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

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TATA MEMORIAL CENTRE

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PREFACE

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

NPCIL 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 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 first site selected for the survey was the Tarapur Atomic Power Station, followed by Kakrapar Atomic Power Station, because of their proximity to Tata Memorial Hospital (TMH). The survey at Rawatbhata DAE Centre however, was carried out by SMS Medical College and Hospital, Jaipur, as per the procedures standardised by TMC. The data were processed and analysed by the

Epidemiological Studies Cell of TMH. The actual data collection at Rawatbhata DAE Centre commenced in January 1995 and the survey was completed by December 1995.

One of the important results yielded by 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; nor is there any difference in the prevalence of malignancies 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

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SUMMARY:

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

The present document reports the results of the cross-sectional survey carried out at Rawatbhata DAE Centre, during 1995 by SMS Medical College and Hospital, Jaipur, and covers 3997 employees, 3200 spouses of employees and 6486 offspring of employees. The prevalence of malignancies in these three groups has been studied and 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 Rawatbhata DAE Centre. The observed (O) to expected (E) ratio of prevalent cancer cases in males was 1.34(3/2.24) with 95% confidence limit (CI) of 0.28 to 3.92. Similarly no significant difference in the prevalence of malignancies was observed between the radiation workers of Rawatbhata DAE Centre and non-radiation workers of Bhabha Atomic Research Centre (BARC, Mumbai), [O/E = 1.05(3/2.87), 95% CI = 0.22 - 3.05]. 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 female 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. The prevalence of malignancies in spouses of employees of Rawatbhata DAE Centre is low as compared to that of spouses of BARC employees [O/E = 0.34 (4/11.7), 95% CI = 0.09 - 0.87].

As in the case of the spouses, in the offspring also there is no direct exposure to radiation of power plant origin. There were no cancer cases reported in the offspring group, both in males and females.

There were 35 cases of congenital anomalies (major and minor) among 6486 offspring of employees, giving prevalence of 0.5% (0.5% in males and 0.6% in females). The prevalence of congenital anomalies in a comparable

cross-section of the population was not available with which the present data could be compared.

In conclusion, no increase in cancer prevalence was observed in the radiation workers of Rawatbhata DAE Centre as compared to the non-radiation workers, nor was there excess of cancer prevalence in the spouses of employees compared to the corresponding control group. No cancers were reported in the offspring of employees. The prevalence of congenital anomalies in the offspring of the employees does not seem high. This data could not be compared with any other data since prevalence in a comparable cross section of the population is 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 awarded a Consultancy Service Contract to Tata Memorial Centre (TMC) to undertake epidemiological survey in the employees and their families at various project sites. NPC also constituted various committees (composition given in Appendix G) to monitor the progress of the project. TMC conducted the survey at two sites viz. Tarapur DAE Centre and Kakrapar Atomic Power Station. For surveys at other stations TMC provides guidelines regarding the format for data collection, the questionnaire, and the software for data entry. This data is then transferred to TMC for processing and analysis at its Epidemiological Studies Cell especially set up for the purpose.

This report deals with data collected at Rawatbhata 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 group, their spouses and their offspring. Additionally, for the offspring group prevalence of congenital anomalies is also to be studied.

3. OPERATIONAL METHODOLOGY

The survey which included 13683 individuals was initiated in December 1994 and was concluded by December 1995. The survey involved filling a questionnaire with respect to demographic and medical data and other relevant details as well as undertaking medical examination.

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 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 Rawatbhata DAE Centre to participate in the survey and to come to the hospital of Rawatbhata Atomic Power Station (RAPS), where investigations were conducted and data collected. For this survey, a team from SMS Medical College and Hospital, Jaipur, comprising of 3 medical doctors, 1 pathologist and 1 cytotechnician visited RAPS Hospital every week. The general part of the proforma was filled by the enumerators specially appointed for the epidemiological survey. Doctors from SMS Medical College and Hospital 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.

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

1. All adults above the age of 40 years and smokers 35 years and above had to undergo 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 SMS Medical College and Hospital, Jaipur for further investigations. The database was created from the

completed proformas at RAPS Hospital and the same was transported for processing to the Epidemiological Studies Cell, especially set up at TMH for the survey. Software for data-entry was installed at RAPS Hospital by TMH.

