EFFECTS OF LOW-DOSE IONIZING RADIATION AMONG THE EMPLOYEES AT THE NARORA ATOMIC POWER STATION: A CROSS-SECTIONAL STUDY

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Report Prepared
by
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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 in Maharashtra; Rawatbhata in Rajasthan; Kalpakam in Tamil Nadu; Narora in Uttar Pradesh; Kakrapar in Gujarat and Kaiga in Karnataka.

NPCIL set up a Corporate Committee for Epidemiological Studies (COCES). The first meeting of COCES was held on 6th April 1992. 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 as the officer in-charge of Epidemiological Surveys. These committees met periodically. In the initial phase of the study, several issues were debated and decisions were taken regarding the target population, the controls, the types of health indicators to be studied, the instrument for data collection and several technical issues.

Tarapur Atomic Power Station was the first site selected for the survey, because of its proximity to the Tata Memorial Hospital (TMH), which allowed enumerators, statistician and doctors from TMH to visit the site regularly to carry out the work. This was followed by Kakrapar Atomic Power Station. Besides these two power stations, the data at other power stations were collected by the local

academic/medical institutes as per the guidelines provided by TMH and the data transported to the Epidemiological Studies Cell at TMH for processing and analysis.

Todate four reports of surveys carried out at Atomic Power Stations located at Tarapur, Kakrapar, Rawatbhata and now Narora Power Station have been generated. The Department of Community Medicine, Jawaharlal Nehru Medical College, Aligarh Muslim University, Aligarh, was responsible for collection of data at the Narora Atomic Power Station.

One of the important results yielded by all these surveys carried out upto now, at various power stations, is that there is no increase in the prevalence of malignancies in the radiation workers as compared to non-radiation workers. There was also no difference in the prevalence of malignancies, if encountered, in the 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
Director, TMC

CONTENTS

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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 of India Limited (NPCIL) recognised the need for more precise information on the biological effects of low dose radiation on human population. In response to this concern NPCIL 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 stations/projects sites. At Tarapur and Kakrapar Power Stations, TMC undertook the survey. The surveys at other sites have been conducted by nearby academic/medical institutions as per the procedures standardised by TMC, and the data were 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 Narora Atomic Power Station (NAPS) during 1997 by the Department of Community Medicine, Jawaharlal Nehru Medical College, Aligarh Muslim Universiy, Aligarh and covers 1598 employees, 1433 spouses of employees and 3746 offspring of employees. The prevalence of malignancies in these three groups has been studied and the prevalence of congenital anomalies in the offspring of employees has also been reported on.

There was no statistically significant difference between the prevalence of malignancies in radiation workers as compared to that of non-radiation workers of Narora Atomic Power Station. The observed (O) to expected (E) ratio of prevalent cases in males was 2.20 (2/0.91) with 95% confidence limit (CI) of 0.27 to 7.94. Similarly no significant difference in the prevalence of malignancies was observed between the radiation workers of NAPS and non-radiation workers of Bhabha Aomic Research Centre (BARC, Mumbai), [O/E = 1.01(2/1.99), 95% CI = 0.12 - 3.65]. The female employee group was very small and there were no cancer cases in this group. Numerous studies have demonstrated that a cohort of workers is healthier than the general population cohort (healthy worker effect), and they experience lower risks for cancer and other diseases. To avoid this bias, general population controls were not utilized.

There is no exposure to radiation of nuclear installation origin, to the spouses and offspring of employees. There were no cancer cases reported in both these groups and therefore the question of comparing the prevalence with suitable control groups does not arise.

There were 18 cases of congenital anomalies (major and minor) among 3746 offspring of employees, giving a prevalence of 0.5% (0.6% in males and 0.3% in females). The prevalence of congenital anomalies in the offspring does not seem to be high.

In conclusion, no increase in cancer prevalence was observed in the radiation workers of NAPS as compared to that in non-radiation workers. This finding has been consistently observed at all the power stations where the surveys

have been carried out to date viz. Tarapur Atomic Power Station, and Rajsthan Atomic Power Station. However at Kakrapar Atomic Power Station, there was not a single case of cancer in the employees both in the radiation and non-radiation workers.

