EFFECTS OF LOW-DOSE IONIZING RADIATION AMONG THE EMPLOYEES AT THE KAKRAPAR DAE CENTRE : A CROSS-SECTIONAL STUDY

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PREFACE

In January 1992, the Nuclear Power Corporation of India Ltd. (NPCIL) entered into a Consultancy Service Contract (No.CSC-92-1-TMC) with the Tata Memorial Centre (TMC) to carry out epidemiological studies in the employees and their families. The aim of the study was to investigate whether any health hazards were associated with exposure, if any, to low-dose ionizing radiation. The contract was to undertake the studies at 6 power stations or project sites. These were located at Tarapur, Maharashtra; Rawatbhata, Rajasthan; Kalpakam, Tamilnadu; Narora, Uttar Pradesh; Kakrapar, Gujarat and Kaiga, Karnataka.

NPCIL also set up a Corporate Committee for Epidemiological Studies (COCES). At the first meeting of COCES held on 6th April 1992, a decision was taken to initiate the study at Tarapur Atomic Power Station because of its proximity to Tata Memorial Hospital (TMH). The next site chosen, again because of its proximity to TMH, was at Kakrapar. Two additional committees were also constituted viz. Senior Technical Advisory Group (STAG) and Planning and Implementation Supervisory Committee for Epidemiological Studies (PISCES), and their functions and terms of references were laid down. Member-Secretary PISCES was designated to be officer incharge of Epidemiological Surveys.

These committees met periodically. In the initial phase of the study, several issues were debated and decisions taken regarding the target population, the controls, the types of health indicators to be studied, the instrument for data collection and several technical issues. The actual data collection at Kakrapar DAE

Centre commenced in April 1995 and the survey was completed by December 1995.

One of the important results yielded by these surveys revealed no increase in the prevalence of malignancies in the radiation workers as compared to non-radiation workers; nor was there any difference in the prevalence of malignancies in spouses and offspring of employees as compared to relevant control groups. The study has provided useful indicators and generated reliable baseline data for carrying out further work.

The Tata Memorial Centre has been privileged to undertake this research project to address a problem which is not only scientifically important but also socially relevant. This report, I am sure, will be of interest to a wide range of readers from epidemiologists, scientists, physicians as well as physicists concerned with these issues.

Dr.K.A.Dinshaw 5/1/99
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SUMMARY:

The potential effect of ionizing radiation on human population has been a concern to the scientific community and to the public at large, for a long time. The Nuclear Power Corporation (NPC) recognised the need for more precise information on the biological effects of low dose radiation on human population. In response to this concern, NPC awarded a Consultancy Service Contract to the Tata Memorial Centre (TMC), to carry out epidemiological studies in radiation occupational workers and their families at various power station/project sites. Unlike Tarapur and Kakrapar Power Stations, where TMC undertook the survey, the surveys at other sites are being conducted by local academic/medical institutions as per the procedures standardised by TMC, and the data are transported for processing and analysis to its Epidemiological Studies Cell especially set up for the purpose.

The present document reports the results of the cross-sectional survey carried out at Kakrapar DAE Centre between 1995 and 1996, and deals with the prevalence of malignancies observed, if any, in 1414 employees, 1022 spouses of employees and 1537 offspring of employees. Prevalence of congenital anomalies in the offspring of employees has also been reported on.

The primary interest was to study prevalence of malignancies in the study group, in particular to see if the prevalence was higher in radiation workers as compared to that in non-radiation workers. There were, however, no cases of cancer reported in all the three groups studied i.e. the employees, their spouses, and their offspring. This was not surprising since the study groups were small, all being less than 1500 individuals. Furthermore, cancer is known to increase with age, while in the present study 80% of the employees and their spouses were below 40 years of age. Secondly working personnel and their families are generally healthier than the general population.

There were 23 cases of congenital anomalies (major and minor) among 1537 offspring of employees, giving a prevalence of 1.5% (2.3% in males and 0.6% in females). The prevalence of congenital anomalies in a comparable cross-section of the population was not available with which the present data could be compared. The prevalence of anomalies in the offspring of radiation workers was lower than that in the offspring of non-radiation workers. Such a comparison is of limited value, since it does not answer the question regarding the effects of in-utero exposure.

Finally, the study population at Kakrapar is small and therefore no definitive statements can be made. However, it is seen that there is no difference in prevalence of cancer in the radiation and non-radiation workers at Kakrapar Atomic Power Station (KAPS). The information on KAPS study group will help augment the base when analysis of pooled data, from all power stations, is undertaken.

1. INTRODUCTION

The potential effect of ionizing radiation on human population has been a concern to the scientific community and the public at large, for a long time. The Nuclear Power Corporation (NPC) recognized the need for more precise information on the biological effects of low dose radiation on human population. In response to this concern the NPC initiated an epidemiological survey in the employees and their families at its various sites and awarded a Consultancy Service Contract to Tata Memorial Centre (TMC). NPC also constituted various committees (composition given in Appendix G); one was the Corporate Committee for Epidemiological Studies (COCES) for ensuring suitable organizational arrangements and budgetary deployment. The other two committees were Senior Technical Advisory Group (STAG) to give guidelines on the conduct of the study and review the reports prepared by the other committee viz. Planning and Implementation Supervisory Committee for Epidemiological Studies (PISCES), which actually planned detailed methodology of carrying out the epidemiological survey. TMC conducted the survey at 2 sites viz. Tarapur DAE Centre and Kakrapar Atomic Power Station. For surveys at other stations, TMC provides guidelines regarding the format for data collection, the questionnaire, and the software for data entry. This data is then transferred to TMC for processing and analysis at its Epidemiological Studies Cell especially set up for the purpose.

This report deals with data collected at Kakrapar Atomic Power Station (KAPS). The first unit of KAPS started generating electricity on September 3, 1992 and the second unit on January 8, 1994.

2. OBJECTIVES

The general aim of the project was to conduct health survey in employees and their families residing with them and assess morbidity due to various diseases and evaluate the impact, if any, of low-dose radiation.

Specific aims, for this report, are to compute morbidity (prevalence) of cancer and compare with suitable controls; for 3 groups viz. the employee group, their spouses and their offspring. Additionally, for the offspring group prevalence of congenital anomalies is also to be studied.

3. OPERATIONAL METHODOLOGY

The data collection on the study population which included interview and physical examination, was initiated at Kakrapar Atomic Power Project (KAPS) in April 1995 and was completed by December 1995. A few visits were undertaken in 1996 to wind-up the incomplete information.

3.1 Questionnaire

A detailed questionnaire was designed for collection of information on demographic characteristics and medical and health history and radiation exposure history. Besides, data were also obtained on lifestyle factors like tobacco use, alcohol consumption, dietary intake and other occupational exposures. This was necessary, since environmental/lifestyle factors determine a large fraction of cancer rates. Thus, the confounding/modifying effects of these factors could be taken into account, if required. Occupational history including the type of occupational

radiation exposure and period of exposure prior to and after joining the power station was obtained. Radiation exposure history, occupational as well as medical exposures were noted. Medical history giving details of past and/or present illness, if any, and details of clinical examinations, reproductive history, congenital anomalies, if any, among offspring, were also recorded.

The questionnaire used for data collection was field-tested earlier at Tarapur DAE Centre; which was the first power station selected for the study.