4. POPULATION COVERAGE

This report is based on information on 3997 employees, 3200 spouses of employees and 6486 offspring of employees i.e. a total of 13,683 individuals as given in Table 1 below. Of these 13,062 members were individually examined and interviewed. On a small number of 621 individuals i.e. 5% of the study population, information on health status with respect to malignancies and congenital anomalies in the offspring, if any, was obtained by reviewing the medical records maintained at RAPS 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 (1995)

Groups	Covered in the Survey			Information obtained from the medical records of Rawatbhata DAE Centre			Total (%)
	Males	Females	Total	Males	Females	Total	
Employees	3700	186	3886	110	1	111(3%)	3997(100)
Spouses	32	2861	2893	2	305	307(10%)	3200(100)
Offspring	3562	2721	6283	111	92	203(3%)	6486(100)
Total			13062(95%)			621(5%)	13683

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 purpose 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 Rawatbhata 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 Rawatbhata DAE Centre vs. Non-Radiation Workers of Rawatbhata DAE Centre

2. Radiation Workers of Rawatbhata DAE Centre vs. Non-Radiation Workers of BARC(Mumbai)

3. Overall comparison of Rawatbhata data with data of BARC (Mumbai), and separately for :
   a. Radiation Workers, and
   b. Non-Radiation Workers

6.2 Comparison Groups for Evaluating Cancer Prevalence in Spouses and offspring 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.

No cancer cases were seen in the offspring of employees and therefore the question of selection of a comparison group does not arise.

6.3 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 Rawatbhata 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 available 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 are only two female radiation workers and they have received negligible cumulative radiation doses of 8.0 mSv and 4.9 mSv.

7. RADIATION EXPOSURE : DEFINITION AND MEASUREMENT

The details of annual radiation dose received by employees was provided by Rawatbhata 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 (TLD) or film badge type dosimeters. For day-to-day dose management direct reading type dosimeters (DRD) 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 Rawatbhata DAE Centre is given in Appendix A. The cumulative dose of an employee is measured by adding annual doses from initial employment upto end-1995, when the survey ended. The mean cumulative radiation dose per worker was 137 ± 4 mSv in males. There were only 2 female radiation workers and the cumulative dose received were 8.0 mSv and 4,9 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 1007 male radiation workers

were below 50 mSv/year; except 8 employees who were exposed to annual doses between 50 mSv and 60 mSv, while only 10 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. Age distribution by 5 year age categories is given in appendix B.

Table 2 : Age Distribution of Employees of Rawatbhata DAE Centre by Radiation Status (1995)

	Males		Females	
	Radiation Workers	Non-Radiation Workers	Radiation Workers	Non-Radiation Workers
Age	No.(%)	No.(%)	No.(%)	No.(%)
Upto 39	482(48)	1334(48)	2(100)	96(52)
40 - 49	334(33)	838(30)	0	60(32)
50+	191(19)	631(22)	0	29(16)
Total	1007(100)	2803(100)	2(100)	185(100)

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

Besides age and sex differences, which have been adjusted for in all comparisons, it is of importance to see the profile of the radiation and non-radiation workers with respect to other characteristics which could influence, exposure-cancer prevalence relationship. This information was available for

Table 3 : Profile of Male Employees (interviewed) of Rawatbhata DAE Centre by Radiation Status (1995)

Group	Radiation Workers (n=1005) No.	%	Non-Radiation Workers (n=2695) No.	%	Total (n=3700) No.	%
• **Marital Status**						
Unmarried	54	6	267	10	321	9
Married	946	94	2412	90	3358	91
Widowed/Divorced/ Separated	5	0.5	16	0.6	21	0.6
• **Community**						
Hindu	887	88	2418	90	3305	89
Muslims	41	4	104	4	145	4
Christians	17	2	60	2	77	2
Others	60	6	113	4	173	5
• **Education**						
Upto primary	123	12	478	18	601	16
Middle (V-VII std)	86	9	378	14	464	12
Secondary and Technical after SSC (VII-XII Std)	444	44	1014	37	1458	39
Undergraduate and above	352	35	825	31	1177	32
• **Habits**						
No habit	565	56	1524	57	2089	57
Chewers only	84	9	251	9	335	9
Smokers only	141	14	366	14	507	14
Alcohol consumers only	43	4	120	4	163	4
Combination of Habits	172	17	434	16	606	16
• **Cadre of Work**						
Administration	11	1	368	14	379	10
Scientific	308	31	607	22	915	25
Technical	637	63	973	36	1610	43
Security	9	1	247	9	256	7
Labour	40	4	401	15	441	12
School teacher	0	0	99	4	99	3

3886 (3700 males and 186 females) interviewed employees. The distributions of these 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 (over 90% were married), community distribution (almost 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 (around 56% had no habit). There was however a higher proportion of scientific/technical staff in the group of radiation workers than non-radiation workers.