EFFECTS OF LOW-DOSE IONIZING RADIATION AMONG THE EMPLOYEES AT THE NARORA ATOMIC POWER STATION : A CROSS-SECTIONAL STUDY

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 of India Limited (NPCIL) recognized the need for more precise information on the biological effects of low dose radiation on human population. In response to this concern, the NPCIL 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). NPCIL also constituted various committees (composition given in Appendix G) to monitor the progress of the project. TMC conducted the survey at 2 sites viz. Tarapur DAE Centre and Kakrapar Atomic Power Station. For surveys at other stations TMC provided guidelines regarding the format for data collection, the questionnaire, and the software for data entry. This data were then transferred to TMC for processing and analysis, at its Epidemiological Studies Cell especially set up for the purpose.

This report deals with the data collected at Narora Atomic Power Station (NAPS).

2. OBJECTIVES

The general aim of the project was to conduct health survey in the 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

Department of Community Medicine, J. N. Medical College, Aligarh Muslim University, Aligarh, collected the data for this survey at Narora Atomic Power Station (NAPS). The actual data collection was initiated in January 1997 and was concluded by December 1997. The survey involved filling a questionnaire with respect to demographic and medical data and other relevant details as well as carrying out medical examination.

3.1 Questionnaire

A detailed questionnaire was designed for collection of information on demographic characteristics, medical and health history and radiation exposure history. Besides, data was 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 was field-tested earlier at Tarapur DAE Centre, and was used in the present survey also.

3.2 Field Survey, Data Collection and Processing

The employees and their families were invited by the local authorities of the NAPS to participate in the survey and to come to the hospital of Narora Atomic Power Station, where investigations were conducted and data collected. The general part of the proforma was filled by the social workers specially appointed for the epidemiological survey. Doctors from J. N. Medical College, Aligarh Muslim University 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 cytological investigations.

The following criteria were set for carrying out these investigations :-

1. All adults above the age of 40 years and smokers 35 years and above had to undergo 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.

The database was created from the completed proformas, with the software installed at NAPS hospital by the Epidemiological Studies Cell. The floppies containing the databases were then transported to this cell for processing and analysis.

4. POPULATION COVERAGE

This report is based on information on 1598 employees, 1433 spouses of employees and 3746 offspring of employees i.e. a total of 6777 individuals as given in Table 1. Of these 5782 members were individually examined and interviewed. On the remaining 995 individuals information on health status with respect to malignancies and additionally for the offspring congenital anomalies, if any, was obtained by reviewing the medical records maintained at NAPS Hospital. Both these conditions are such that they would be brought to the notice of the doctor and recorded and hence there was little likelihood of missing these cases.

Table 1 : Population Covered - Employees, their Spouses and Offspring by Sex (1997)

Groups	Covered in the Survey			Information obtained from the medical records of NAPS			Total
	Males	Females	Total	Males	Females	Total	
Employees	1465	47	1512	84	2	86(5%)	1598(100%)
Spouses	17	1166	1183	3	247	250(17%)	1433(100%)
Offspring	1707	1380	3087	386	273	659(18%)	3746(100%)
Total			5782(85%)			995(15%)	6777(100%)

5. HEALTH OUTCOMES FOR STUDY

The basic study design was a 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 the comparison group. One was to have internal comparison group i.e. compare radiation workers with non-radiation workers of NAPS. 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 carry 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 perhaps 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.

We have therefore made several comparisons for prevalence of cancer in the employees :

1. Radiation Workers of NAPS vs. Non-Radiation Workers of NAPS
2. Radiation Workers of NAPS vs. Non-Radiation Workers of BARC (Mumbai)
3. Overall comparison of Narora data with data of BARC (Mumbai), and separately for :
   a. Radiation Workers, and
   b. Non-Radiation Workers

6.2 Comparison Group for Evaluating Cancer Prevalence in Spouses and Offspring of employees

No prevalent cancer cases were observed in both the groups i.e. spouses and children of employees and hence further discussion regarding the comparison groups utilised, is not relevant.