3.2 Field Survey, Data Collection and Processing

The employees and their families were invited by the local authorities of KAPS to participate in the survey and to come to the hospital of Kakrapar Atomic Power Station, where clinical investigations were conducted and data collected. For this survey, a team from TMH comprising of 2 medical doctors, 1 statistician, 2 enumerators and 1 radiotechnician visited KAPS hospital for 6 days every alternate week. The general part of the proforma was filled by the enumerators and the statistician of the Epidemiological Studies Cell. Doctors from TMH examined each and every participant as they presented themselves and filled the medical part of the proforma. The investigations that were carried out included testing of complete blood count (C.B.C.), chest x-ray and cytology investigations.

Following criteria were set up for carrying out these investigations :-

1. All adults above the age of 40 years and smokers 35 years and above had to undergo a chest x-ray.
2. All females above the age of 35 years had to undergo pap-smear test.

3. All children had to undergo blood test (C.B.C.).
4. Adults had to undergo blood test (C.B.C.) only if it was not done for the past one year.

Suspected cancer cases were referred to Tata Memorial Hospital, Mumbai for further investigations. Completed proforma were transported for data processing to the Epidemiological Studies Cell, especially set up at TMH for the survey.

4. POPULATION COVERAGE

This report is based on information on 1414 employees, 1022 spouses of employees and 1537 offspring of employees i.e. a total of 3973 individuals as seen in Table 1 below. Of these 3823 members were individually examined and interviewed. The information on health status with respect to malignancies and congenital anomalies in the offspring, if any, in the small group of 150 individuals that was not examined, was obtained by reviewing the medical records maintained

Table 1 : Population Covered i.e. Employees, Their Spouses and Offspring by Sex (1995-96)

Groups	Covered in the Survey			Information obtained from the medical records of KAPS Hospital			Total
	Males	Females	Total	Males	Females	Total	
Employees	1328	80	1408	6	0	6(0%)	1414(100%)
Spouses	19	935	954	0	68	68(7%)	1022(100%)
Offspring	777	684	1461	45	31	76(5%)	1537(100%)
Total			3823(96%)			150(4%)	3973(100%)

at KAPS Hospital. Cancer and congenital anomalies are serious enough conditions to be brought to the notice of the doctor and also recorded and hence there is little likelihood of missing any case.

5. HEALTH OUTCOMES FOR STUDY

The basic study design was cross-sectional type with no follow-up. It was simply a one time survey so that only prevalence of various conditions could be assessed. Neither the incidence nor mortality were studied. The health outcomes reported on here are

1. Malignant disease in three groups viz. employees, their spouses and their offspring,
2. Congenital anomalies in the offspring.

Members of the surveyed group were given a thorough medical check-up. However for the purposes of this report only the above two conditions have been considered.

6. SELECTION OF COMPARISON GROUP

Several options were available for selection of controls for the three groups viz., the employees, their spouses and offspring that were to be surveyed. One was to have internal comparison group i.e. compare radiation workers with non-radiation workers of the power station. The other was to have external comparison group such as the general population. A third suggestion made by the STAG/PISCES committee members was to obtain comparison group from

Bhabha Atomic Research Centre (BARC), Mumbai employees and their family members. Each of these groups carries both useful and restrictive elements.

6.1 Comparison Group for Evaluating Cancer Prevalence in Employees

General population groups are not ideal in studies evaluating occupational exposures, because workers are usually healthier than the general population (the healthy worker effect) - healthier people are more likely to get jobs and continue at work. Hence the workers are generally expected to experience lower risks for cancer and for other diseases than the general population. Furthermore, there are no cancer prevalence data available for the general population and prevalence estimated from available incidence rates by a fixed multiplier (1.5, 2 or 3) as an estimate of average duration, would not be strictly proper.

The second alternative of comparing with BARC (Mumbai) employees and their families, may also be questionable because in the perception of the lay public, these employees also come under the umbrella of radiation workers.

The better alternative is to have an internal comparison group i.e. compare prevalence of cancer among those exposed to radiation with those who were not exposed, within the same study group.

As for Kakrapar DAE Centre, there were no malignancies reported in the employees and the question of comparison therefore does not arise.

6.2 Comparison Group for Evaluating Cancer Prevalence in Spouses of Employees

As regards spouses of employees, comparing this group with the general population does not pose a problem if the prevalence data were to be available, because the question of 'healthy worker effect' does not arise. However, one expects the study group to be socio-economically somewhat better off than the general population and comparison with the spouses of employees of BARC (Mumbai), would be more relevant. In the present study however, no malignancies were observed in the spouses of the KAPS employees.

6.3 Comparison Group for Evaluating Cancer Prevalence in Offspring of Employees

To evaluate cancer prevalence in the offspring of the employees of Kakrapar Atomic Power Station, the following comparisons have been planned.

1. To compare offspring of Radiation Workers vs. Offspring of Non-Radiation Workers of the power station.
2. To compare offspring of Radiation Workers of the power station vs. Offspring of Non-Radiation Workers of BARC (Mumbai).
3. To compare offspring of employees of the power station vs. Offspring of employees of BARC (Mumbai).

Again, no malignancies were observed in the offspring of employees of Kakrapar DAE Centre.

6.4 Controls For Congenital Anomalies in Offspring of Employees

It has not been possible to obtain the prevalence of congenital anomalies in a comparable cross-section of the population independent of radiation-

occupational groups. The only data available from the country deals with prevalence of congenital anomalies in the new borns (Master-Notani et al;1968, Agarwal et al;1991) and hence are not comparable with the present data. We have compared the prevalence of congenital anomalies in the offspring of employees of KAPS with those of BARC (Mumbai) employees. Internal comparison i.e. comparing offspring of radiation workers versus those of non-radiation workers, though undertaken, is of limited value. That is because such a comparison does not answer the question regarding the effects of in-utero exposure that is not work-related, as reliable information on such an exposure for spouses of male employees is not available. In-utero work-related exposure of female employees is restricted to not more than 2 mSv during the pregnancy period as per the recommendation of AERB/ICRP. Overall also there are only 17 female radiation workers and they have received negligible radiation dose (an average cumulative radiation dose of 0.8 mSv), as can be seen from the following section and Appendix A.

7. RADIATION EXPOSURE : DEFINITION AND MEASUREMENT

The details of annual radiation dose received by employees was provided by KAPS. An employee who has been given a TLD number for measuring radiation exposure is defined for the purposes of this study as a radiation worker. The radiation exposure to an employee at a nuclear installation can either be external or internal and is mainly due to gamma and beta radiations.

External exposure is caused due to radioactive source external to the body and is measured by means of personal dosimeters. These dosimeters can

either be thermoluminescent dosimeters or film badge type dosimeters. For day-to-day dose management direct reading type dosimeters are also employed. For special applications, some other types of dosimetry devices are used.

Internal exposure is caused due to radioactive materials entering the human body through inhalation, ingestion and injection. This type of exposure is monitored by bioassay and whole body counting techniques.

The external radiation exposure received by an employee is controlled by suitable adjustment of distance, time and shielding, while the internal exposure is controlled by protective equipment and clothing.

The dose received by the personnel is controlled and is kept well below the stipulated exposure limits recommended by International Commission on Radiological Protection (ICRP) and Atomic Energy Regulatory Board (AERB), from time to time.

The distribution of cumulative radiation dose in mSv (external cum internal), received by radiation workers of KAPS is given in Appendix A. The cumulative dose of an employee is measured by adding annual doses from initial employment upto end-1995, when the survey ended. The mean cumulative radiation dose per worker was 8.9 mSv in males and 0.8 mSv in females. Furthermore, not a single annual radiation dose exceeded 250 mSv, which is considered to be a radiation incident of medical significance for the population in United States (Fry,1980). Infact, all the annual radiation doses for 1197 radiation workers were below 20 mSv.

