali kurli) Esturine crab	Sunkeri	2.1±0.4	<50	0.5±0.2	0.3±0.1	21.4±2.5
Crassostria madrasensis (kalva) Esturine (Oyster near shore)	Sunkeri	1.7±0.4	<50	<0.44	0.5±0.1	0.9±0.2
Kaleri, River fish	Ulga	0.3±0.2	100±77	<0.44	0.84±0.6	106±12
Piditol River fish	Ulga	0.2±0.2	69±59	<0.44	2.3±0.5	39.8±10

Table –11(A)
Results of ^{3}H Analysis of Water Collected During 1993 & 1995

Sampling Location	Nature of Sample	^{3}H activity levels (Bq/l)	
		1995	1993
Kuchegar	Down stream	<0.6	-
Virje	Stream	0.74 ±0.55	-
Kuchegar	Borewell	<0.6	1.0 ± 0.8
Kalihalli Township	Borewell	0.93 ±0.56	-
Kadra	River	0.90 ±0.56	-
Kalihalli Township	Stream	<0.6	-
Kaiga site	Stream	<0.6	-
Devkar	Ground Water	0.69 ±0.55	1.3 ± 0.8
Kaiga site	Borewell	<0.6	-
Kinner	Borewell	<0.6	-
Malavalli	Borewell	0.66 ±0.55	-
Sunkeri	Stream	0.86 ±0.56	-
Vajaralli	Borewell	<0.6	-
Bare	Borewell	1.43 ±0.55	-
Arabail (Gangavali)	River	1.13 ±0.56	-
Kodibag	Stream	<0.6	-
Arabail	Borewell	0.6 ±0.55	-
Mastikkatta	Borewell	<0.6	-
Ulvi	Ground well	0.98 ±0.56	-
Balemane	Borewell	0.74 ±0.55	-
Kodasalli	River	<0.6	-
Shejwad	Borewell	-	0.9 ± 0.8

TABLE-11(B)

Results of ^{3}H Analysis of Water Collected During 1998-99

Sampling location	Nature of sample	^{3}H activity levels(Bq/l)
Ganeshgudi	Well	<1.28
Anshi	Tap	<1.28
Bidoli	Well	2.75 ±1.3
Ulvi	Tap	2.12 ±1.28
Hartuga	Lake	10.85 ±1.52
Virje	Lake	1.62 ±1.28
Kaiga	Stream	2.69 ±1.3
Kuchegar	Lake	1.63 ±1.28
Sulgeri	Well	<1.28
Arabail	Bore well	1.84 ±1.3
Kadibag	Estuary	<1.28
Kaiga	Stream	<1.28
Intake canal	Lake	<1.28
Devkar	Well	<1.28
Virje	Lake	3.42 ±1.32
Sadasivgad	Bore well	<1.28

Table-12

Monthly Maximum and Minimum Air Temperature at 1.2 m Height Above Ground Level for the Period 1995-98

Months	Maximum and minimum temperature(°C) for the years							
	1995		1996		1997		1998	
	Max	Min	Max	Min	Max	Min	Max	Min
January	33.0	10.9	36.5	13.0	35.0	13.6	36.0	16.5
February	35.6	13.8	38.0	13.0	37.8	11.7	36.4	11.5
March	36.4	14.8	39.6	16.9	39.0	15.7	38.0	15.7
April	38.0	17.8	38.2	20.2	37.8	17.5	39.8	20.6
May	34.8	21.0	37.5	21.0	38.5	22.9	40.1	22.5
June	35.1	21.2	37.5	22.9	37.5	23.2	38.7	22.2
July	29.2	20.8	31.4	22.7	30.7	22.5	32.5	22.1
August	32.0	21.0	31.0	22.5	30.2	23.1	32.5	23.5
September	30.2	20.2	30.7	21.6	31.6	23.2	32.1	22.8
October	34.5	22.0	35.0	20.5	35.7	22.3	33.6	20.0
November	34.1	15.0	34.6	17.5	36.0	20.9	34.0	13.0
December	34.6	14.0	34.1	13.2	35.9	19.2	33.6	12.0