6.3 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 NAPS 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 there is no reliable information on such an exposure for spouses of male employees. 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. There is only one female radiation worker and she has received negligible cumulative radiation dose of 8.4 mSv.

7. EXPOSURE : DEFINITION AND MEASUREMENT

The details of annual radiation dose received by employees was provided by NAPS. 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 by 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 NAPS is given in Appendix A. The cumulative dose of an employee is measured by adding annual doses from initial employment upto end-1997, when the survey ended. The mean cumulative radiation dose per worker was 40.7 mSv in males and there was only one female radiation worker who has received cumulative radiation dose of 8.4 mSv. Furthermore, not a single annual radiation dose exceeded 250 mSv or more, which is considered to be a radiation incident of medical significance for the United States population (Fry,1980). Infact, almost all the annual radiation doses for 932 radiation workers were below 50 mSv/year, except for 5

employees. Three employees were exposed to annual doses between 50 mSv and 60 mSv, and the other two received annual doses of 62.4 mSv and 77.4 mSv.

8. CHARACTERIZATION OF EMPLOYEE POPULATION : UNIVARIATE DESCRIPTION

Table 2 describes the age and sex distribution of the radiation and non-radiation workers and the distribution by 5 year age interval is given in Appendix B.

Table 2 : Age Distribution of Employees of NAPS by Radiation Status (1997)

	Males		Females	
	Radiation Workers	Non-Radiation Workers	Radiation Workers	Non-Radiation Workers
Age	No.(%)	No.(%)	No.(%)	No.(%)
Upto 39	591(63)	254(41)	1(100)	23(48)
40 - 49	250(27)	263(43)	0	23(48)
50+	90(10)	101(16)	0	2(4)
Total	931(100)	618(100)	1(100)	48(100)

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

It is of importance to see the profile of the radiation and non-radiation workers with respect to other characteristics besides age and sex, which have anyway been adjusted for, and which could influence, exposure-cancer prevalence relationship. This information was available for 1512 (1465 males and 47 females) interviewed employees. The distribution of several characteristics are shown in Table 3 for male employees only, because

Table 3 : Profile of Male Employees (interviewed) of NAPS by Radiation Status (1997)

Group	Radiation Workers (n=891)		Non-Radiation Workers (n=574)		Total (n=1465)	
	No.	%	No.	%	No.	%
• **Marital Status**						
Unmarried	71	8	32	6	103	7
Married	820	92	542	94	1362	93
• **Community**						
Hindu	843	95	551	96	1394	95
Muslims	21	2	15	2	36	2
Christians	6	1	4	1	10	1
Others	21	2	4	1	25	2
• **Education**						
Upto primary	95	10	120	21	215	15
Middle (V-VII std)	62	7	44	8	106	7
Secondary and Technical after SSC (VII-XII Std)	479	54	200	35	679	46
Undergraduate and above	255	29	210	36	465	32
• **Habits**						
No habit	720	81	443	77	1163	79
Chewers only	26	3	12	2	38	3
Smokers only	88	10	83	15	171	12
Alcohol consumers only	9	1	5	1	14	1
Combination of Habits	48	5	31	5	79	5
• **Cadre of Work**						
Administration	9	1	162	28	171	12
Scientific	293	33	45	8	338	23
Technical	463	52	169	30	632	43
Security	29	3	8	1	37	2
Labour	97	11	138	24	235	16
School teacher	0	0	52	9	52	4

there were very few female employees. The radiation and non-radiation workers were found to be similar with respect to marital status (over 90% were married), community distribution (over 95% belonged, as expected, to the majority community), educational level (over 30% had studied upto undergraduate level or above, unlike the general population) and also the habit pattern (about 80% had no habit). Expectedly, there was a higher proportion of administrative staff and lower proportion of scientific/technical staff in the group of non-radiation workers compared to radiation workers.