8. CHARACTERIZATION OF EMPLOYEE POPULATION : UNIVARIATE DESCRIPTION

Table 2 describes the age and sex distribution of the radiation and non-radiation workers. It is seen that most of the employees are below 40 years of age. The 5-year age group distribution is given in appendix B Table 1.

Table 2 : Age Distribution of Employees of KAPS by Radiation Status (1995-96)

	Males		Females	
Age	Radiation Workers No.(%)	Non-Radiation Workers No.(%)	Radiation Workers No.(%)	Non-Radiation Workers No.(%)
Upto 39	1005(84)	100(73)	17(100)	51(81)
40 - 49	90(7)	29(21)	0	11(17)
50+	102(9)	8(6)	0	1(2)
Total	1197(100)	137(100)	17(100)	63(100)

For age distribution by 5-year age interval see appendix B.

Besides age and sex, it is also relevant to compare the profile of the radiation and non-radiation workers with respect to other characteristics. This information was available for 1408 (1328 males and 80 females) interviewed employees. The distribution of various characteristics is shown in Table 3 for male employees only, because there were very few female employees. The radiation and non-radiation workers were found to be similar with respect to marital status (almost 80% were married), community distribution (over 90% belonged, as expected, to the majority community), educational level (almost 50% had studied upto undergraduate level or above, unlike the general population) and

Table 3 : Profile of Male Employees (interviewed) of KAPS by Radiation Status (1995-96)

Group	Radiation Workers (n=1192`) No.	%	Non-Radiation Workers (n=136) No.	%	Total (n=1328) No.	%
• **Marital Status**						
Unmarried	250	21	20	15	270	20
Married	941	79	114	84	1055	80
Widowed/Divorced/ Separated	1	-	2	1	3	-
• **Community**						
Hindu	1132	95	125	92	1257	95
Muslims	28	3	3	2	31	2
Christians	27	2	8	6	35	3
Others	5	-	-	-	5	-
• **Education**						
Upto primary	31	3	3	2	34	3
Middle (V-VII std)	36	3	5	4	41	3
Secondary and Technical after SSC (VII-XII Std)	558	47	39	29	597	45
Undergraduate and above	567	47	89	65	656	49
• **Habits**						
No habit	779	65	79	58	858	65
Chewers only	162	14	24	18	186	14
Smokers only	157	13	24	18	181	14
Alcohol consumers only	14	1	1	-	15	1
Combination of Habits	79	7	8	6	87	6
Snuff	1	-	0	-	1	-
• ***Cadre of* Work**						
Administration	43	4	90	66	133	10
Scientific	456	38	18	13	474	36
Technical	546	46	11	8	557	42
Security	7	1	0	-	7	-
Labour	99	8	15	11	114	9
School teacher	0	-	1	1	1	-
Trainee	41	3	1	1	42	3

also the habit pattern (over 60% had no habit). There was however a higher proportion of scientific/technical staff in the group of radiation workers than non-radiation workers.

There were only 6 male employees who were not interviewed and all were below 35 years of age. The cumulative radiation dose received, by each of the 5 radiation workers amongst these six employees were below 10 mSv.

9. STATISTICAL METHODS

This is a cross-sectional survey with no follow-up, so that only the prevalence of conditions of interest can be studied. The primary interest is to study the prevalence of malignancies, particularly in the radiation workers and compare with that in adequate control groups of non-radiation workers, after controlling for environmental/life style factors, which determine a large fraction of cancer rates of a population (Higginson and Muir, 1979; Doll and Peto, 1981).

As mentioned earlier, there were no prevalent cancer cases in the groups studied. The other outcome of interest was congenital anomalies in the offspring of the employees. The observed (O) number of anomalies was compared with the expected (E) number arrived at from the corresponding control group, after adjusting for age and sex differences. The observed number of cases is considered to follow a Poisson distribution with mean E and under the null hypothesis, the ratio O/E is unity. The confidence intervals were read from the tables prepared by Bailar and Ederer for the ratio of an observed value of a Poisson variable to its

expectation. The ratio O/E with 95% confidence intervals are exhibited in the relevant tables.

10. OBSERVATIONS AND DISCUSSION

The core question of the study concerns whether the employees of the Nuclear Power Plants, if exposed to low doses of ionizing radiation, are at higher risk for any disease condition; in particular cancer. The query is also extended to the family members i.e. their spouses and offspring. The interest is focused on cancer induction, since it is considered to be the most important long-term somatic effect of radiation exposure. However, it is not possible to distinguish between malignancies caused by ionizing radiation from those caused by other factors. There is no radiation specific tumor pathobiology. In general, only the frequency of an already prevalent tumor is expected to be elevated by radiation exposure. The age-adjusted incidence rate of cancer of different sites reported from 6 population based Indian registries is attached in Appendix D, for reference (ICMR, Biennial Report, 1992).

10.1 Cancer Prevalence

This survey is a cross-sectional type. As mentioned earlier, no malignancy was seen in the members of the study group. This is not a surprising observation as all the 3 groups studied were small, comprising less than 1500 individuals. Furthermore, almost 80% of employees and their spouses were below 40 years of age. The offspring group was also very small, 1537 in number, of which 1215 were children 14 years of age and under.

However several benign conditions were observed. Of the three benign conditions observed in the male employee group, one was atypical follicular adenoma of thyroid, another was lipoma in right vallecula and the third was abnormality in the bone as detected by CAT scan.

Similarly three benign conditions were observed in the group of female spouses of the employees. Two of the conditions were benign ovarian cysts and the other was fibroadenoma of breast -a benign condition.

Neither benign nor malignant conditions were observed in the offspring of the employees.

10.2 Prevalence of Congenital Anomalies in the Offspring

Among the somatic effects of radiation, other than cancer, developmental effects in the unborn child are of great concern. Exposure to high doses of radiation can cause death, anomaly, growth retardation and functional impairment depending on the fetal stage at which exposures occur.

Several abnormalities have been reported in humans after in-utero irradiation. The commonly reported ones are microcephaly, often combined with mental retardation, some central nervous system defects and growth retardation.

Because of large environmental and genetic variables encountered in human populations, it is very difficult to measure any effect that might be produced by low-dose radiation, on the developing fetus.

Table 4 : Prevalence of Congenital Anomalies (Major and Minor) in Offspring of Employees of KAPS (1995-96)

Offspring of		Males	Females	Total
Radiation Workers	No.	695	614	1309
	Cases(%)	15(2.16)	3(0.49)	18(1.38)
Non-Radiation Workers	No.	127	101	228
	Cases(%)	4(3.15)	1(1.00)	5(2.19)
Total	No.	822	715	1537
	Cases(%)	19(2.31)	4(0.56)	23(1.50)

Table 4 gives the number of congenital anomalies both major and minor observed in the offspring of the employees with details of anomalies given in Table 5. The information on anomalies that might have occurred in the stillborn fetuses or in neonatal deaths was not available.

There are certain anomalies, indicated in Table 5 which fall outside the range of anomalies classified as congenital by the International Classification of Diseases (ICD) codes; 740 to 759. For example, umbilical hernia (ICD 553.1), or inguinal hernia (ICD 550), though outside the range have been considered in UNSCEAR reports as congenital. Therefore, for the time being we have considered all the observed anomalies for analysis.

Total number of congenital anomalies (major and minor) recorded were 23 in numbers, of which 19 were in male offspring and 4 in female offspring; giving an overall prevalence of 1.5%. The prevalence of congenital anomalies in a comparable cross-section of the population is not available with which the present data could be compared.

