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

TATA MEMORIAL CENTRE

TATA MEMORLAL HOSPITAL

DR. E. BORGES MARG, PAREL

MUMBAI - 400 012

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TATA MEMORIAL CENTRE

Director, Tata Memorial Centre	: Dr.(Ms.) K.A.Dinshaw
Epidemiological Studies Cell Tata Memorial Hospital	: Mrs. P.N.Notani Hon.Consultant Epidemiologist Mr.S.D.Talole Scientific Officer
Medical Staff Tata Memorial Hospital	: Dr.S.A.Pradhan Surgeon, Chief of Head & Neck "A" Unit Dr.O.P.Sharma Head, Department of Radiodiagnosis (Retd. Jan.1998) Dr.(Mrs.) S.G.Malvi Head, Department of Cytology

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. 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 Tarapur DAE Centre commenced in November 1992 and the survey was completed by December 1994.

One of the important results yielded by this survey 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
Director, TMC

CONTENTS

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 stations/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 data 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 Tarapur DAE Centre between 1992 and 1994, and deals with the prevalence of malignancies observed in 3340 employees, 2271 spouses of employees and 4478 offspring of employees. Prevalence of congenital anomalies in the offspring of employees has also been reported on.

There was no statistically significant excess in the prevalence of malignancies in radiation workers as compared to that of non-radiation workers of Tarapur DAE centre. The observed (O) to expected (E) ratio of prevalent cases in males was 1.77(4/2.25) with 95% confidence limit (CI) of 0.48 to 4.53. Similarly no significant difference in the prevalence of malignancies was observed between the radiation workers of Tarapur DAE

centre and non-radiation workers of BARC (Mumbai), [O/E = 0.74(4/5.39), 95% CI = 0.20 - 1.89]. The female employee group was very small and there was no case of cancer among the radiation workers while only one case was observed in the non-radiation workers. 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 of employees. All the cancer cases were seen in female spouses only. The prevalence of malignancies in the spouses has been compared with that seen in the spouses of BARC (Mumbai) employees. There was no significant difference in the prevalence of malignancies in the two groups [O/E = 1.12 (8/7.16), 95% CI = 0.48 - 2.20].

As in the case of the spouses, in the offspring also there is no direct exposure to radiation (of power plant origin). Malignancies were studied in the age group 19 years and under. There were two cases in the male offspring and one in the female offspring of employees of Tarapur DAE centre and the prevalence in males was not significantly different from that observed in the offspring of BARC (Mumbai) employees [O/E = 1.84(2/1.09), 95% CI= 0.22-6.64]. There were no cases (<=19 years) in the female offspring of BARC(Mumbai). Internal comparison i.e. comparing offspring of radiation workers with that of non-radiation workers of the power plant was not possible. In male offspring of radiation workers there were no cancers seen while two were observed in the offspring of non-radiation workers. In the

females the position was reverse, i.e. no cancers were seen in the offspring of non-radiation workers, while one was seen in the offspring of radiation workers.

There were 62 cases of congenital anomalies (major and minor) among 4478 offspring of employees, giving prevalence of 1.4% (1.5% in males and 1.3% 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.

In conclusion, no increase in cancer prevalence was observed in the radiation workers of Tarapur DAE Centre as compared to the non-radiation workers, nor was there excess of cancer prevalence in the spouses and offspring of the employees compared to the corresponding control groups. The prevalence of congenital anomalies in the offspring of the employees does not seem high, but it could not be compared with any other data as the information was not available.

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) 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 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 data analysis, at its Epidemiological Studies Cell especially set up for the purpose.

This report deals with data collected at Tarapur DAE Centre.

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

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group, their spouses and their offspring. Additionally, for the offspring group prevalence of congenital anomalies is also to be studied.

3. OPERATIONAL METHODOLOGY

Before initiating the actual field work, several trips were made to Tarapur by the Directors of Tata Memorial Hospital (TMH) in 1992, to familiarize the study group about the rationale of the work. The workers were addressed to acquaint them with the project and the procedures that would be followed, so that their fears, if any, in participating in the survey could be allayed. The actual collection of data started in November 1992 and was completed by December 1994.

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 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 and modified several times before it was finalized by March 1993.

3.2 Field Survey, Data Collection and Processing

The employees and their families were invited by the local authorities of the Tarapur DAE centre to participate in the survey and to come to the hospital of Tarapur Atomic Power Station (TAPS), where investigations were conducted and data collected. For this survey, a team from TMH comprising of 2 medical doctors, 1 statistician, 2 enumerators, 1 radiotechnician and 1 cytotechnician visited Tarapur DAE hospital for two consecutive days every 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.

Certain 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 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. Software for data-entry was prepared by the staff of the Computer Division of Tata Memorial Hospital.