Table-13

Monthly Maximum and Minimum Atmospheric Pressure

Months	Monthly maximum and minimum atmospheric pressure(mbar) for the years					
	1996		1997		1998	
	Max.	Min.	Max.	Min.	Max.	Min.
January	-	-	1011.5	1002.2	1011.2	1002.1
February	1009.8	999.7	1010.8	1001.7	1010.7	1003.1
March	1008.7	997.3	1010.1	1000.1	1008.9	998.8
April	1008.2	997.1	1008.2	999.9	1006.7	995.5
May	1008.5	996.4	1008.0	997.6	1004.3	997.8
June	1006.2	992.6	1006.4	996.0	1004.7	996.8
July	1007.0	997.6	1004.8	997.3	1005.8	996.1
August	1005.3	999.5	1008.0	999.5	1005.9	996.8
September	1005.9	998.1	1010.2	1001.0	1005.0	996.5
October	1007.5	999.4	1012.8	1002.8	1008.1	997.0
November	1010.0	999.0	1009.2	1002.0	1008.5	1000.4
December	1012.8	1002.1	1010.1	1001.4	1012.0	1002.6

Table-14

Monthly Maximum and Minimum Relative Humidity in % at 1.2 m Height Above Ground Level for the Years 1995 -98

Month	Monthly maximum and minimum relative humidity(%) for the years							
	1995		1996		1997		1998	
	Max	Min	Max	Min	Max	Min	Max	Min
January	78	10	87	26	84	07	87	21
February	82	04	-	-	86	02	81	13
March	80	13	87	13	86	07	82	12
April	80	18	86	28	87	07	84	17
May	81	18	88	40	85	20	84	24
June	97	42	90	46	92	32	96	27
July	96	82	94	70	94	67	99	75
August	98	74	98	68	93	67	98	74
September	96	70	97	59	88	58	99	74
October	97	60	94	32	86	33	99	46
November	92	34	92	26	87	34	98	36
December	86	22	84	16	91	23	92	24

TABLE-15
Monthly Rainfall in mm During the Period 1996-98

Month	1996	1997	1998
January	-	-	-
February	-	-	-
March	-	10.2	-
April	6.3	-	1.2
May	28.2	-	93.0
June	966.5	996.4	1128.5
July	1260.0	1942.7	910.4
August	548.8	1114.6	718.5
September	141.5	95.8	500.5
October	296.7	73.4	289.5
November	16.6	51.8	54.7
December	39.7	38.9	1.0
Cumulative rain fall	**3304.3**	**4323.8**	**3697.3**

Table-16
Mean Annual External Radiation Dose Measured in Kaiga Site using Environmental TLDs (1987-97)

Location	μSv/Y
Storage yard near dome structure	500
Way to River	720
Concrete Testing Lab	872
Junction of rear Gate and Wireless Station	644
Way to River (via of pipe)	652
Beside the Pan Shop	564
Way to River (near stream)	568
Satellite Communication Build.(Security)	492
Y Gate	520
Way to River (pipe cross road)	491
Way to Water Fall	404
Yellapur Road	576
Junction of Ring and Main Road	480
Way to Kaiga (12^{th} km)	640
Way to School	596
Way to Kaiga (9^{th} km)	540
Near MMLab.(Kaiga village)	540
L&T workshop	548
Way to Kaiga (8^{th} km)	560
Township (Security)	680
L&T Quarters	652
MMLab (Outside)	484
Township (Sintex tank)	664
DG Building. T/ship Outside	448

Table-17
Mean Annual External Radiation Dose Measured in 1998 using Environmental TLD's around Kaiga Site