Table 5: List of Prevalent Congenital Anomalies(Major and Minor) in Offspring of Employees of KAPS (1995-96)

CONG.ANOMALIES (ICD 9TH :740-759)	Males		Females		Total
	No.(age)	(Parent/employee Radiation Status)	No.(age)	(Parent/employee Radiation Status)	
1.Cardio-Vascular System (745-747)					
Ventricular Septal Defect	1(15)	NR	-		1
?Congenital Heart Disease	1(10)	R	2(6,1)	R,NR	3
total	2		2		4
2.Musculo-Skeletal System (754-756)					
Cleft Palate with Talipes equinovarus	-		1(4)	R	1
Deviated Nasal Septum	3(6,15,17)	R,R,R	-		3
Pigeons Chest	1(12)	R	-		1
Lower Limb Deformity	1(3)	R	-		1
*Umbilical Hernia (553.1)	-		1(1)	R	1
total	5		2		7
3.Genito-urinary System (752-753)					
Undescended Testis	4(10,12,7,4)	R,R,R,R	-		4
*Inguinal Hernia (550)	2(2,2)	R,R	-		2
*Hydrocele Congenital (778)	1(5)	R	-		1
total	7		-		7
4.Anomalies of Eyes (743)					
Obstruction In Lacrimal Apparatus	1(1)	NR	-		1
Bilateral Congenital Cataract	1(1)	R	-		1
total	2		-		2
5. Anomalies of Ear (744)					
Bat Ear	1(10)	NR	-		1
6. Multiple Congenital Anomalies (759.7)					
Ventricular Septal Defect with Undescended Testis	1(1)	NR	-		1
7.*Mental Retardation (319)					
?Cause	1(20)	R	-		1
TOTAL	19(2.31%)		4(0.56%)		23(1.50%)
Total Number of Offspring	822		715		1537

* These anomalies fall outside the range of ICD-9th 740-759
R : Radiation Worker, NR : Non-Radiation Worker

Attempt was made to compare the prevalence in the offspring of employees of KAPS with the prevalence in offspring of BARC (Mumbai) employees. On closer scrutiny of BARC (Mumbai) data (Appendix C, Table 5) it was obvious that not all congenital anomalies (major and minor) have been recorded. From Table 6 below it is seen that the prevalence of these anomalies is well below 0.5%; a definite underestimate, naturally yielding significantly different results when compared with KAPS data. The classification of congenital anomalies followed by the two centres may not be identical. There are several questions of classificatory nature that need to be answered. For example, whether anomalies like mental retardation falling outside the ICD range, should or should not be included in the list of malformations. Therefore for the time being till such questions remain unanswered, the comparison of BARC (Mumbai) data with Kakrapar data does not seem feasible.

Table 6 : Prevalence of Congenital Anomalies in Offspring of Employees of BARC, Mumbai (1994)

	Males	Females	Total
No. of Offspring	14,446	12,645	27,091
No. of Congenital Anomalies	55	42	97
Prevalence (%)	0.38	0.33	0.36

Internal comparison i.e. comparing offspring of radiation workers of KAPS with those of non-radiation workers, as mentioned earlier, is of limited value, since that would not answer the question of effects of in-utero exposure. However, the results of comparison are shown in Table 7. The prevalence of congenital anomalies is seen to be, in fact lower in the offspring of radiation workers compared to the offspring of non-radiation workers, both for male and

female offspring. In male offspring of radiation workers, 15 cases of congenital anomalies were observed compared to 23.4 expected cases based on prevalence of anomalies in offspring of non-radiation workers. This yielded an observed to expected ratio of 0.64 with 95% CI of 0.36 to 1.06. Similarly, a significantly low O/E of 0.3 (CI : 0.6 - 0.88) was obtained on comparison of prevalence of anomalies in female offspring of radiation workers to those of non-radiation workers.

Table 7: Comparison of Prevalence of Congenital Anomalies in Offspring of Radiation Workers vs. Offspring of Non-Radiation Workers of KAPS

Groups Compared	Male Offspring			Female Offspring		
	Observed cases O	Expected cases E	O/E (95%CI)	Observed cases O	Expected Cases E	O/E (95%CI)
Offspring of Radiation Workers (KAPS) vs. Offspring of Non-Radiation Workers (KAPS)	15	23.4	0.64 (0.36-1.06)	3	9.85	0.30 (0.06-0.88)

E =Expected based on the corresponding comparison group, adjusted for age.
CI= Confidence Interval.

The prevalence of congenital anomalies in the male offspring of employees was 2.3% and in females it was 0.6% giving an overall prevalence of 1.5%. An earlier exhaustive study at a large maternity hospital catering to the Mumbai population, has reported the prevalence of congenital anomalies in the new born on clinical examination only, to be 1.4% (Master-Notani et al, 1968).

11. CONCLUSION

This survey was carried out among the employees of the Kakrapar Atomic Power Station and their spouses and offspring. The study end points were prevalence of malignancies in the above 3 groups as well as prevalence of congenital anomalies in the offspring, to be compared with suitable controls. Prevalence, no doubt, is not such a desirable study-end-point for evaluating etiological associations, and a cohort follow-up study would be the method of choice. Nonetheless, cross-sectional surveys do provide important indicators.

In the present survey, it was of interest to study if prevalence of malignancies in radiation workers was different from that in non-radiation workers. However no malignancies were observed in any employee. This was not surprising since the employee group was very small, less than 1500 individuals. Furthermore, cancer is a disease of old age, while almost 80% of employees were below 40 years of age.

Similarly, there were no malignancies seen in the spouses and offspring of employees as well. Again, both these groups were small, less than 1500 individuals. Almost 80% of spouses also, expectedly, were below 40 years of age.

As regards congenital anomalies in the offspring of employees, the prevalence in a comparable cross-section of the population was not available with which the data of the present survey could be compared. Internal comparison yielded lower prevalence of anomalies in offspring of radiation workers as compared to that of non-radiation workers. However, this comparison is of

limited value, since it does not answer the question of in-utero exposure. The small group of 17 female radiation workers in this survey received minuscule cumulative radiation doses varying from less than 0.2 mSv to 2.5 mSv. All the annual doses were below 1.7 mSv. Thus annual exposure was even lower than the 2 mSv, a dose limit set by AERB/ICRP for exposure of a pregnant employee. The prevalence of congenital anomalies in the offspring in the present survey was only 1.5% which did not seem to be high.

The cumulative dose distribution in the radiation workers provided by Kakrapar DAE Centre has been shown in Appendix A. Most of the radiation workers do not receive any significant dose. Even the dose received is generally kept well within the upper-bound of annual dose stipulated by ICRP/AERB and is thus not likely to cause any health effects. The mean cumulative radiation dose per worker is 8.9 mSv for males and 0.8 mSv for females. Furthermore the dose received by the family members or the members of the general population residing near KAPS is a small fraction of the dose permitted by AERB/ICRP for the public.

Undoubtedly, the study group is small and therefore no definitive conclusion can be drawn. Nonetheless, these numbers would help augment the base, when the analysis is done on the data pooled across all power stations.

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APPENDIX A

Radiation Exposure Data Of Kakarapar DAE Employees.