4. POPULATION COVERAGE

This report is based on information on 3340 employees, 2271 spouses of employees and 4478 offspring of employees i.e. a total of 10,089 individuals as seen in Table 1 below. Of these 7805 members were individually examined and interviewed. On the remaining 2284 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 TAPS 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 i.e. Employees, Their Spouses and Offspring by Sex (1992-1994)

Groups	Covered in the TMH Survey			Information obtained from the medical records of Tarapur DAE centre			Total
	Males	Females	Total	Males	Females	Total	
Employees	2434	166	2600	679	61	740(22%)	3340(100%)
Spouses	31	1809	1840	4	427	431(19%)	2271(100%)
Offspring	1776	1589	3365	598	515	1113(25%)	4478(100%)
Total			7805(77%)			2284(23%)	10089(100%)

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 comparison group. One was to have internal comparison group i.e. compare radiation workers with non-radiation workers of Tarapur DAE Centre. 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 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 Tarapur DAE Centre vs. Non-Radiation Workers of Tarapur DAE Centre
2. Radiation Workers of Tarapur DAE Centre vs. Non-Radiation Workers of BARC(Mumbai)
3. Overall comparison of Tarapur 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 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. Therefore, cancer prevalence in the spouses has been compared with the prevalence in the spouses of BARC(Mumbai) employees.

6.3 Comparison Group for Evaluating Cancer Prevalence in Offspring of Employees

Cancer prevalence in the offspring has been studied by comparing

1. Offspring of Radiation Workers of Tarapur DAE Centre vs. Offspring of Non-Radiation Workers of Tarapur DAE Centre.
2. Offspring of Radiation Workers of Tarapur DAE Centre vs. Offspring of Non-Radiation Workers of BARC(Mumbai).
3. Offspring of employees of Tarapur DAE Centre vs. Offspring of employees of BARC(Mumbai).

6.4 Comparison Group for Evaluating 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 of new borns (Master-Notani et al;1968, Agarwal et al;1991) and hence are not comparable with the present data. We have therefore compared the prevalence of congenital anomalies in the offspring of employees of Tarapur DAE Centre 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 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. Overall also there are only 50 female radiation workers and they have received negligible radiation dose (an average annual radiation dose of 4.0 mSv), as can be seen from the following section and Appendix A.

7. EXPOSURE : DEFINITION AND MEASUREMENT

The details of annual radiation dose received by employees was provided by Tarapur DAE Centre. 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 Tarapur DAE Centre is given in Appendix A. The cumulative dose of an employee is measured by adding annual doses from initial employment upto end-1994, when the survey ended. The mean cumulative radiation dose per worker was 145.12 mSv in males and 4.02 mSv in females. 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 2155 radiation workers were below 50 mSv/year; except 142 employees who were exposed to annual doses between 50

mSv and 60 mSv, while only 8 were above 60 mSv/year.

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 almost half the male employees are less than 40 years, a third between 40 and 50 and the rest are 50 years of age or over. Furthermore there is no significant difference in the broad age categories, of the radiation and non-radiation workers, both in males (X^2= 4.72, df = 2, p = 0.10) as well as in the small group of female workers (X^2= 0.50, df = 2, p = 0.78).

Table 2 : Age Distribution of Employees of Tarapur DAE Centre by Radiation Status (1992-94)

	Males		Females	
	Radiation Workers	Non-Radiation Workers	Radiation Workers	Non-Radiation Workers
Age	No.(%)	No.(%)	No.(%)	No.(%)
Upto 39	1101(53)	569(57)	36(72)	136(77)
40 - 49	680(32)	296(29)	11(22)	32(18)
50+	324(15)	143(14)	3(6)	9(5)
Total	2105(100)	1008(100)	50(100)	177(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 2600 (2434 males

and 166 females) interviewed employees. The distribution of several characteristics are 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 90% were married), community distribution (over 90% 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 (over 55% had no habit). There was however a higher proportion of scientific/technical staff in the group of radiation workers than non-radiation workers.

A comment on the not-interviewed employees is in order. They (males) were younger than the interviewed employees (27% vs. 19% :Age <30 years) had a higher proportion of non-radiation workers (38% vs. 31%), and among radiation workers also, the proportion of employees with cumulative dose of less than 10mSv was higher at 58% as against 27% in the interviewed employees. Similar picture was seen for the 61 not-interviewed female employees.

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

Table 3 : Profile of Male Employees (interviewed) of Tarapur DAE Centre by Radiation Status (1992-1994)

Group	Radiation Workers (n=1686) No.	%	Non-Radiation Workers (n=748) No.	%	Total (n=2434) No.	%
• **Marital Status**						
Unmarried	235	14	70	10	305	13
Married	1447	86	675	90	2122	87
Widowed/Divorced/ Separated	4	0.2	3	0.4	7	0.2
• **Community**						
Hindu	1564	93	692	93	2256	93
Muslims	52	3	20	3	72	3
Christians	57	3	29	3	86	3
Others	13	1	7	1	20	1
• **Education**						
Upto primary	113	7	57	8	170	7
Middle (V-VII std)	192	11	84	11	276	11
Secondary and Technical after SSC (VII-XII Std)	787	47	367	49	1154	48
Undergraduate and above	594	35	240	32	834	34
• **Habits**						
No habit	967	58	420	56	1387	57
Chewers only	139	8	67	9	206	8
Smokers only	221	13	109	15	330	14
Alcohol consumers only	87	5	20	3	107	4
Combination of Habits	269	16	132	17	401	17
Snuff use	3	0.2	0	-	3	0.1
• **Cadre of Work**						
Administration	24	1	142	19	166	7
Scientific	479	28	105	14	584	24
Technical	994	59	189	25	1183	49
Security	59	4	130	18	189	8
Labour	130	8	174	23	304	12
School teacher	0	0	8	1	8	0.3