Location	Average Exposure μSv/Yr	# Surveymeter reading (μSv/h)
Balemane	520	0.03-0.05
Ulvi	900	0.05-0.11
Ganeshgudi	780	0.04-0.06
Devkar	460	0.02-0.05
Kalche	660	0.03-0.04
Vajaralli	680	0.04-0.05
Basal	560	0.03-0.05
Arabail	640	0.04-0.05
Bare north	520	0.03-0.04
Mavinamane-2 (Malavalli)	440	0.03-0.04
Ramanguli	620	0.03-0.05
Bare south	580	0.03-0.04
Sunksal	720	0.03-0.04
Mastikatta	600	0.02-0.05
Agsur	480	0.02-0.05
Hattikkeri	660	0.03-0.05
Hartuga	600	0.03-0.05
Kuchegar	480	0.03-0.05
Devalmakki	420	0.03-0.05
Karwar	-	0.03-0.06
Kalihalli	560	0.03-0.05
Kadra	480	0.02-0.05
Anshi	660	0.04-0.07
Main Gate (Plant)	420	0.03-0.05
Waste management area	560	0.03-0.05

 # Instrument used: Scintillometer / μR Surveymeter

Table-18

Particulars of Samples Collected & Analysed for Pre-operational Survey during the period April1998 to March1999

Sl No.	Type Of Samples	Radionuclides Analysed					
		I-131	Cesium	Strontium	Gross Beta	Gross Alpha	Total
1	Rain Water	*	4	2	*	*	6
2	Lake Water	*	30	27	1	*	58
3	Drinking Water	*	3	3	*	*	6
4	Tap Water	*	7	6	*	*	13
5	Stream	*	16	11	5	*	32
6	River	*	7	6	1	*	14
7	Salt Water	*	5	5	1	*	11
8	Open Well	*	22	17	6	*	45
9	Bore Well	*	10	9	2	*	21
10	Discharge Canal	*	3	3	*	*	6
11	Sediments	*	3	3	*	*	6
12	Cereals	*	11	10	5	*	26
13	Soil	*	25	16	10	*	51
14	Vegetables	*	12	11	9	*	32
15	Fish	*	7	6	2	*	15
16	Milk	*	3	3	2	*	8
17	Meat	*	2	2	1	*	5
18	Diet	*	5	5	4	*	14
19	Leaf	*	31	31	26	*	88
20	Fruits/Nuts/Honey	*	25	24	22	*	71
21	Air Samples	*	2	2	69	69	142
22	Goat's Thyroid	2	*	*	*	*	2
23	Total	2	233	202	166	69	672

Table -19

Particulate Air Activity Levels at ERL Township Kaiga During 1997-99.

Number of samples	Gross α (mBq/m³)			Gross β (mBq/m³)		
	Range	GM	GSD	Range	GM	GSD
78	BDL-0.61	0.08	2.8	BDL-4.45	1.33	1.6

Table No-20

Activity levels in Water Samples (mBq/l) during 1998-99

Sl. No.	Type of Sample	Radionuclide	No. of samples	Range	GM	GSD
1	Bore Well	Radiocesium	10(2)	BDL - 19.78	5.45	1
		Radiostrontium	9(5)	BDL - 8.62	3.87	1.5
2	Drinking Water	Radiocesium	3(1)	BDL - 6.71	4.56	1.5
		Radiostrontium	3(2)	BDL - 5.86	4.42	1.2
3	Estuary	Radiocesium	2(0)	7.97 - 11.96	-	-
		Radiostrontium	2(2)	BDL	BDL	-
4	Lake Water	Radiocesium	30(6)	BDL - 20.42	5.41	1.9
		Radiostrontium	27(1)	BDL - 9.05	3.93	1.5
5	Sea Water	Radiocesium	3(0)	8.92 - 14.61	8.99	1
		Radiostrontium	3(3)	BDL	BDL	-
6	Stream Water	Radiocesium	16(5)	BDL - 25.60	5.67	2
		Radiostrontium	11(7)	BDL - 9.01	3.52	1.4
7	Tap Water	Radiocesium	7(1)	BDL - 21.02	5.64	2.3
		Radiostrontium	6(4)	BDL - 6.12	3.3	1.4
8	River Water	Radiocesium	7(3)	BDL - 24.06	6.64	2.2
		Radiostrontium	6(5)	BDL - 7.69	4.16	1.6
9	Open Well	Radiocesium	22(4)	BDL - 19.49	5.33	1.6
		Radiostrontium	17(7)	BDL - 9.49	4.59	1.5
10	Rain Water	Radiocesium	4(0)	3.05 - 6.37	4.56	1.3
		Radiostrontium	2(1)	BDL - 3.00	-	-