DOSE DISTRIBUTION OF KAKARAPAR DAE EMPLOYEES

Table 1: Cumulative Radiation Dose in mSv from Initial Employment upto December 1995 of Kakrapar Radiation Workers, by Age and Sex

A) MALES

Exposure (in mSv)	No.of Persons in Different Age Groups 18-	30-	40-	50+	Total	%
0-	181	215	41	54	491	41.0
1-	376	148	28	36	588	49.1
10-	47	9	1	2	59	4.9
20-	11	9	4	3	27	2.3
50-	0	3	4	0	7	0.6
100-	0	4	7	1	12	1.1
200-	0	2	5	3	10	0.8
400+	0	0	0	3	3	0.3
Total	615	390	90	102	1197	100.0

Mean Cumulative Radiation dose per worker = 8.9 mSv

B) FEMALES

Exposure (in mSv)	No.of Persons in Different Age Groups 18-	30-	40-	50+	Total	%
0-	8	3	0	0	11	64.7
1-	6	0	0	0	6	35.3
Total	14	3	0	0	17	100.0

Mean Cumulative Radiation dose per worker = 0.8 mSv

APPENDIX B

Kakrapar Study Population Distribution By Age, Sex And Radiation Status

Table 1: Distribution by Age,Sex and Radiation status of Kakrapar Study Population (1995-96)

A] Employees :

Sex / Radiation status	Age <20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
Males											
Radiation Workers	0	159	456	280	110	56	34	67	35	0	1197
Non-Radiation Workers	0	12	33	30	25	16	13	4	4	0	137
Total	0	171	489	310	135	72	47	71	39	0	1334
Females											
Radiation Workers	0	2	12	2	1	0	0	0	0	0	17
Non-Radiation Workers	0	6	22	15	8	5	6	1	0	0	63
Total	0	8	34	17	9	5	6	1	0	0	80

B] Spouses of Employees :

Sex	Age 15-	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
Males	0	1	4	7	7	0	0	0	0	0	19
Females	28	277	318	154	81	73	49	19	4	0	1003
Total	28	278	322	161	88	73	49	19	4	0	1022

C] Offspring of Employees :

i) Offspring of Radiation Workers

Sex	Age 0-4	5-9	10-14	15-19	20-24	25-29	30-34	Total
Males	244	182	118	87	59	5	0	695
Females	256	164	79	67	46	1	1	614
Total	500	346	197	154	105	6	1	1309

ii) Offspring of Non-Radiation Workers

Sex	Age 0-4	5-9	10-14	15-19	20-24	25-29	30-34	Total
Males	34	38	25	20	10	0	0	127
Females	26	34	15	14	11	0	1	101
Total	60	72	40	34	21	0	1	228

APPENDIX C

BARC (Mumbai) Data

Table 1: Distribution of BARC(Mumbai) study population by Age, Sex and Radiation Status (1994).

A] Employees :

Sex / Radiation status	Age <20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
Males											
Radiation Workers	0	6	58	214	288	325	519	573	417	16	2416
Non.Radiation Workers	9	497	1826	2204	1896	1787	1926	2011	1479	101	13736
Total	9	503	1884	2418	2184	2112	2445	2584	1896	117	16152
Females											
Radiation Workers	0	0	12	19	13	20	20	21	8	1	114
Non.Radiation Workers	2	163	616	522	268	328	333	243	110	5	2590
Total	2	163	628	541	281	348	353	264	118	6	2704

B] Spouses of Employees :

Sex	Age 15-	20-	25-	30-	35-	40-	45-	50-	55-	60+
Males	0	3	48	139	142	141	166	168	145	95
Females	70	851	2135	2196	1992	2443	2287	1142	169	13
Total	70	854	2183	2335	2134	2584	2453	1310	314	108

C] Offspring of Employees :

Sex / Radiation status	Age <1	1-4	5-9	10-14	15-19	20-24	25+	Total
Males								
Rad.Workers Children	24	171	324	430	552	546	200	2247
Non-Rad. Workers Children	313	1649	2293	2281	2462	2188	1013	12199
Total	337	1820	2617	2711	3014	2734	1213	14446
Females								
Rad.Workers Children	33	174	324	385	474	441	131	1962
Non-Rad. Workers Children	299	1578	2210	2075	2163	1717	641	10683
Total	332	1752	2534	2460	2637	2158	772	12645

Table 2: Prevalent Cases of Cancer in Employees of BARC(Mumbai) by Age, Sex, Radiation status and Site (ICD 9th), 1994

A] Radiation Workers (Males) :

		AGE GROUPS										
ICD 9TH	SITE	<20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
152	SMALL INTESTINE								1			1
154	COLON								1	2		3
162	LUNG							1	1			2
202	NON.HODGKIN'S LYMPHOMA								1			1
205	LEUKEMIA MYELOID							1				1
TOTAL		0	0	0	0	0	0	2	4	2	0	8

B] Radiation Workers (Females) :

		AGE GROUPS										
ICD 9TH	SITE	<20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
180	CERVIX							1				1
202	NON.HODGKIN'S LYMPHOMA							1				1
TOTAL		0	0	0	0	0	0	2	0	0	0	2

C] Non-Radiation Workers (Males) :

		AGE GROUPS										
ICD 9TH	SITE	<20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
143	ALVEOLUS		1									1
145	PALATE								1			1
150	ESOPHAGUS						1					1
151	STOMACH						1		3	2		6
154	RECTUM							1				1
155	LIVER									1		1
157	PANCREAS							1		1		2
160	ETHMOID						1	1				2
161	LARYNX								1			1
162	LUNG								2			2
162	TRACHEA					1						1
170	BONE							1				1
171	CONNECTIVE TISSUE							1				1
172	MELANOMA						1					1
185	PROSTATE					1						1
188	BLADDER							2		1		3
189	URETER							1		1		2
191	BRAIN								1			1
193	THYROID						2		1			3
195	ILL DEFINED SITES				1				1			2
201	HODGKIN'S LYMPHOMA		1									1
202	OTHER LYMPHOMA								1	1		2
204	LEUKEMIA LYMPHOID				1					1		2
205	LEUKEMIA MYELOID						1					1
TOTAL		0	2	0	2	2	7	8	11	8	0	40

D] Non-Radiation Workers (Females) :

		AGE GROUPS										
ICD 9TH	SITE	<20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
174	BREAST						2	1	1	1		5
183	OVARY					1						1
TOTAL						1	2	1	1	1		6

Table 3: Prevalent cases of cancer in Spouses of Employees of BARC(Mumbai) by age,sex and site (ICD 9th), 1994

A) MALES

		AGE GROUPS										
ICD 9TH	SITE	<20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
191	BRAIN				1							1
TOTAL					1							1

B) FEMALES

		AGE GROUPS										
ICD 9TH	SITE	<20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
151	STOMACH							1				1
153	COLON				1	1	1					3
154	RECTUM					1				1		2
162	LUNG						1					1
171	CONNECTIVE/ SOFT TISSUE					1						1
174	BREAST				2	3	6	11	7	1		30
179	UTERUS					1			1			2
180	CERVIX						1			1		2
183	OVARY						2	2	1			5
184	VAGINA						1					1
191	BRAIN				1							1
193	THYROID						1	1	1			3
205	LEUKEMIA MYELOID			1	1							2
TOTAL		0	0	1	5	7	13	15	10	3	0	54

Table 4: Prevalent Cases of Cancer in Offspring of Employees of BARC(Mumbai)+ by Age,Sex and Site (ICD 9th), 1998

A) MALES

		AGE GROUPS						
ICD 9TH	SITE	<5	5-	10-	15-	20-	25-	Total
171	CONNECTIVE/ SOFT TISSUE				1	1		2
173	SKIN OTHER			1				1
186	TESTIS				1			1
191	BRAIN		1	1				2
202	NON.HODGKIN'S LYMPHOMA						1	1
205	LEUKEMIA MYELOID				1			1
	TOTAL	0	1	2	3	1	1	8

B) FEMALES

		AGE GROUPS						
ICD 9TH	SITE	<5	5-	10-	15-	20-	25-	Total
191	BRAIN						1	1
	TOTAL	0	0	0	0	0	1	1

+Note: All cases were in offspring of the Non-Radiation Workers.