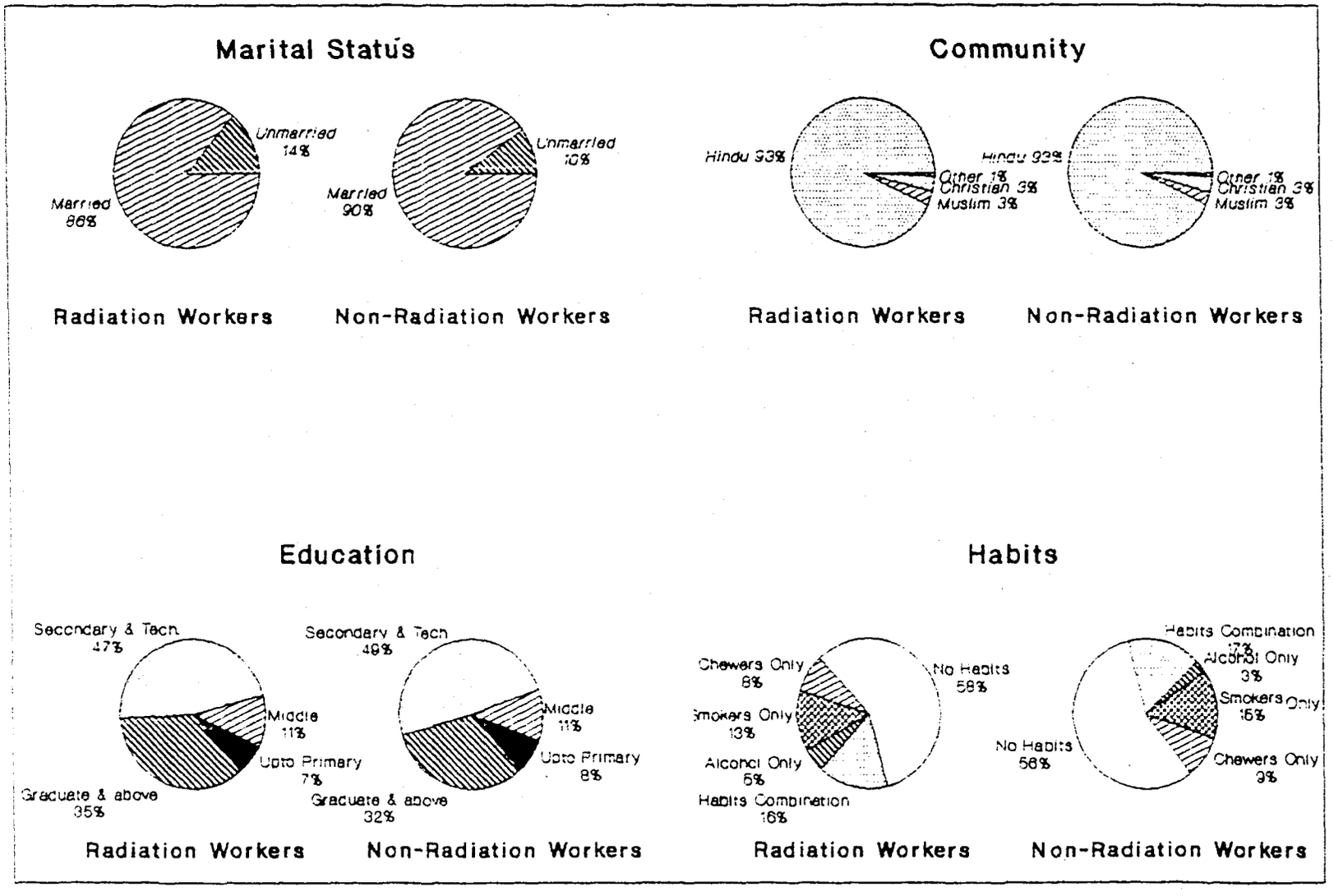

fig.1.Demographic and habit profile of male employees(interviewed) of Tarapur DAE Centre by radiation status

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 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 these 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 have also been studied to see the effect of low-dose radiation in the unborn child.

10.1 Employees : Cancer Prevalence

In all there were six prevalent cancer cases in the employee group; five in male and one in female employees. The distribution of cases by radiation status is seen in Table 4 below :

Table 4 : Prevalent Cancer Cases in Employees of Tarapur DAE Centre by Sex and Radiation Status. (1992-1994)

		Males	Females	Total
Radiation Workers	No.	2105	50	2155
	Cases	4	0	4
Non-Radiation Workers	No.	1008	177	1185
	Cases	1	1	2
Total	No.	3113	227	3340
	Cases	5	1	6

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 of lung cancer, one of pyriform fossa, one of penis, one of chronic myeloid leukemia and one of Hodgkin's disease. The one female case was Hodgkin's disease.