There were 110 males employees who were not-interviewed. Of these, 108 were non-radiation workers and only 2 were radiation workers.

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 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 cancer 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 Cancer Prevalence in Employees.

In all there were eleven prevalent cancer cases in the employee group; ten in males and one in females. The distribution of cases by radiation status is shown in Table 4.

Table 4 : Prevalent Cancer Cases in Employees of Rawatbhata DAE Centre by Sex and Radiation Status. (1995)

		Males	Females	Total
Radiation Workers	No.	1007	2	1009
	Cases	3	0	3
Non-Radiation Workers	No.	2803	185	2988
	Cases	7	1	8
Total	No.	3810	187	3997
	Cases	10	1	11

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 there was one case of cancer at each of the following sites: soft palate, vocal cord, lung, skin, testis and kidney and one case of Hodgkin's disease and three cases of colon cancer. In the females there was one case of cervical cancer.

The three radiation workers who developed cancer of the rectum, cancer of the vocal cord and Hodgkin's disease have received very low cumulative radiation doses of 96, 20 and 22 mSv respectively over a period of 15 to 25 years which cannot possibly have caused the disease. The remaining 8 cancer cases occurred among the group of non-radiation workers and could only be

attributable to other lifestyle factors. For example, the employee who developed

Table 5: Details of Prevalent Cancer Cases in Employees of Rawatbhata DAE Centre (1995)

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
Soft palate (145)	55	M	1991	1957	Driver	Non-Radiation Worker	Smoking Alcohol
Rectum (154)	42	M	1995	1971	Tradesman	95.5	No habits
Colon (154)	42	M	1986	1968	Tradesman	Non-Radiation Worker	Smoking
Colon (154)	56	M	1991	1961	Foreman	Non-Radiation Worker	Chewing
Vocal cord (161)	50	M	1991	1965	Tradesman	20.1	No habits
Lung (162)	51	M	1993	1965	Tradesman	Non-Radiation Worker	Smoking Alcohol
Skin (172)	50	M	1989	1968	UDC	Non-Radiation Worker	Smoking Alcohol
Testis (186)	56	M	1992	1974	Watchman	Non-Radiation Worker	Smoking
Kidney (189)	51	M	1995	1970	Foreman	Non-Radiation Worker	No habits
Hodgkin's Disease (201)	46	M	1983	1968	Tradesman	21.7	No habits
Cervix (180)	49	F	1995	1966	Stenographer	Non-Radiation Worker	No habits

M - Male, F - Female

lung cancer was a heavy smoker, smoking 40 cigarettes a day, which is a well established risk factor. Smoking 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). Cancer of the soft palate could also be attributable to the employee's tobacco/alcohol use which has been established as risk factors for oral and pharyngeal cancers in several Indian studies (Jussawalla and Deshpande, 1971; Notani and Jayant, 1987; Notani, 1988).

The prevalence of the cancers of all-sites together in the radiation workers (males-3 cases, females - none) was compared with that in non-radiation workers (males - 7 cases, females - 1 case), after adjusting for differences in age distribution.

Table 6 : Comparison of Cancer Prevalence in Radiation Workers of Rawatbhata DAE Centre with Non-Radiation Workers of 1)Rawatbhata DAE Centre 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 (Rawatbhata DAE Centre) vs. Non-Radiation Workers (Rawatbhata DAE Centre)	3	2.24	1.34 (0.28-3.92)	0	0	-
Radiation Workers (Rawatbhata DAE Centre) vs. Non-Radiation Workers (BARC, Mumbai)	3	2.87		0	0	-

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

In males, the observed to expected ratio was 1.34 with 95% confidence interval of 0.28 to 3.92 as given 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 Rawatbhata DAE Centre.

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 Rawatbhata 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 Rawatbhata 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 1.05 with 95% of confidence interval of 0.22 to 3.05 (Table 6).

Infact when all male employees of Rawatbhata DAE Centre were compared with BARC(Mumbai) male employees there was no significant

difference in cancer prevalence of these 2 groups, (O:10, E:10.43, O/E:0.96, 95% CI:0.46-1.76), and also in the subgroups of radiation workers and non-radiation workers.