APPENDIX C

Table 5: CONGENITAL ANOMALIES OBSERVED IN OFFSPRING OF EMPLOYEES OF BARC(Mumbai) (1994)

CONG.ANOMALIES (ICD 9TH : 740-759)	Males No.(Age)(Parent/Employee's Rad.Status)	Females No.(Age)(Parent/Employee's Rad. Status)	Total
1.Central Nervous System (740-742)			
Microcephalus	1(12) (NR)	3(2,7,14) (NR,NR,R)	4
Hydrocephalus	5(1,2,5,14,15)(NR,NR,NR,NR,NR)	1(8) (NR)	6
Meningomyelocele	1(4) (NR)	2(4,15) (NR,NR)	3
total	7	6	13
2.Cardio-Vascular System (745-747)			
Pulm.Valvotomy	1(1) (NR)	-	1
Atrial Septal Defect(ASD)	6(2,2,4,6,16,19) (NR,NR,NR,NR,NR,NR)	11(1,2,4,46,12,15,20,29,22,25) (NR,NR,NR,NR,NR,NR,NR,NR,NR,R,R)	17
Ventricular Septal Defect(VSD)	9(1,9,12,12,17,18,24,27,20) (NR,NR,NR,NR,NR,NR,NR,NR,R)	7(1,2,5,19,8,12,17) (NR,NR,NR,NR,R,R,R)	16
ASD + VSD	1(11) (NR)	-	1
Fallot's Tetrology	3(3,14,16) (NR,NR,NR)	-	3
Cong.Heart	5(3,4,13,20,4)(NR,NR,NR,NR,R)	2(10,10) (NR,NR)	7
Patent Ductus Arteriosus	3(8,13,16) (NR,NR,NR)	3(0,6,18) (NR,NR,NR)	6
total	28	23	51
3.Musculo-skeletal System (754-756)			
Talipes	2(3,26) (NR,NR)	-	2
Talipes equinovarus	1(9) (NR)	-	1
Polydactyly	-	1(4) (NR)	1
total	3	1	4
4.Digestive System (749-751)			
Cleft Lip + Palate	1(1) (NR)	2(21,26) (NR,NR)	3
Cleft Palate	1(8) (NR)	4(3,5,7,7) (NR,NR,NR,R)	5
total	2	6	8
5.Genito-Urinary System (752-753)			
Hypospadias	1(19) (NR)	-	1
Undescended Testis	1(20) (NR)	-	1
Cong.Hydronephrosis	-	1(4) (NR)	1
total	2	1	3
6.Syndrome			
Down's Syndrome (758)	10(2,3,7,8,10,14,18,19,20,21) (NR,NR,NR,NR,NR,NR,NR,NR,NR,R)	3(11,20,2) (NR,NR,R)	13
7.Hereditary Condition			
*Thalassemia (282)	3(1,8,10) (NR,NR,NR)	2(11,26) (NR,NR)	5
Total	55(0.4%)	42(0.3%)	97(0.4%)
Total no. of offspring	14446	12645	27091

* This anomaly falls outside the range of ICD-9th 740-759

APPENDIX D

Annual Age-Adjusted Cancer Incidence Rate Per 100,000 Population From 6 Population-Based Indian Registries, 1989

APPENDIX D

Table :Annual Age-Adjusted (World Population) Cancer Incidence Rate per 100,000 persons, India. **Males; 1989**

		REGISTRY					
ICD9th	SITE	BANGALORE	BOMBAY	MADRAS	DELHI	BHOPAL	BARSHI
140	LIP	0.4	0.3	0.6	0.5	0.2	0.0
141	TONGUE	4.7	6.5	5.3	7.7	13.2	2.1
142	SALIVARY GLAND	0.8	0.4	0.4	0.8	0.5	0.5
143	GUM	0.6	1.5	0.9	1.1	1.3	1.4
144	FLOOR OF MOUTH	0.3	0.6	0.1	0.2	1.0	0.0
145	OTHER MOUTH	2.1	3.7	6.3	2.4	8.1	2.0
146	OROPHARYNX	1.9	3.2	1.9	3.2	3.8	0.0
147	NASOPHARYNX	0.6	0.6	0.6	0.6	0.0	0.0
148	HYPOPHARYNX	5.9	8.2	6.5	2.3	8.4	3.5
149	PHARYNX	0.2	1.8	1.0	0.6	2.3	1.3
150	OESOPHAGUS	9.4	11.5	10.2	6.4	7.7	6.7
151	STOMACH	9.5	7.0	16.5	3.4	3.7	1.2
152	SMALL INTESTINE	0.0	0.5	0.1	0.2	0.0	0.0
153	COLON	2.7	4.0	2.0	2.0	1.4	2.0
154	RECTUM	4.3	3.9	4.5	3.0	5.5	4.0
155	LIVER	3.2	3.5	1.9	2.2	2.1	2.6
156	GALLBLADDER	0.5	1.6	0.3	1.9	2.6	0.0
157	PANCREAS	1.7	2.5	1.4	2.3	2.4	0.0
158	RETROPERITONEUM	0.9	0.3	0.1	0.3	0.0	2.1
159	OTHER DIGESTIVE	0.8	0.7	0.0	0.6	0.0	0.0
160	NASAL CAVITY	0.3	1.4	0.6	0.5	1.6	0.0
161	LARYNX	4.1	8.8	5.5	8.6	2.9	1.3
162	LUNG	8.6	14.6	11.1	11.9	14.1	2.0
163	PLEURA	0.6	0.2	0.2	0.2	0.4	0.0
164	THYMUS	0.1	0.1	0.2	0.1	0.0	0.0
165	OTHER RESPIRATORY	0.0	0.0	0.0	0.0	0.0	0.0
170	BONE	1.3	0.8	0.9	1.2	0.6	0.0
171	CONNECTIVE TISSUE	0.6	1.5	1.0	1.5	0.8	1.0
172	SKIN MELANOMA	0.1	0.3	0.3	0.2	0.0	0.0
173	SKIN OTHER	2.0	1.3	2.2	1.4	0.7	2.7
175	BREAST MALE	0.2	0.3	0.7	0.7	0.0	0.0
185	PROSTATE	7.1	6.9	3.6	6.3	5.6	1.9
186	TESTIS	0.6	0.9	1.1	0.7	0.1	0.8
187	PENIS	1.8	1.6	2.8	1.7	0.6	5.1
188	URINARY BLADDER	2.7	4.2	3.8	5.6	0.6	0.8
189	KIDNEY	1.1	1.4	0.9	1.8	0.7	0.4
190	EYE	0.2	0.4	0.3	0.2	0.2	0.0
191	BRAIN	3.8	3.0	1.8	3.4	3.2	0.0
192	NERVOUS SYSTEM	0.2	0.1	0.0	0.1	0.0	0.0
193	THYROID	0.9	0.7	0.9	0.8	0.3	0.5
194	OTHER ENDOCRINE	0.1	0.2	0.1	0.3	0.0	0.0
195	ILL DEFINED	1.1	0.3	0.9	1.8	0.0	0.7
196	SECONDARY LYMPH	1.9	3.5	2.0	0.0	1.3	1.9
197	SECONDARY RESPI	1.7	2.6	3.3	0.4	2.8	1.4
198	SECONDARY OTHER	0.7	1.5	0.9	0.1	0.7	0.0
199	PRIM UNKNOWM	9.0	1.1	3.3	11.6	0.0	2.1
200	LYMPHOSARCOMA	0.4	1.3	0.6	0.0	0.0	0.7
201	HODGKINS	2.4	1.2	1.7	1.6	1.5	1.0
202	OTHER LYMPHOID	2.7	2.7	3.3	5.1	0.5	1.2
203	MULTIPLE MYELOMA	0.6	1.3	0.5	2.7	0.3	0.0
204	LEUKEMIA LYMPHOID	1.6	1.6	1.5	2.5	1.5	0.8
205	LEUKEMIA MYELOID	2.3	1.9	1.4	2.5	0.7	1.9
206	LEUKEMIA MONOCYTIC	0.1	0.0	0.2	0.0	0.0	0.0
207	LEUKEMIA OTHER	0.0	0.2	0.0	0.0	0.0	0.0
208	LEUK UNSPECIFIED	0.7	0.3	0.3	1.3	0.2	0.0
	ALL SITES	112.2	130.4	118.5	118.8	106.2	57.6