Ionizing radiation is a proven risk factor for leukemia (excluding chronic lymphoid leukemia). However, in the present case of chronic myeloid leukemia the radiation dose received by the employee from the year of his joining DAE upto 1992, when he developed the disease was only 241.8 mSv, giving an

average annual dose of 24.2 mSv. If a lag of 2 years is allowed for latent period, the cumulative dose received would be even lower at 190.3 mSv.

Hodgkin's disease has so far not been conclusively shown to be induced by ionizing radiation. Besides, both the cases of Hodgkin's disease occurred before the workers joined DAE employment.

Table 5: Details of Prevalent Cancer Cases in Employees of Tarapur DAE Centre (1992-94)

Diagnosis (ICD-9TH)	Age	Sex	Year of Diag.	Year of joining DAE	Designation at survey time	Cumulative dose in mSV upto the year of diagnosis	Habits
*Pyriform fossa (148)	54	M	1993	1975	Tradesman"E"	358.3	Smoking Alcohol
Lung (162)	46	M	1993	1971	Tradesman [Prefre]	343.4	Smoking Chewing
Penis (187)	43	M	1991	1979	Helper [Civil]	Non-Radiation Worker	Smoking Alcohol
Hodgkin's Disease (201)	27	M	1984	1988	Tradesman [Ele.Maint]	0.0	No habits
*Chronic Myeloid Leukemia (205.1)	30	M	1992	1983	Tradesman [QC]	241.8	No habits
Hodgkin's Disease (201)	34	F	1982	1994	Medical Officer	Non-Radiation Worker	No habits

* Information from medical records maintained at Tarapur DAE Hospital
M - Male, F - Female

Lung cancer is another malignancy known to be associated with radiation exposure. In the present study the cumulative dose received by the employee diagnosed having lung cancer in 1993 was 343.4 mSv, giving an average annual dose of 15.6 mSv. If a lag period of 10 years is assumed to account for minimum latent period for development of solid tumour, then the cumulative dose drops even further to 116.5 mSv. Furthermore this employee was a cigarette smoker, which has been recognized as a cause of lung cancer ever since the 1950s, with the studies of Doll and Hill (1950) in U.K. and Wynder and Graham (1950) in USA, followed by the definitive report of the Advisory Committee to the US Surgeon General in 1964. In India, both bidi and cigarette smoking has been shown to be associated with lung cancer (Notani and Sanghvi, 1974 ; Jussawalla and Jain, 1979).

Of the remaining 2 cases, penile cancer occurred in a non-radiation worker. Pyriform fossa even though it occurred in a radiation worker; the cause of the disease could be attributed to his habits. In several Indian studies, tobacco-use has been demonstrated to be a strong risk factor for pharyngeal cancer along with alcohol drinking and dietary factors (Jussawalla and Deshpande, 1971; Notani and Jayant, 1987; Notani, 1988). In the present case the employee was not only a heavy smoker(1 packet cigarette and one bundle bidi per day) but also consumed alcohol daily.

The prevalence of the cancers of all-sites together in the radiation workers (males-4 cases, females - none) was compared with that in non-radiation workers (males - 1 case, female - 1 case), after adjusting for differences in age distribution.

In males, the observed to expected ratio was 1.77 with 95% confidence interval of 0.48 to 4.53 as seen in Table 6. In females there was no case of cancer in radiation workers but one occurred in the non-radiation workers.

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

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

	Males			Females		
Groups Compared	Observed cases O	Expected cases E	O/E (95%CI)	Observed cases O	Expected Cases E	O/E (95%CI)
Radiation Workers (Tarapur DAE Centre) vs. Non-Radiation Workers (Tarapur DAE Centre)	4	2.25	1.77 (0.48-4.53)	0	0.15	-
Radiation Workers (Tarapur DAE Centre) vs. NonRadiation Workers (BARC, Mumbai)	4	5.39	0.74 (0.20-1.89)	0	0.09	-

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

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 was observed in radiation workers compared to non-radiation workers.

Furthermore, the cancer prevalence in the radiation workers of Tarapur DAE Centre 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 Tarapur DAE Centre were compared with non-radiation workers of BARC(Mumbai), there was no significant difference in cancer prevalence and the observed to expected ratio for males was only 0.74 with 95% of confidence interval of 0.20 to 1.89. (Table 6).

Infact when all male employees of Tarapur DAE Centre were compared with BARC(Mumbai) male employees there was no significant difference in cancer prevalence of these 2 groups, (O:5, E:7.46, O/E:0.67, 95% CI:0.22-1.57), and also in the subgroups of radiation workers and non-radiation workers.

10.2 Spouses : Cancer Prevalence

There were eight prevalent cancer cases in the spouses of employees of Tarapur DAE Centre and all were females as seen in Table 7 below.