Note:- Figures within parenthesis indicate number of samples Below Detection Limit (BDL)..

Table No-21

Radioactivity Levels in Aquatic Samples. (Bq/kg dry wt.) During 1998-99

Sample type	Radiocesium				Radiostrontium			
	No. of samples	Range	GM	GSD	No. of samples	Range	GM	GSD
Sea fish (Bq/kg Flesh wt.)	2(0)	0.20-0.48	0.31	1.55	2(0)	0.11-0.14	0.12	1.13
River fish (Bq/kg Flesh wt)	5(0)	0.28-0.71	0.45	1.59	4(0)	0.11-0.44	0.22	1.97
Sediment(Bq/kg dry wt)	3(0)	1.17-5.88	2.62	2.24	3(0)	0.63-1.22	0.88	1.39

Table-22

Water Quality Parameters of Different Water Bodies During 1998-99

Nature of water sample	Total Dissolved solids (TDS) (mg/l)	Total suspended solids (TSS) (mg/l)	Alkalinity (mg/l as $CaCO_3$)	pH	Chloride (mg/l)
Lake	37.4-57.2	4.8-9.2	18.7-21.8	7.3-7.7	12.3-16.8
Drinking water	50.6-79.0	3-9.3	9.3-22.7	7.2-7.8	12.7
River/stream	38.4-109.2	0.4-191.5	9.8-22.2	6.8-7.6	9.7
Open well	66.2-166.4	0.6-28.6	24.5-122.2	7.9-8.3	21.7
Bore well	57.2-280	1.8-56.8	24.7-148.9	6.9-8.5	15.4-101.7

Table No.23

Baseline Activity Levels in Terrestrial Samples During 1998-99

Type of samples	No.of Samples (BDL)	Radiocesium			No.of Samples (BDL)	Radiostrontium		
		Range	G.M.	GSD		Range	G.M.	GSD
Soil (Bq/kg dry wt.)	25 (3)	2.21 – 34.57	9.14	2.1	16 (10)	BDL - 2.99	1.57	1.6
Cereals (Bq/kg dry wt.)	11 (0)	0.38 – 5.55	2.05	1.9	10 (4)	BDL – 0.82	0.23	2.0
Vegetable (Bq/kg Fresh wt.)	12(1)	BDL – 0.74	0.19	2.5	11 (3)	BDL –0.23	0.07	1.7
Milk (Bq/L)	3 (0)	0.13 –0.34	0.22	1.5	3 (1)	BDL – 0.08	0.06	1.3
Meat (Bq/kg flesh wt.)	2 (0)	0.34 – 0.72	-	-	2 (1)	BDL – 0.08	-	-
Diet (Bq/kg fresh wt.)	5 (0)	0.16 –0.72	0.34	2.1	5 (3)	BDL – 0.22	0.09	2.3
Leaves (Bq/kg dry wt.)	31 (0)	0.53 – 14.34	3.16	2.9	31(4)	BDL – 10.45	2.52	2.1
Honey/Fruits/Nuts (Bq/kg Fresh wt.)	25 (1)	BDL –1.79	0.44	2.2	24 (8)	BDL –0.90	0.16	2.2

Table -24

^{40}K activity Levels in Environmental Matrices During 1998-99

S.No	Type of Sample	Range(Bq/kg dry wt.)
1	Soil	42.0 – 718.0
2	Leaves	94.2 – 1624.64
3	Cereals	41.26 – 77.37
4	Fruit	28.53 - 218.33(wet)

TABLE –25

Results of Whole Body Counting During 1998-99

Radio nuclide	No. of persons counted	No. of persons with activity	
		Below Detection Limit	Below Recording Level
^{137}Cs	330	330	330
^{60}Co	330	330	330

For ^{137}Cs Detection Limit is 300 Bq and Recording Level is 11 kBq.
For 60Co Detection Limit is 120 Bq and Recording Level is 1.5 kBq.