10.2 Cancer Prevalence in Spouses and Offspring

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

Table 7 : Prevalent Cancer Cases in Spouses of Employees of Rawatbhata DAE Centre (1995)

Spouses	Males	Females	Total
Number	34	3166	3200
Cases	0	4	4

One of these 4 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).

Of the remaining three cases, two cases were breast cancer and one was rectum cancer as shown in Table 8.

Although high doses of radiation is an established risk factor for breast cancer (Boice et al,1979), 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.

Table 8 : Details of Prevalent Cancer Cases in Spouses of Employees of Rawatbhata DAE Centre (1995)

				Employee's Details		
Diagnosis (ICD-9TH)	Age	Sex	Year of Diag.	Year of joining DAE	Designation	Radiation Status
Rectum (154)	38	F	1995	1974	Tradesman [Elect]	R
Breast (174)	59	F	1993	1966	Tradesman [Mech]	R
Breast (174)	45	F	1987	1967	Sci. Officer [Bio-chem]	NR
Cervix (180)	25	F	1995	1989	Driver	NR

R - Radiation Worker, NR - Non-Radiation Worker, F - Female

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(Mumbai) 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 a lower prevalence of cancer in the spouses of employees of Rawatbhata DAE Centre as compared to that of BARC (Mumbai) employees. The observed to expected ratio was 0.34 with 95% confidence interval of 0.09 to 0.87.

Table 9 : Comparison of Cancer Prevalence in Spouses of Employees of Rawatbhata 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 Rawatbhata DAE Centre vs Spouses of Employees of BARC(Mumbai)	4	11.7	0.34 (0.09-0.87)

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

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

As mentioned earlier there was no case of cancer reported in the offspring of employees of Rawatbhata DAE Centre.

10.3 Prevalence of Congenital Anomalies in the Offspring

Among the somatic effects of radiation, other than cancer, developmental effects in the unborn child are of great concern. Exposure to high doses of radiation can cause death, anomaly, growth retardation and functional impairment depending on the 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 10 : Prevalence of Congenital Anomalies (Major and Minor) in Offspring of Employees of Rawatbhata DAE Centre (1995)

		Males	Females	Total
Offspring of Radiation Workers	No.	995	787	1782
	Cases(%)	5(0.50)	2(0.25)	7(0.39)
Offspring of Non-Radiation Workers	No.	2678	2026	4704
	Cases(%)	13(0.49)	15(0.74)	28(0.59)
Total	No.	3673	2813	6486
	Cases(%)	18(0.49)	17(0.60)	35(0.54)

Table 10 gives the number of congenital anomalies both major and minor observed in the offspring of the employees with details of anomalies given in Table 11. 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 11 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 were considered in UNSCEAR reports as congenital. Therefore, for the time being we have considered all the observed anomalies for the analysis.

Table 11: List of Prevalent Congenital Anomalies(Major and Minor) in Offspring of Employees of Rawatbhata DAE Centre (1995)

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)					
Microcephaly (with growth or mental retardation)	3(14,12,2)	(NR,NR,NR)	-		3
Microcephaly (with delayed milestone)	-		1(1)	(NR)	1
total	3		1		4
2.Cardiovascular System (745-747)					
Ventricular septal defect	1(13)	(NR)	-		1
Patent ductus arteriosus	-		1(12)	(NR)	1
total	1		1		2
3.Musculo-Skeletal System (754-756)					
Arthrogryposis multiplex	-		1(8)	(NR)	1
Polydactyly	1(12)	(NR)	-		1
Short & poor development right limb	-		1(3)	(R)	1
Torticollis	1(1)	(NR)	-		1
Short right leg	-		1(11)	(NR)	1
Other anomalies of upper limb	-		1(13)	(R)	1
total	2		4		6
4.Gastro-intestinal System (749-751)					
Cleft palate	-		1(13)	(NR)	1
5.Genito-Urinary System (752-753)					
Polycystic kidney	-		1(10)	(NR)	1
6.Anomalies of Eye (743)					
Ptosis	2(8,11)	(R,R)	-		2
Cataract	1(23)	(NR)	-		1
*Convergent squint (378)	1(10)	(NR)	-		1
total	4		-		4
7.Anomalies of Ear (744)					
Deformity external ear	-		2 (6,11)	(NR,NR)	2
Pre-auricular sinus	1(9)	(R)	-		1
total	1		2		3

Contd.

Table 11 contd.