Such a comparison of radiation workers of NAPS with non-radiation workers of BARC (Mumbai) could not be undertaken, because the information on confounding factors, other than age and sex, was not available on the employees of BARC (Mumbai).

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.

While comparing prevalence of malignancies in different groups, it is essential to control for confounding factors, since a large fraction of cancer rates of a population are affected by local environmental/life style factors (Higginson and Muir, 1979; Doll and Peto, 1981). Since most of the factors looked at, as

shown in Table 3, particularly the life style factors which could affect cancer pattern, are similarly distributed between radiation and non-radiation workers, their confounding effect is likely to be minimal, even though it has not been possible to control for them because of small number of cancer cases in the employees.

All comparisons, however, have been controlled for age and sex differences. The observed (O) number of cases in the 'study' group is compared with the expected (E) number, arrived at from the corresponding control group. This has been calculated under the assumption that the age-specific prevalence, in 5-year age intervals in the study group is the same as that in the corresponding control group and is obtained by summing the products of the age-specific prevalence of the control group with the age distribution of the 'study' group. This has been done individually for males and females. 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 are read from the tables prepared by Bailar and Ederer for the ratio of an observed value of a Poisson variable to its expectation. For interpretation, if the 95% confidence interval covers the null value of unity, then there is no significant difference between the observed and expected values, at the 5% level of significance. If this interval does not cover unity, then the observed value is significantly higher or lower than the expected value depending on whether the interval covers values that are higher or lower than unity.

This methodology is followed for all comparisons that have been undertaken in this document.

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).

In this survey, which is a cross-sectional type, the question is being addressed by assessing prevalence of cancer in the study population comprising of a) employees, b) spouses and c) offspring and comparing it with the prevalence in relevant control groups, to see if there is any excess in disease prevalence.

Besides malignant conditions, prevalence of congenital anomalies in the offspring has also been studied to see the effect of low-dose radiation in the unborn child.

10.1 Employees : Cancer Prevalence

There were three prevalent cancer cases in the employee group and all were males. There was no case of cancer in the small group of female employees. The distribution of cases by radiation status is seen in Table 4.

Table 4 : Prevalent Cancer Cases in Employees of NAPS by Sex and Radiation Status (1997)

Workers		Males	Females	Total
Radiation Workers	No.	931	1	932
	Cases	2	0	2
Non-Radiation Workers	No.	618	48	666
	Cases	1	0	1
Total	No.	1549	49	1598
	Cases	3	0	3

The description of cases giving details of age, sex, year of diagnosis and employee's designation at time of survey, year of joining DAE and radiation status is given in Table 5. Among the male employees the cases were : one each of adenocarcinoma neck, testis and chronic myeloid leukemia.

Ionizing radiation is a proven risk factor for leukemia (excluding chronic lymphoid leukemia). However, in the present [illegible] myeloid leukemia the radiation dose received by the employee from the year of his joining DAE

upto 1995, when he developed the disease was only 9.93 mSv, giving an average annual dose of 0.63 mSv, which is quite negligible.

Table 5: Details of Prevalent Cancer Cases in Employees of NAPS (1997)

Diagnosis (ICD-9th)	Age at time of survey	Sex	Year of Diag.	Year of joining DAE	Designation at time of survey	Cumulative dose in mSv upto the year of diagnosis	Tobacco/ Alcohol use
Adenocarcinoma Neck (Secondary) (196)	42	M	1997	1990	Sweeper	Non-Radiation Worker	No
Testis (186)	36	M	1996	1979	Helper	33.13	No
Chronic Myloid Leukemia (205)	44	M	1995	1979	Helper	9.93	Smoking & Alcohol use

The aetiology of testicular cancer is not so well defined and ionizing radiation has not been implicated as a risk factor. In the present case of testicular cancer the radiation dose received by the employee from the year of his joining DAE upto 1996 when he developed the disease was 33.1 mSv, giving an average annual dose of just 1.9 mSv. The diagnosis of the third case is adenocarcinoma neck and the primary site is not known.