Table-26
Proposed Sampling Program during Operational Phase

Location	Sector	Zone (km)	Background Radiation	Frequency for different types of samples (Number of samples per year)							
				Water	Soil	Sediment.	Bio-sample (Terrestrial)	Bio- sample (Aquatic)	^{3}H air	Air (Particulate)	Rain Water
ERL, Township	N	8-16	TLD	-	-	-	-	-	52	52	26
Township-intake	N	8-16	-	26	-	4	-	-	-	-	-
Virje	M	8-16	-	26	-	4	-	-	-	-	-
Intake canal	O	-	-	52	-	-	-	-	-	-	-
Discharge canal	O	-	-	52	-	4	4	4	26	-	-
Kaiga	H	2.3-5	TLD	26	4	-	-	-	26	-	26
Balemane	A	2.3-5	TLD	26+26*	-	-	-	-	52	-	-
Hartuga	L	2.3-5	TLD	26+26*	4	-	12	-	52	-	-
Opp. Devkar	C	5-8	-	26	-	-	-	-	26	-	-
Sulgeri	C	8-16	-	26	-	-	12	-	12	-	-
Kodasalli	D	8-16	-	12	-	-	-	-	26	-	-
Mallapur	N	8-16	-	26+12*	-	-	12	-	12	-	-
Devkar	D	5-8	TLD	4	4	-	12	-	4	-	-
Kuchegar	M	5-8	TLD	52	4	-	12	-	4	-	-
Devalmakki	M	16-32	TLD	4+4*	-	-	-	4	4	-	-
Karwar/Kodibag	M	>32	TLD	8	-	4	-	-	4	-	-
Sadashivgad	M	>32	-	2+2*	-	-	-	-	4	-	-
Ulge	M	16-32	-	4	-	-	-	4	4	-	-
Kadra	N	8-16	TLD	12+12*	-	-	40	-	4	-	-
Anshi	P	8-16	TLD	4	-	-	-	-	4	-	-
Bidoli	A	8-16	-	4	-	-	-	-	4	-	-
Ulvi	B	16-32	TLD	4	-	-	-	-	4	-	-
Arbail	E	16-32	TLD	4	-	-	-	-	4	-	-
Bare	F	5-8	TLD(2)	4	-	-	-	-	4	-	-
Mavinamane-II	F	8-16	TLD	4	-	-	-	-	4	-	-
Basal	E	8-16	TLD	4	-	-	4	-	4	-	-
Vajaralli	E	8-16	TLD	4	-	-	-	-	4	-	-
Kalche	D	8-16	TLD	4	4	-	4	-	4	-	-
Yellapur	D	16-32	-	4	-	-	-	-	4	-	-
Ganeshgudi	C	16-32	TLD	4	-	-	-	-	-	-	-
Agsur	J	16-32	TLD	-	-	-	4	-	-	-	-
Mastikkatta	I	16-32	TLD	-	-	-	-	-	-	-	-
Ramanguli	F	16-32	TLD	-	-	-	-	-	-	-	-
In site boundary	-	-	TLD	-	-	-	-	-	-	-	-
Township	N	16-32	TLD	-	-	-	-	-	-	-	-
Hattikkeri	K	16-32	TLD	-	-	-	-	-	-	-	-
Total			**25**	**536**	**20**	**16**	**116**	**12**	**352**	**52**	**52**