APPENDIX D

Table :Annual Age-Adjusted (World Population) Cancer Incidence Rate per 100,000 persons, India. **Females; 1989**

		Registry					
ICD9TH	SITE	BANGALORE	BOMBAY	MADRAS	DELHI	BHOPAL	BARSHI
140	LIP	0.1	0.2	0.3	0.3	0.0	0.0
141	TONGUE	1.0	1.9	2.1	1.3	1.4	0.0
142	SALIVARY GLAND	0.5	0.3	0.2	0.5	0.0	0.0
143	GUM	2.8	1.0	1.5	1.1	1.5	0.0
144	FLOOR OF MOUTH	0.4	0.1	0.2	0.0	0.0	0.0
145	OTHER MOUTH	7.9	2.8	6.5	1.4	5.3	0.6
146	OROPHARYNX	0.5	0.6	0.4	1.0	0.5	0.0
147	NASOPHARYNX	0.4	0.2	0.3	0.2	0.5	0.0
148	HYPOPHARYNX	1.2	1.5	2.7	0.6	0.8	0.5
149	PHARYNX	0.1	0.9	0.5	0.0	0.4	0.0
150	OESOPHAGUS	10.2	8.2	7.7	4.6	5.2	1.4
151	STOMACH	4.3	3.4	7.1	2.4	1.1	1.3
152	SMALL INTESTINE	0.0	0.3	0.0	0.2	0.0	0.0
153	COLON	2.3	2.4	0.8	2.0	2.1	0.5
154	RECTUM	2.2	2.6	2.6	1.8	0.0	1.7
155	LIVER	1.0	1.8	0.6	1.1	1.1	0.0
156	GALLBLADDER	0.8	2.3	0.6	6.6	5.2	0.0
157	PANCREAS	1.0	1.8	0.7	1.3	0.8	0.6
158	RETROPERITONEUM	0.5	0.6	0.1	0.3	0.0	0.0
159	OTHER DIGESTIVE	0.5	0.5	0.0	0.3	0.0	0.0
160	NASAL CAVITY	0.4	1.0	0.8	0.4	0.4	0.0
161	LARYNX	0.7	1.3	0.3	1.8	0.5	0.0
162	LUNG	1.6	3.7	1.7	2.2	3.2	0.0
163	PLEURA	0.5	0.2	0.0	0.2	0.5	0.0
164	THYMUS	0.1	0.1	0.0	0.0	0.0	0.0
165	OTHER RESPIRATORY	0.0	0.0	0.0	0.0	0.0	0.0
170	BONE	0.9	0.7	0.6	1.2	1.1	2.4
171	CONNECTIVE TISSUE	0.3	0.9	0.7	1.7	0.5	0.6
172	SKIN MELANOMA	0.1	0.3	0.2	0.2	0.0	0.0
173	SKIN OTHER	1.6	1.2	0.7	1.6	0.7	2.3
174	BREAST FEMALE	22.3	26.1	24.6	28.3	21.9	6.8
179	UTERINE	0.6	1.5	0.4	1.2	0.5	0.0
180	CERVIX UTERI	26.4	19.4	43.5	30.1	24.3	26.2
181	PLACENTA	0.0	0.1	0.2	0.2	0.3	0.0
182	BODY UTERUS	2.0	2.2	1.9	2.5	4.2	0.0
183	OVARY	4.7	7.0	6.0	8.7	6.2	0.9
184	VAGINA	1.4	1.7	2.0	1.5	0.5	1.3
188	URINARY BLADDER	0.8	1.3	1.1	1.0	0.0	0.0
189	KIDNEY	0.4	0.8	0.7	1.4	0.0	0.0
190	EYE	0.0	0.2	0.6	0.4	0.0	0.0
191	BRAIN	1.7	2.2	0.8	2.6	1.6	0.0
192	NERVOUS SYSTEM	0.0	0.1	0.0	0.1	0.0	0.0
193	THYROID	3.2	2.0	1.1	2.2	2.1	0.0
194	OTHER ENDOCRINE	0.1	0.1	0.1	0.1	0.0	0.0
195	ILL DEFINED	0.7	0.5	0.4	1.5	0.0	1.3
196	SECONDARY LYMPH	0.6	1.3	0.6	0.0	0.2	0.7
197	SECONDARY RESPI	0.8	1.9	2.4	0.5	2.2	0.0
198	SECONDARY OTHER	0.5	1.2	0.5	0.0	1.0	0.0
199	PRIM UNKNOWN	7.4	0.7	3.8	12.1	0.0	1.1
200	LYMPHOSARCOMA	0.2	0.9	0.3	0.0	0.0	0.6
201	HODGKINS	0.7	0.7	0.7	1.0	0.2	0.0
202	OTHER LYMPHOID	1.9	2.1	1.5	2.4	0.5	1.4
203	MULTIPLE MYELOMA	0.7	0.6	0.2	2.1	0.5	0.0
204	LEUKEMIA LYMPHOID	0.6	1.1	0.5	1.4	0.6	0.0
205	LEUKEMIA MYELOID	2.0	1.3	0.9	2.0	0.5	0.0
206	LEUKEMIA MONOCYTIC	0.0	0.0	0.2	0.1		0.0
207	LEUKEMIA OTHER	0.0	0.1	0.0	0.0	0.0	0.0
208	LEUK UNSPECIFIED	0.9	0.4	0.2	1.1	0.0	0.0
	ALL SITES	124.7	120.4	135.0	140.7	100.1	52.2

APPENDIX E

Glossary Of Terms Used

APPENDIX F

Abbreviations

GLOSSARY OF TERMS USED

Cross-Sectional Study	:	One of the observational analytical epidemiological methods to examine relationship between disease and other variables of interest as they exist in a defined population at a particular time. (The other two well-known methods in this category are Cohort studies and Case-Control studies).
Incidence Rate	:	The rate of occurrence of a disease within a specified period; expressed as number of cases per unit of population per unit of time. In particular, cancer incidence rate is conventionally expressed per 100,000 population, per year.
Ionizing Radiation	:	Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.
Morbidity	:	1. The condition of being diseased. 2. The incidence, or prevalence, of illness in a group.
Mortality Rate	:	Is analogous to incidence rate but refers to the occurrence of death rather than the occurrence of disease and is expressed as number of deaths per unit of population per unit of time.
Prevalence	:	The number of cases of a disease in existence at a given time per unit of population.
Relative Risk	:	Expression of risk due to exposure, as a ratio of the risk among the exposed to that among those not exposed.
Sievert (Sv)	:	SI unit of radiation dose equivalent. It is equal to absorbed dose in Gray, times a quality factor, times other modifying factors.
TLD	:	Thermoluminescent Dosimeter.