Table 7 : Prevalent Cancer Cases in Spouses of Employees of Tarapur DAE Centre (1992-1994)

Spouses	Males	Females	Total
Number	35	2236	2271
Cases	0	8	8

Three of these 8 cases involved the cervix as seen in Table 8. To date there is no evidence regarding the inducibility of carcinoma of the cervix by radiation. Certain aspects of lifestyles have been well established as risk factors (Ponten et al,1995). These are infection with human papilloma virus, early age marriage, multiple sexual partners and circumcision status of the partner(possibly).

Table 8 : Details of Prevalent Cancer Cases in Spouses of Employees of Tarapur DAE Centre (1992-94)

				Employee's Details		
Diagnosis (ICD-9TH)	Age	Sex	Year of Diag.	Year of joining DAE	Designation at survey time	Radiation Status
Parotid (142)	35	F	1987	1971	Tradesman [Civil]	R
Oesophagus (150)	42	F	1992	1969	Tradesman [Civil]	NR
Breast (174)	42	F	1985	1971	Tradesman [Fabrication]	R
Thyroid (193)	39	F	1994	1980	Tradesman [Operation]	R
Cervix (180)	48	F	1992	1975	Helper [Prefre]	R
Cervix (180)	47	F	1978	1962	Tradesman [FRD]	R
*Cervix (180)	51	F	1992	1970	Watchman	R
Hodgkin's Disease (201)	41	F	1971	1964	Tradesman [Garage]	R

* Information from medical records maintained at Tarapur DAE Hospital
R - Radiation Worker, NR - Non-Radiation Worker, M - Male, F - Female

Of the remaining five cases, one was Hodgkin's disease and the other four sites involved were parotid, esophagus, breast and thyroid as seen in Table 8.

Although high doses of radiation is an established risk factor for breast cancer (Boice et al,1979) and possible association between radiation exposure and development of thyroid malignancies has been reported in literature (Shore, 1992); several other factors have also been established as risks. However, none of the malignancies in the spouses could be attributed to radiation, since none of them was an employee.

As discussed in the earlier section (6.2), for evaluating excess of cancer prevalence, if any, in spouses of employees, the most relevant control group would be the spouses of BARC employees who would be from a similar socio-economic strata. The prevalent number of cancer cases in spouses of BARC(Mumbai) employees is given in Appendix C Table 3.

Table 9 shows the results of comparison and it is seen that there is no significant difference in the prevalence of cancer in the 2 groups i.e. between the spouses of employees of Tarapur DAE Centre and that of BARC (Mumbai) employees. The observed to expected ratio was just 1.12 and was not significant, the 95% confidence interval being 0.48 to 2.20.

As there were no cases of cancer in the male spouses of employees of Tarapur DAE Centre the comparison has been restricted to females only.

Table 9 : Comparison of Cancer Prevalence in Spouses of Employees of Tarapur DAE Centre vs. Spouses of Employees of BARC, Mumbai

Groups Compared	Observed cases O	Expected cases E	O/E (95%CI)
Spouses of Employees of Tarapur DAE Centre vs Spouses of Employees of BARC(Mumbai)	8	7.16	1.12 (0.48-2.20)

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

10.3 Offspring : Cancer Prevalence

We have considered cancer prevalence in the offspring and not restricted to childhood cancers only. Conventionally, childhood cancers imply cancers in children 14 years of age and under. However, the age-group considered for analysing cancer pattern in offspring seems to vary from study to study. Infact, in the Dounreay study of childhood leukemia in Northern Scotland, the age group considered was 0 to 24 years (Darby and Doll,1987). We have taken 19 years as the cut-off point, because 2 out of 3 cancer cases were 18 and 19 years of age. Besides, almost 88% of the offspring were 19 years of age and under (Appendix B).

The three prevalent cancer cases occurred in 3909 offspring who were 19 years of age and under. Table 10 shows the prevalence of cancer in the offspring.

Table 10 : Prevalent Cancer Cases in the Offspring (<=19 years) of Employees of Tarapur DAE Centre (1992-1994)

Offspring of		Males	Females	Total
Radiation Workers	No.	1384	1216	2600
	Cases	0	1	1
Non-Radiation Workers	No.	643	666	1309
	Cases	2	0	2
Total	No.	2027	1882	3909
	Cases	2	1	3

Two cases were male offspring of non-radiation workers. One was tumor of the jaw and the other was acute lymphoblastic leukemia as seen from Table 11. The third case was oestogenic sarcoma in a female offspring of a radiation worker.

Table 11: Details of Prevalent Cancer Cases in the Offspring of Employees of Tarapur DAE Centre (1992-94)

				Employee's Details		
Diagnosis (ICD-9TH)	Age	Sex	Year of Diag.	Year of joining DAE	Designation at survey time	Radiation Status
*Tumor Jaw (170)	19	M	1994	1987	Helper [Security]	NR
*Osteogenic Sarcoma (170)	18	F	1994	1983	Tradesman[Inst.maint] (Provided by Tarapur DAE Centre)	R
Acute Lymphoblastic Leukemia (204)	4	M	1994	1978	Teacher	NR

* Died before interview. Born before the father joined DAE.
R - Radiation Worker, NR - Non-Radiation Worker, M - Male, F - Female

Radiation in high doses is the only environmental agent known to produce bone cancer, particularly osteogenic sarcoma. There is no possibility that these 2 cases of bone cancer in the offspring were exposed to high doses of radiation in their life time. Genetic susceptibility has also been suggested in view of the high risk of osteogenic sarcoma among patients with hereditary form of retinoblastoma even at sites away from the irradiated (therapeutic) field and also in the absence of radiation.