*Ground and surface water samples

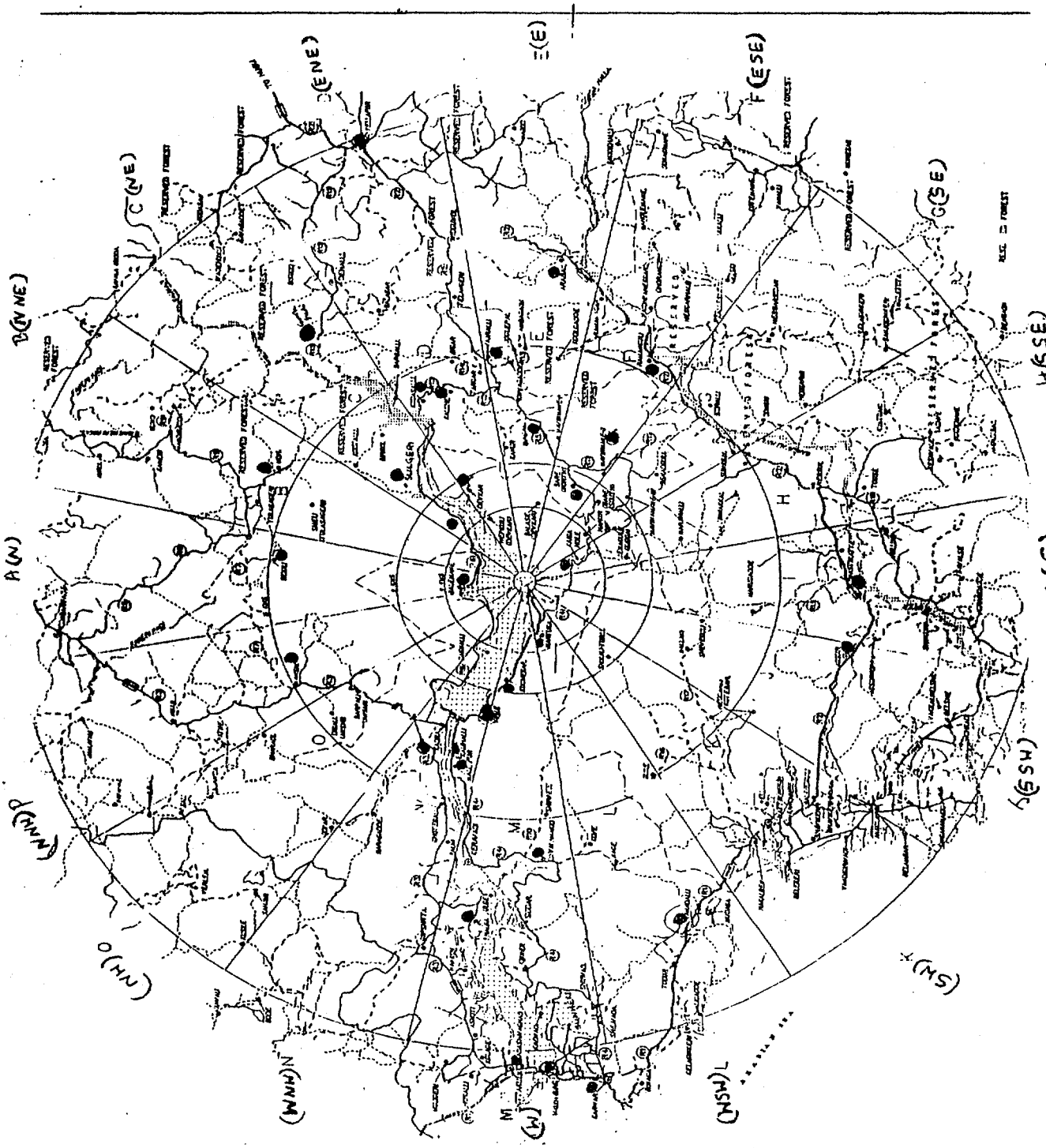

Figure-1 Kaiga Site Map and Sampling Locations

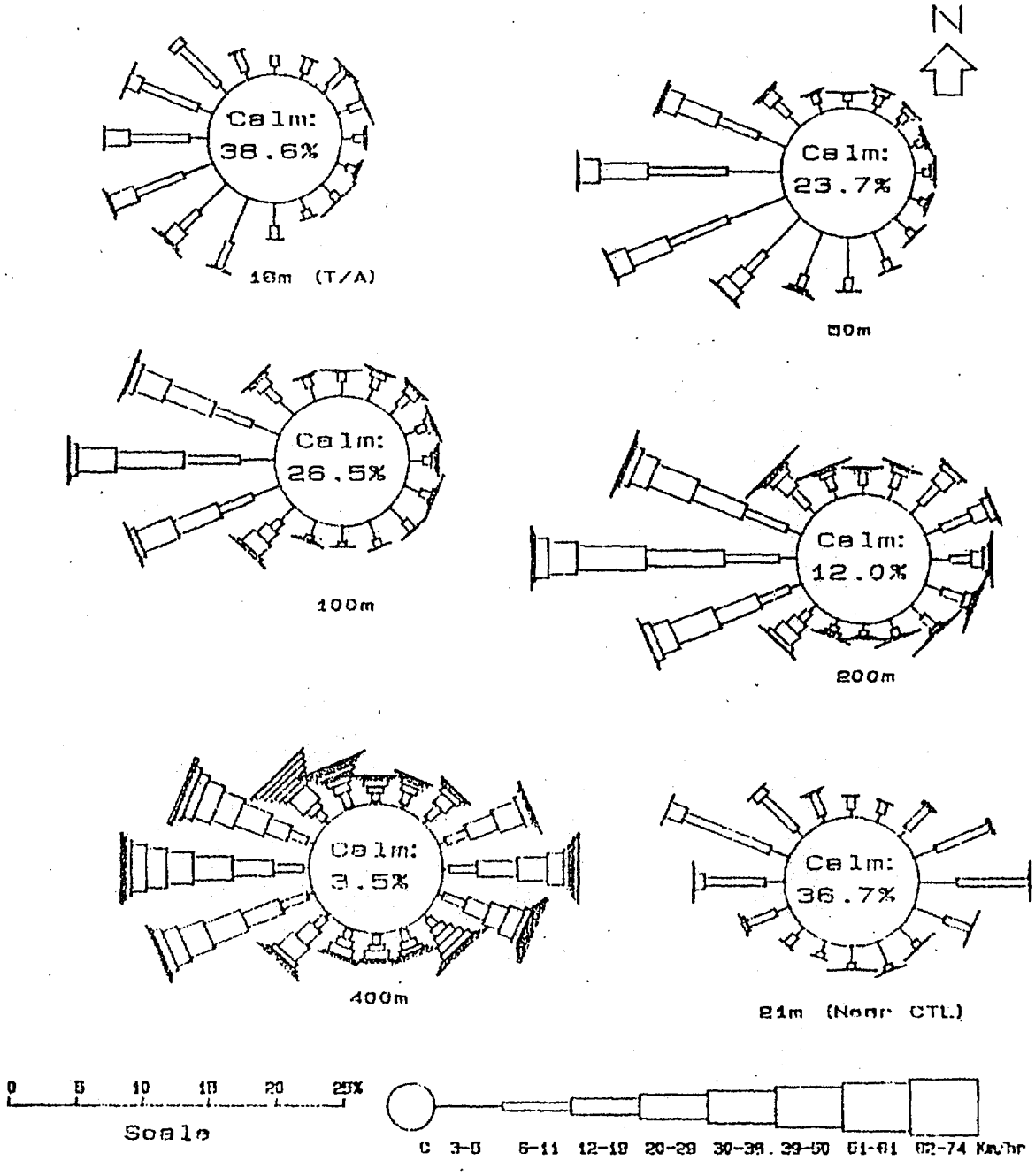

Figure-2 Typical Annual Wind Roses Based on the data from SODAR and Met. Tower

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