ABBREVIATIONS

AERB	:	Atomic Energy Regulatory Board
BARC	:	Bhabha Atomic Research Centre
COCES	:	Corporate Committee for the Epidemiological Studies (Constituted by NPC)
DAE	:	Department of Atomic Energy
ICRP	:	International Commission on Radiological Protection
NPC	:	Nuclear Power Corporation
PISCES	:	Planning and Implementation Supervisory Committee for Epidemiological Studies (Constituted by NPC)
STAG	:	Senior Technical Advisory Group (Constituted by NPC)
TMC	:	Tata Memorial Centre
TMH	:	Tata Memorial Hospital

APPENDIX G

Composition of Committees
(COCES, STAG, PISCES)

APPENDIX G

CORPORATE COMMITTEE FOR THE EPIDEMIOLOGICAL STUDIES (COCES) (1992-)

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	M.D., NPC	
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	Mr. S.K. Chattarjee	
	Mr. Y.S.R.Prasad	
2.	ED (P&F), NPC	- Member
	Mr. C.K.Koshy	
	Mr. R.C. Joshi	
3.	ED (O), NPC	- Member
	Mr. K. Nanjundeswaran	
	Sri C.H. Surendar	
4.	Director,	
	National Institute of Occupation Health (NIOH)	
	Ahmedabad	- Member
	Dr. S.K. Kashyap	
	Dr. S.P.Sayed	
5.	Director	
	(Health Safety & Environment) BARC, Mumbai	- Member
	Dr. D.V. Gopinath	
	Dr. U.C. Mishra	
6.	Director, TMC	- Member
	Dr. P.B. Desai	
	Dr. K.A. Dinshaw	
7.	Director,Biomedical Group, BARC, Mumbai	- Member
	Dr. C.R. Bhatia	
	Dr. P.C. Kesavan	
8.	Director (E & PA), NPC	- Member
	Mr. B.N. Jayram	
	Mr. M.L. Mitra	
9.	Director (Health & Safety), NPC	- Member Secretary
	Dr. L.G.K. Murthy	
	Mr. G.R. Srinivasan	
	Mr. B.K.Bhasin	
	Mr. M. Das, Chief Engineer	
10.	Director, TMH	- Member
	Dr. R.S. Rao	
	Dr. K.A. Dinshaw	
11.	Director, CRI	- Member
	Dr. M.G. Deo	
	Dr. A.N. Bhisey	

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3. Mr. K. Muthuswamy, CAO, TMC
4. Mr. G.V. Nadkarni, Consultant E&PA, NPC
5. Mr. B.M.L. Sah, Head, Health Physics Group, NPC
6. Mr. V. Rangarajan, Director(O), NPC
7. Dr. I.S. Bhatt, Head, EG, Directorate of E&PA, NPC
8. Dr. S.A. Pradhan, Surgeon, TMH
9. Mrs. P.N. Notani, Consultant, TMH
10. Dr.B.S.Arya, Medical Officer, TAPS Hospital, Tarapur
11. Dr.P.K.Sinha, Medical Supdt, KAPS Hospital, Kakrapar.
12. Mr. M.R.Sachdev, Health Physicist, NPC
13. Dr. S.K. Dave, Dy.Director, NIOH

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2. Dr. R.S. Rao, Director, TMH	- Member
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4. Dr. K.C. Pillai, Head Health Physics Division,BARC	- Member
5. Dr. L.D. Sanghvi, TMH	- Member
6. Dr. Chattopadhyay, NIOH, Ahmedabad	- Member
7. Dr. D.B. Mendhekar, Medical Officer,TAPS	- Member
8. Dr. (Ms) K.A. Dinshaw, Head, Radiation oncology, TMH	- Member
9. Dr. P.S.S. Sundar Rao Prof. and Head, Dept. of Biostatistics Christian Medical College, Vellore	- Member
10. Dr. S.S. Agarwal Prof.& Head, Dept. of Genetics Sanjay Gandhi Post Graduate Institute of Medical Sciences, Lucknow	- Member
11. Dr. I.C. Verma Prof. of Pediatrics Dept. of Genetics, All India Institute of Medical Sciences, Ansari Nagar, New Delhi	- Member
12. Sri. B.M.L. Sah, Head Health Physics Group, NPC	- Member Secretary

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4.	Mr. S. Krishnamony Mr. V.K.Gupta Head, Health Physics Division,BARC	- Member
5.	Dr. Chattopadhyay,Dy.Director ,NIOH, Ahmedabad Dr. S.K.Dave, Dy.Director, NIOH	- Member
6.	Dr. P.S.S. Sundar Rao Director, Schieffelin Leprosy Research and Training Centre, Karigiri	- Member
7.	Dr. S.S. Agarwal Prof.& Head, Dept. of Genetics Sanjay Gandhi Post Graduate Institute of Medical Sciences, Lucknow	- Member
8.	Dr. I.C. Verma Prof. of Pediatrics Dept. of Genetics, All India Institute of Medical Sciences, Ansari Nagar, New Delhi	- Member
9.	Dr.B.S.Arya, Medical Supdt. TAPS Hospital, Tarapur	- Member
10.	Mrs. P.N.Notani, Honorary Consultant, TMH	- Member
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12.	Mr. B.M.L. Sah Mr. M.R.Sachdev Health Physics Group, NPC	- Member Secretary

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2. Shri M.L.Mitra, Director, E & PA, NPC
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4. Dr.I.S.Bhat, Head, Environment Group, NPC
5. Dr. Ganesh B, TMH
6. Dr. G. Narayanan, Director, Govt. Arinagar Anna Memorial Cancer Research Institute, Kanchipuram
7. Dr. M.Yunus, Professor & Chairman, Dept. of Community Medicine, J.N.Medical College, Aligarh.
8. Mr. M.R.Sachdev, Health Physics Group, NPC
9. Mr. B.K.Bhasin, SD, TAPS
10. SD, RAPS
11. SD, KAPS
12. SD, NAPS
13. SD, MAPS
14. Dr.B.S. Arya, Medical Supdt., TAPS Hospital, Tarapur
15. Dr.N.K.Ajmera, Medical Supdt., RAPS Hospital, Rawatbhata
16. Dr.M. Nagarajan, Medical Supdt, DAE Hospital, Kalpakkam
17. Dr.S.K.Jain, Medical Supdt., NAPS Hospital, Narora
18. Dr.P.K.Sinha, Medical Supdt., KAPS Hospital, Kakarapar
19. Dr.K.R.Lele, TMH
20. Mr. A.C.R. Subba Reddy, MS, Kaiga

SUB-COMMITTEE OF SENIOR TECHNICAL ADVISORY GROUP (STAG)

1. Mrs. P.N.Notani, Hon. Consultant, TMH - Member & Convener
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3. Dr. A. Seshan, BARC Hospital, Mumbai - Member
4. Dr. K.S.V.Nambi, Head, EAD,BARC,Mumbai - Member
5. Dr. Ganesh B, TMH - Member
6. Mr. S.D.Talole, TMH - Member

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4. Dr. S.H.Advani, Head,Medical Oncology, TMH - Member
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6. Shri. P.Vishwanathan, Head, Health Physics Dept. TMH - Member
7. Dr. A.N.Bhise, CRI - Member
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2. Dr.B.S.Vachharajani, TAPS
3. Dr.S.K.Dave, Dy.Director, NIOH, Ahmedabad
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7. Dr.B.Warad, TMH
8. Mr.S.D.Talole, TMH