The prevalence of the cancers of all-sites together in the radiation workers (males - 2 cases, females - none) was compared with that in non-radiation workers (males - 1 case, females - none), after adjusting for differences in age distribution.

In males, the observed to expected ratio was 2.20 with 95% confidence interval of 0.27 to 7.94 as seen in Table 6. In female employees there were no cases of cancer in both the groups, radiation workers and non-radiation workers.

Table 6 : Comparison of Cancer Prevalence in Radiation Workers of NAPS with Non-Radiation Workers of 1) NAPS and 2) BARC, Mumbai

Groups Compared	Males			Females		
	Observed cases O	Expected cases E	O/E (95%CI)	Observed cases O	Expected Cases E	O/E (95%CI)
Radiation Workers (NAPS) vs. Non-Radiation Workers (NAPS)	2	0.91	2.20 (0.27-7.94)	0	0	-
Radiation Workers (NAPS) vs. Non-Radiation Workers (BARC, Mumbai)	2	1.99	1.01 (0.12-3.65)	0	0	-

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

Thus, there was no statistically significant excess of prevalent cancer cases (all-sites) in the radiation workers as compared to non-radiation workers of NAPS.

This observation is in line with the results reported by Nambi and Mayya (1997). In their study of cancer mortality of employees of five units of DAE (India), no excess cancer mortality was observed in radiation workers compared to non-radiation workers.

Furthermore, the cancer prevalence in the radiation workers of NAPS has also been compared with the prevalence in non-radiation workers of BARC (Mumbai), adjusting for sex and age differences. Details of the prevalent cancer cases in BARC (Mumbai) employees is given in Appendix C Table 2.

Thus, even when radiation workers of NAPS were compared with the large group of non-radiation workers of BARC (Mumbai), there was no significant difference in cancer prevalence and the observed to expected ratio for males was only 1.01 with 95% of confidence interval of 0.12 to 3.65. (Table 6).

Infact when all male employees of NAPS were compared with BARC (Mumbai) male employees there was no significant difference in cancer prevalence of these 2 groups, (O:3, E:3.58, O/E:0.84, 95% CI:0.17-2.46), and also in the subgroups of radiation workers and non-radiation workers.

No attempt was made to study the dose-response relationship because the number of cases were few in this small group of employees.

10.2 Cancer Prevalence in Spouses and Offspring

Neither benign nor malignant conditions were reported in the spouses or offspring of employees of NAPS.

10.3 Prevalence of Congenital Anomalies in Offspring of Employees

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 foetal 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 foetus.

Table 7 : Prevalence of Congenital Anomalies (Major and Minor) in Offspring of Employees of NAPS (1997)

		Males	Females	Total
Offspring of Radiation Workers	No.	1113	897	2010
	Cases(%)	9(0.81)	2(0.22)	11(0.55)
Offspring of Non-Radiation Workers	No.	980	756	1736
	Cases(%)	4(0.41)	3(0.39)	7(0.40)
Total	No.	2093	1653	3746
	Cases(%)	13(0.62)	5(0.30)	18(0.48)

Table 7 gives the number of congenital anomalies both major and minor observed in the offspring of the employees with details of anomalies given in Table 8. The information on anomalies that might have occurred in the stillborn fetuses or in neonatal deaths was not available.

Table 8: List of Prevalent Congenital Anomalies (Major and Minor) in Offspring of Employees of NAPS (1997)