In the present survey, both the cases of bone cancers viz. tumor jaw and osteogenic sarcoma occurred in offspring who were born before their fathers started working for DAE, and hence cannot even be attributed to parental pre-conception exposure, as had been suggested for leukemia by Gardner et al (1990).

In the third case of acute lymphoblastic leukemia, there was no history of in-utero exposure to radiation for medical purposes. The occupation of the mother (employee) was that of a school teacher i.e. an occupation not related to work involving radiation exposure. The father was also not a DAE employee.

Thus all the three cases seem to be due to causes not related to radiation exposure at the power station.

The comparison of cancer prevalence in offspring of radiation workers with that of non-radiation workers of Tarapur DAE Centre cannot be undertaken. The reason being, as seen from Table 10, that there are no cancers

seen in male offspring of radiation workers to compare with that of non-radiation workers. In the female group it was the reverse i.e. there were no cancers seen in the female offspring (<=19 years) of non-radiation workers, either of Tarapur DAE Centre (Table 10) or of BARC(Mumbai) (Appendix C, Table 4), to compare with the lone cancer case in the offspring of radiation workers. Infact, this offsp.ring, as mentioned earlier, was born before the employee joined DAE.

Overall comparison of prevalent cancer cases in the male offspring of employees of Tarapur DAE Centre with those of BARC(Mumbai) employees showed no significant difference. The observed to expected ratio of 1.84 had 95% confidence interval of 0.22 to 6.64. There were no cancers in the female offspring(<=19 years) of BARC (Mumbai) employees to compare with one case seen in the offspring of Tarapur DAE Centre.

Prenatal exposure (obstetric x-rays) and occurrence of cancer in children has been extensively studied ever since the association was first reported in the Oxford survey of childhood cancers in 1958. A 40% higher risk was reported of leukemia and solid tumors in children who were exposed to diagnostic x-rays as fetuses compared to those who were not exposed (Bithell and Stewart 1975, Muirhead and Kneale 1989). There are probably as many studies for as against this association reported in the literature. We are in no position to study this effect as there was just one childhood malignancy, and as mentioned above there was no history of in-utero exposure for medical purposes.

10.4 Offspring : Prevalence of Congenital Anomalies

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 fetus.

Table 12 : Prevalence of Congenital Anomalies (Major and Minor) in Offspring of Employees of Tarapur DAE Centre (1992-1994)

Offspring of		Males	Females	Total
Radiation Workers	No.	1641	1378	3019
	Cases(%)	28(1.71)	16(1.16)	44(1.46)
Non-Radiation Workers	No.	733	726	1459
	Cases(%)	7(0.95)	11(1.52)	18(1.23)
Total	No.	2374	2104	4478
	Cases(%)	35(1.47)	27(1.28)	62(1.38)

Table 12 gives the number of congenital anomalies both major and minor observed in the offspring of the employees with details of anomalies given in

Table 13: List of Prevalent Congenital Anomalies(Major and Minor) in Offspring of Employees of Tarapur DAE Centre (1992-94)

CONG.ANOMALIES (ICD 9TH :740-759)	Males		Females		Total
	No.(age)	(Parent/employee Radiation Status)	No.(age)	(Parent/employee Radiation Status)	
1.Central Nervous System (740-742)					
Hydrocephalus	-		1(6)	(R)	1
Microcephalus	1(5)	(R)	1(12)	(NR)	2
total	1		2		3
2.Cardiovascular System (745-747)					
Atrial Septal Defect	2(6,18)	(R,R)	-		2
Ventricular Septal Defect	5(4,4,13,22,20)	(R,R,R,R,R)	2(6,13)	(R,R)	7
Fallot's Tetralogy	1(17)	(R)	1(7)	(R)	2
Valvular Heart Disease	1(1)	(R)	1(15)	(R)	2
Mitral Valve Prolapse	1(20)	(NR)	-		1
Patent Ductus Arteriosus	-		1(20)	(NR)	1
total	10		5		15
3.Musculo-Skeletal System (754-756)					
Osteogenesis Imperfecta	-		1(8)	(R)	1
Facial Assymetry	1(8)	(R)	-		1
Syndactyly	1(9)	(R)	-		1
Polydactyly	1(9)	(R)	-		1
*Umbilical Hernia (553.1)	-		1(6)	(NR)	1
Hammer Toes	-		1(1)	(NR)	1
Kyphoscoliosis	-		1(23)	(NR)	1
Talipes Equinovarus	1(19)	(R)	1(1)	(R)	2
Short Left Lower Limb	-		1(7)	(R)	1
total	4		6		10
4.Gastro-Intestinal System (749-751)					
Imperforate Anus	1(14)	(R)	-		1
Congenital Malformed Anus	-		1(15)	(NR)	1
total	1		1		2
5.Genito-Urinary System (752-753)					
Undescended Testis	1(14)	(R)	-		1
*Inguinal Hernia (550)	4(4,8,9,17)	(R,NR,R,NR)	-		4
*Hydrocele Congenital (778)	2(1,7)	(R,R)	-		2
Hypospadias	2(2,8)	(NR,R)	-		2
?Malposition of Kidney	1(13)	(R)	-		1
Partially Open Hymen	-		1(14)	(R)	1
total	10		1		11

Contd.