CONG.ANOMALIES (ICD 9TH :740-759)	Males No.(age)	(Parent/employee Radiation Status)	Females No.(age)	(Parent/employee Radiation Status)	Total
8.*Mental Retardation (319)					
?Cause	5(12,5,16,5,24)	(R,R,NR,NR, NR)	2(17,19)	(NR,NR)	7
?Birth asphyxia	-		1(14)	(NR)	1
total	5		3		8
9.*Growth Retardation (783)					
?Cause	2(8,11)	(NR,NR)	2(7,17)	(NR,NR)	4
?Nutritional	-		2(14,6)	(NR,NR)	2
total	2		4		6
TOTAL	18(0.49%)		17(0.60%)		35(0.54%)
Total Number of Offspring	3673		2813		6486

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

Total number of congenital anomalies (major and minor) recorded were 35 in numbers, of which 18 were in male offspring and 17 in female offspring; giving an overall prevalence of 0.54%. 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 12. The detailed description of anomalies in the offspring of BARC(Mumbai) employees is given in Appendix C, Table 5. No significant difference in the prevalence of congenital anomalies in the two groups was observed [Males: O=18, E=16.75, O/E=1.07, 95% CI=0.6-1.7; Females: O=17, E=9.81, O/E=1.73, 95% CI=1.0-2.8].

Table 12 : 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 Rawatbhata 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 13 below. The prevalence in males is not significantly different in the offspring of radiation workers compared to offspring of non-radiation workers; while in the female offspring the prevalence in the offspring of radiation workers was lower than the prevalence in the offspring of non-radiation workers.

Table 13: Comparison of Prevalence of Congenital Anomalies in Offspring of Radiation Workers vs. Offspring of Non-Radiation Workers of Rawatbhata DAE Centre

Groups Compared	MALES			FEMALES		
	Observed cases O	Expected cases E	O/E (95%CI)	Observed cases O	Expected Cases E	O/E (95%CI)
Offspring of Radiation Workers (Rawatbhata DAE Centre) vs. Offspring of Non-Radiation Workers (Rawatbhata DAE Centre)	5	4.95	1.01 (0.33-2.36)	2	6.01	0.33 (0.11-0.78)

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

Questions of classificatory nature 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.

However, the overall prevalence of congenital anomalies seen in the offspring of employees is only 0.5% (0.5% in males and 0.6% in females). An earlier exhaustive study at a large maternity hospital in Mumbai, has reported the prevalence of congenital anomalies after clinical examination of new borns to be 1.4% (Master-Notani et al, 1968).

11: CONCLUSION

This survey was carried out among the employees of the Rawatbhata DAE Centre and their spouses and offspring. The study end points were prevalence of malignancies in the above three 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 Rawatbhata 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 Rawatbhata 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 Rawatbhata 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 Rawatbhata DAE Centre has been shown in Appendix A. Furthermore, because of small numbers involved, no attempt was made to see the dose-response relationship. The employees were classified 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 Rawatbhata 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 of employees of Rawatbhata DAE Centre was somewhat lower than the prevalence in the corresponding BARC groups. While no malignancies were observed in the offspring of Rawatbhata employees.

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. Comparison with the prevalence in the offspring of BARC employees did not show significant difference. Internal comparison of offspring of radiation and non-radiation workers is of limited value, and did not answer the question of in-utero exposure.

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APPENDIX A

Radiation Exposure Data
Of Rawatbhata DAE Employees.

DOSE DISTRIBUTION OF RAWATBHATA DAE EMPLOYEES

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

A) MALES

Exposure (in mSv)	No.of Persons in Different Age Groups 18-	30-	40-	50+	Total	%
0-	12	7	7	3	29	2.9
1-	21	7	17	25	70	6.9
10-	18	10	22	20	70	6.9
20-	15	37	55	27	134	13.3
50-	22	80	49	23	174	17.3
100-	7	139	81	35	262	26.0
200-	0	99	84	43	226	22.4
400+	0	8	19	15	42	4.2
Total	95	387	334	191	1007	100.0

Mean Cumulative Radiation dose per worker = 137.4 ± 3.8 mSv

B) FEMALES

	Age	Cumulative exposure in mSv
1.	24	8.0
2.	25	4.9

APPENDIX B

Rawatbhata Study Population Distribution By Age, Sex And Radiation Status

APPENDIX B

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

A] Employees :