	Males		Females		Total
CONG.ANOMALIES (ICD 9 th :740-759)	No.(age at survey time)	(Radiation Statusof Parent / employee)	No.(age at survey time)	(Radiation Status of Parent / employee)	
1.Musculo-Skeletal System (754-756)					
Scoliosis	-		1(12)	R	1
Torticollis	1(14)	R	-		1
Pectus carinatum	1(12)	R	-		1
Absence of 3 finger nails	1(10)	R	-		1
Total	3		1		4
2.Gastro-intestinal System (749-751)					
Cleft lip	1(13)	NR	-		1
Cleft palate	1(7)	NR	-		1
Tongue tie	2(3,5)	R,R	-		2
Total	4		-		4
3.Genito-Urinary System (752-753)					
Undescended testis	3(5,6,20)	R,R,R	-		3
*Inguinal hernia	1(4)	NR	-		1
Total	4		-		4
4. Integumentary System (757)					
Skin pigmentation	-		1(5)	R	1
5. Anomalies of Eye (743)					
*Convergent squint (378)	1(6)	NR	2(8,10)	NR,NR	3
6.*Mental Retardation (319)					
?Cause	1(11)	R	1(5)	NR	2
TOTAL	13(0.62%)		5(0.30%)		18(0.48%)
Total Number of Offspring	2093		1653		3746

* These anomalies fall outside the range of ICD-9th 740-759

R : Radiation Worker, NR : Non-Radiation Worker

There are certain anomalies, indicated in Table 8 which fall outside the range of anomalies classified as congenital by the International Classification of Diseases (ICD) codes; 740 to 759. For example, inguinal hernia (ICD 550), though outside the range has been considered in UNSCEAR reports as congenital. Therefore, for the time being we have considered all the observed anomalies for the analysis.

Total number of congenital anomalies (major and minor) recorded were 18 , of which 13 were in male offspring and 5 in female offspring; giving an overall prevalence of 0.5%. The prevalence of congenital anomalies in a comparable cross-section of the population is not available with which the present data could be compared. However, it has been compared with the prevalence in offspring of BARC (Mumbai) employees as shown in Table 9. The detailed description of anomalies in the offspring of BARC employees is given in Appendix C, Table 5. No significant difference in the prevalence of congenital anomalies in the 2 groups was observed [Males: O=13, E=9.64, O/E=1.35, 95% CI=0.72-2.31; Females: O=5, E=5.77, O/E=0.87, 95% CI=0.28-2.03].

Table 9 : 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 NAPS with those of non-radiation workers, as mentioned earlier, is of limited

value, since that would not answer the question of in-utero exposure. However, the results of comparison are shown in Table 10 below. The prevalence of congenital anomalies in male as well as female offspring of radiation workers was not significantly different from the prevalence in the offspring of non-radiation workers. The observed to expected ratios were 1.60 and 0.57 for male and female offspring respectively and were not significantly different from unity.

Table 10: Comparison of Prevalence of Congenital Anomalies in Offspring of Radiation Workers vs. Offspring of Non-Radiation Workers of NAPS

	Males			Females		
Groups Compared	Observed cases O	Expected cases E	O/E (95%CI)	Observed cases O	Expected Cases E	O/E (95%CI)
Offspring of Radiation Workers (NAPS) vs. Offspring of Non-Radiation Workers (NAPS)	9	5.61	1.60 (0.74 - 3.04)	2	3.50	0.57 (0.07 - 2.06)

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

Questions of classificatory nature, nonetheless, still remain to be answered. Whether one should include anomalies falling outside the ICD range like mental retardation where sometimes the cause is given as due to birth injury while at times no information on cause is provided. Overall, the prevalence of congenital anomalies seen in the offspring of employees is only 0.5% (0.6% in males and 0.3% in females). 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 NAPS 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. 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, the survey has provided important indicators. *It has demonstrated that cancer prevalence in radiation workers was not different from the prevalence seen in non-radiation workers both of NAPS as well as of BARC.*

Efforts were made to ensure comparability of exposed and unexposed groups. We have adjusted for the effects of age and sex differences. The distributions of other possible confounding factors were compared for the radiation and non-radiation workers of NAPS and no major differences were observed. Thus, the possibility of biased results is minimized to the extent possible.

The cumulative dose distribution in the radiation workers provided by NAPS is shown in Appendix A. Exposure was defined to classify the employees as radiation workers and non-radiation workers on the basis of whether they were using personal dosimeters or not. Most of the radiation workers do not receive any significant dose. Even the dose received is generally

well within the maximum annual permissible dose as stipulated by International Commission on Radiological Protection as well as Atomic Energy Regulatory Board of India, and is thus not likely to cause any health effects.