CONG.ANOMALIES (ICD 9TH :740-759)	Males		Females		Total
	No.(age)	(Parent/employee Radiation Status)	No.(age)	(Parent/employee Radiation Status)	
Integumentary System (757)					
*Haemangioma (228)	-		3(4,7,5)	(R,R,R)	3
Nevus Face, Forearm	1(3)	(R)	-		1
total	1		3		4
Anomalies of Eye (743)					
Ptosis	-		2(2,2)	(NR,NR)	2
*Convergent Squint (378)	1(3)	(NR)	-		1
total	1		2		3
Anomalies of other Endocrine Glands (759.2)					
Congenital Thyroglossal Cyst	-		1 (15)	(NR)	1
Multiple Congenital Anomalies (759.7)					
Congenital (L) 3rd Cranial N. Palsy; Left Eye Congenital Ptosis; Prognathism; Abnormal Facies;Flat Foot; Generalized Muscle Wasting	-		1(12)	(R)	1
Delayed Motor and Mental Milestones; Hyper-Pigmented Spots on Trunk,Back & Abdomen; Abnormal Facies	1(3)	(R)			1
total	1		1		2
?Mental Retardation (319)					
?Cause	3(2,21,12)	(NR,R,R)	4(14,15,19,8)	(R,R,NR,R)	7
?Birth Asphyxia/ ?Neonatal Infection	1(1)	(NR)	1(4)	(NR)	2
Cause Cerebral Palsy	1(2)	(R)	-		1
total	5		5		10
?Deaf Mutism (389)	1(1)	(R)	-		1
TOTAL	35(1.47%)		27(1.28%)		62(1.38%
Total Number of Offspring	2374		2104		4478

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

R : Radiation Worker, NR : Non-Radiation Worker

Table 13. 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 13 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 the analysis.

Total number of congenital anomalies (major and minor) recorded were 62 in number , of which 35 were in male offspring and 27 in female offspring; giving an overall prevalence of 1.38%. The prevalence of congenital anomalies in a comparable cross-section of the population is not available with which the present data could be compared.

Attempt was made to compare the prevalence in the offspring of employees of Tarapur DAE Centre 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 14 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 Tarapur data. The classification of congenital anomalies followed by the two centres may not be identical. Thus comparison with BARC(Mumbai) data does not seem feasible.

Table 14 : 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 Tarapur DAE Centre 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 15 below. The prevalence in males is somewhat higher in the offspring of radiation workers compared to offspring of non-radiation workers; while in the female offspring the picture is reverse i.e. the prevalence in the offspring of radiation workers was lower than the prevalence in the offspring of non-radiation workers.

Table 15: Comparison of Prevalence of Congenital Anomalies in Offspring of Radiation Workers vs. Offspring of Non-Radiation Workers of Tarapur DAE Centre

	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 (Tarapur DAE Centre) vs. Offspring of Non-Radiation Workers (Tarapur DAE Centre)	28	14.6	1.92 (1.28-2.77)	16	21.65	0.74 (0.42-1.20)

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

Thus overall there is no consistent picture emerging. This is not surprising because there are several question of classificatory nature that need to be answered. Whether one should include anomalies falling outside the ICD range, should one include anomalies like deaf-mutism which could well be due to hereditary factors or infective agents. How does one classify mental retardation where sometimes the cause is given as due to birth injury while in others no information is provided.

However, the prevalence of congenital anomalies seen in the offspring of employees is only 1.4% (1.5% in males and 1.3% in females) and does not seem to be high.

11. CONCLUSION

This survey was carried out among the employees of the Tarapur DAE Centre 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 Tarapur DAE Centre 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 Tarapur DAE Centre and no major differences were observed. Thus, the possibility of biased results is minimized to the extent possible. Such a comparison of radiation workers of Tarapur DAE Centre 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).

The cumulative dose distribution in the radiation workers provided by Tarapur DAE Centre has been shown in Appendix A. Furthermore, because of small numbers involved, no attempt was made to see the dose-response relationship. 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 kept well within the upper-bound of annual dose stipulated by ICRP/AERB and is thus not likely to cause any health effects.

Furthermore the dose received by the family members or the members of the general population residing near Tarapur DAE Centre is a small fraction of the dose permitted by AERB/ICRP for the public. In the present study, the prevalence of malignancies in spouses and offspring of employees were also not different from that observed in the corresponding BARC groups.

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 of offspring of radiation and non-radiation workers is of limited value, and did not answer the question of in-utero exposure. However, overall 1.4% prevalence of congenital anomalies in the offspring does not seem high.

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APPENDIX A

Radiation Exposure Data Of Tarapur DAE Employees.

DOSE DISTRIBUTION OF TARAPUR DAE EMPLOYEES

Table 1: Cumulative Radiation Dose in mSv from Initial Employment upto 1994 of Tarapur Radiation Workers, by Age and Sex

A) MALES

Exposure (in mSv)	No.of Persons in Different Age Groups 18-	30-	40-	50+	Total	%
0-	94	85	47	16	242	11.5
1-	186	160	96	20	462	21.9
10-	22	41	38	15	116	5.5
20-	74	69	69	29	241	11.5
50-	52	65	76	33	226	10.7
100-	31	69	74	43	217	10.3
200-	16	111	118	77	322	15.3
400+	0	29	160	90	279	13.3
Total	475	629	678	323	2105	100.0

Mean Cumulative Radiation dose per worker = 145.12 mSv

B) FEMALES

Exposure (in mSv)	No.of Persons in Different Age Groups 18-	30-	40-	50+	Total	%
0-	13	9	1	0	23	46.0
1-	8	6	5	1	20	40.0
10-	0	0	5	1	6	12.0
20-	0	0	0	1	1	2.0
Total	21	15	11	3	50	100.0

Mean Cumulative Radiation dose per worker = 4.02 mSv

APPENDIX B

Tarapur Study Population Distribution By Age, Sex And Radiation Status

Table 1: Distribution by Age,Sex and Radiation status of Tarapur Study Population (1992-94)

A] Employees :

Sex / Radiation status	Age <20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
Males											
Radiation Workers	1	140	326	312	322	363	317	203	110	11	2105
Non-Radiation Workers	0	29	141	183	216	161	135	76	61	6	1008
Total	1	169	467	495	538	524	452	279	171	17	3113
Females											
Radiation Workers	0	7	14	8	7	6	5	2	1	0	50
Non-Radiation Workers	0	11	50	54	21	21	11	8	1	0	177
Total	0	18	64	62	28	27	16	10	2	0	227

B] Spouses of Employees :

Sex	Age 15-	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
Males	0	0	2	9	5	6	4	5	3	1	35
Females	24	197	440	434	467	353	222	83	15	1	2236
Total	24	197	442	443	472	359	226	88	18	2	2271

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	289	361	385	349	225	28	4	1641
Females	245	374	332	265	148	14	0	1378
Total	534	735	717	614	373	42	4	3019

ii) Offspring of Non-Radiation Workers

Sex	Age 0-4	5-9	10-14	15-19	20-24	25-29	30-34	Total
Males	161	195	155	132	77	11	2	733
Females	155	219	164	128	55	5	0	726
Total	316	414	319	260	132	16	2	1459

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), 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.

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-)

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

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1. Dr. K.A. Dinshaw, Head, Radiation Oncology, TMH
2. Dr. L.D. Sanghvi, Consultant, TMH
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

SENIOR TECHNICAL ADVISORY GROUP (STAG) FOR EPIDEMIOLOGICAL STUDIES (1992-95)

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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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3. Dr. (Ms) Usha Desai, Head Medical Division, BARC	- Member
4. Mr. S. Krishnamony, Head Health Physics Division,BARC	- Member
5. Dr. Chattopadhyay, NIOH, Ahmedabad	- Member
6. Dr. P.S.S. Sundar Rao Director, Schieffelin Leprosy Research and Training Centre, Karigiri	- Member
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10. Mrs. P.N.Notani, Honorary Consultant, TMH	- Member
11. Dr.S.A.Pradhan, Surgeon, TMH	- Member
12. Sri. B.M.L. Sah, Head Health Physics Group, NPC	- Member Secretary

INVITEES TO SENIOR TECHNICAL ADVISORY GROUP (STAG) FOR EPIDEMIOLOGICAL STUDIES (1992-1995)

1. Shri G.R. Srinivasan, Director, Health & Safety, NPC
2. Shri M.L.Mitra, Director, E & PA, NPC
3. Dr.P.L.Nawalkha, Principal & Controller, SMS Medical College, Jaipur
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

SUB-COMMITTEE OF SENIOR TECHNICAL ADVISORY GROUP (STAG)

1. Mrs. P.N.Notani, Hon. Consultant, TMH - Member & Convener
2. Dr. L.D.Sanghvi - Member
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
5. Dr.(Ms.) M.P.Desai, Consulting Pediatrician, TMH - Member
6. Shri. P.Vishwanathan, Head, Health Physics Dept. TMH - Member
7. Dr. A.N.Bhise, CRI - Member
8. Dr. K.S.V.Nambi, Head, Environment Assessment Division, BARC - Member
9. Mrs. P.N.Notani, Epidemiologist, CRI - Member Secretary

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2. Dr.B.S.Vachharajani, TAPS
3. Dr.S.K.Dave, Dy.Director, NIOH, Ahmedabad
4. Mr.M.S.Mangrulkar, TMH
5. Dr.Ganesh B, TMH
6. Dr.M.Bhansali, TMH
7. Dr.B.Warad, TMH
8. Mr.S.D.Talole, TMH