Furthermore the annual dose received by the family members or the members of the general population residing near NAPS is a small fraction (0.5%) of the dose permitted (1 mSv) by AERB/ICRP for the public. In the present study, no malignancies were reported in spouses and offspring of employees of NAPS.

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APPENDIX A

Radiation Exposure Data of NAPS Employees

DOSE DISTRIBUTION OF NAPS EMPLOYEES

Table 1: Cumulative Radiation Dose in mSv from Initial Employment upto 1997 of NAPS Radiation Workers, by Age and Sex

A) MALES

Exposure (in mSv)	No. of Persons in Different Age Groups 18-	30-	40-	50+	Total	%
0-	0	0	5	3	8	0.9
1-	21	55	71	27	174	18.7
10-	33	90	55	16	194	20.9
20-	93	170	51	15	329	35.3
50-	22	69	40	18	149	16.0
100-	6	27	20	7	60	6.4
200-	0	5	5	4	14	1.5
400+	0	0	2	1	3	0.3
Total	175	416	249	91	931	100.0

Mean Cumulative Radiation dose per worker = 40.7 ± 1.7 mSv

B) FEMALES

There was only one female radiation employee and cumulative radiation dose was 8.4 mSv

APPENDIX B

NAPS Study Population Distribution By Age, Sex and Radiation Status

APPENDIX B

Table 1: Distribution by Age,Sex and Radiation status of NAPS Study Population (1997)

A] Employees :

	Age										
Sex											
Radiation status	<20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
Males											
Radiation Workers	0	28	147	225	191	165	85	56	31	3	931
Non-Radiation Workers	0	11	35	88	120	182	81	71	28	2	618
Total	0	39	182	313	311	347	166	127	59	5	1549
Females											
Radiation Workers	0	0	1	0	0	0	0	0	0	0	1
Non-Radiation Workers	0	0	4	7	12	16	7	2	0	0	48
Total	0	0	5	7	12	16	7	2	0	0	49

B] Spouses of Employees :

	Age										
Sex	15-	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
Males	0	1	0	4	3	6	4	0	1	1	20
Females	0	89	263	306	351	210	133	45	13	3	1413
Total	0	90	263	310	354	216	137	45	14	4	1433

C] Offspring of Employees :

i) Offspring of Radiation Workers

	Age							
Sex	0-4	5-9	10-14	15-19	20-24	25-29	30-34	Total
Males	203	291	314	193	81	27	4	1113
Females	172	238	243	181	57	5	1	897
Total	375	529	557	374	138	32	5	2010

ii) Offspring of Non-Radiation Workers

	Age							
Sex	0-4	5-9	10-14	15-19	20-24	25-29	30-34	Total
Males	116	216	269	253	101	21	4	980
Females	83	191	241	187	47	7	0	756
Total	199	407	510	440	148	28	4	1736

APPENDIX C

BARC (Mumbai) Data

APPENDIX C

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), 1994

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 IN OFFSPRING OF EMPLOYEES OF BARC(Mumbai) (1994)

CONG.ANOMALIES (ICD 9th : 740-759)	Males No.(Age)(Employee's Rad.Status)	Females No.(Age)(Employee's Rad. Status)	Total
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
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
Talipes	2(3,26) (NR,NR)	-	2
Talipes equinovarus	1(9) (NR)	-	1
Polydactyly	-	1(4) (NR)	1
Total	3	1	4
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
Hypospadias	1(19) (NR)	-	1
Undescended Testis	1(20) (NR)	-	1
Cong.Hydronephrosis	-	1(4) (NR)	1
Total	2	1	3
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
*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.

APPENDIX F

ABBREVIATIONS

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

APPENDIX G

Composition of Committees (COCES, STAG, PISCES)

APPENDIX G

COMPOSITION OF COMMITTEES

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APPENDIX G

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APPENDIX G

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