Sex / Radiation status	Age <20	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
Males											
Radiation Workers	0	25	70	175	212	172	162	122	67	2	1007
Non-Radiation Workers	3	140	344	410	437	399	439	387	234	10	2803
Total	3	165	414	585	649	571	601	509	301	12	3810
Females											
Radiation Workers	0	1	1	0	0	0	0	0	0	0	2
Non-Radiation Workers	0	8	36	20	32	28	32	20	9	0	185
Total	0	9	37	20	32	28	32	20	9	0	187

B] Spouses of Employees :

Sex	Age 15-	20-	25-	30-	35-	40-	45-	50-	55-	60+	Total
Males	0	2	0	6	7	8	2	5	1	3	34
Females	9	200	537	649	599	511	444	172	41	4	3166
Total	9	202	537	655	606	519	446	177	42	7	3200

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	161	247	268	210	95	14	0	995
Females	116	218	223	159	62	9	0	787
Total	277	465	491	369	157	23	0	1782

ii) Offspring of Non-Radiation Workers

Sex	Age 0-4	5-9	10-14	15-19	20-24	25-29	30-34	Total
Males	421	587	653	606	349	56	6	2678
Females	321	514	537	452	181	20	1	2026
Total	742	1101	1190	1058	530	76	7	4704

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

Contd.

Table-1 contd.

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
								1
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
								1
191	BRAIN						1	1
	TOTAL	0	0	0	0	0	1	1

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

APPENDIX C

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

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

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

APPENDIX D

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

APPENDIX D

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

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

न्यूक्लियर पावर कारपोरेशन
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NUCLEAR POWER CORPORATION
(A Govt. of India Enterprise)

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डॉ. ये. शिवराम प्रसाद
अध्यक्ष एवं प्रबंध निर्देशक
Dr. Y.S.R. PRASAD
CHAIRMAN & MANAGING DIRECTOR

No. NPC/CMD/99/M/140 June 11, 1999.

MEMORANDUM OF RECONSTITUTION OF CORPORATE COMMITTEE FOR EPIDEMIOLOGICAL STUDIES (COCES)

In partial modification of the earlier Memorandum No. NPC/MD/96/B/104, dated January 31, 1996, COCES committee on epidemiological studies of Radiation Occupational Workers and their families at Atomic Power Project/Station sites is reconstituted as given below :

1.	**Dr. Y.S.R. Prasad,** Chairman and Managing Director, NPC	Chairman
2.	**Dr. (Ms) K.A. Dinshaw,** Director,Tata Memorial Hospital, Mumbai	Member
3.	**Shri Ch. Surendar,** Executive Director (O), NPC	Member
4.	**Shri R.C. Joshi,** Executive Director (F), NPC	Member
5.	**Dr. U.C. Mishra,** Director,H, S & E Group, BARC	Member
6.	**Dr. (Mrs) A.M. Samuel** Director, Bio-Medical Group, BARC	Member
7.	**Dr. H.N. Saiyed** Director, NIOH, Ahmedabad	Member
8.	**Shri M. Das,** Chief Engineer (HSE&PA), NPC.	Member-Secretary

The functions and terms of reference for this committee shall remain the same as given in section 5 of the Consultancy Service Contract (Vide Annexure-1 enclosed).

(Y.S.R. Prasad)

APPENDIX G

CORPORATE COMMITTEE FOR THE EPIDEMIOLOGICAL STUDIES (COCES) (1992- 98)

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

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

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

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तल, कफ परेड, मुंबई - 400 005.
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अध्यक्ष एवं प्रबंध निर्देशक
Dr. Y.S.R. PRASAD
CHAIRMAN & MANAGING DIRECTOR

NPC/CMD/99/M/141

June 11, 1999.

MEMORANDUM OF RECONSTITUTION OF THE SENIOR TECHNICAL ADVISORY GROUP (STAG) FOR EPIDEMIOLOGICAL STUDIES

In partial modification of the earlier Memorandum No. NPC/MD/96/B/103, dated January 31, 1996, the STAG committee is reconstituted as follows :

1.	**Dr. (Ms) K.A. Dinshaw** Director, Tata Memorial Hospital (TMH), Tata Memorial Centre, Mumbai	Chairperson
2.	**Dr. A.N. Bhisey** Director, Cancer Research Institute (CRI), Mumbai	Member
3.	**Dr. B.J. Shankar** Head, Medical Division, BARC	Member
4.	**Dr. Shyam S. Agarwal** Director, Sanjay Gandhi Post-Graduate Institute of Medical Sciences, Lucknow (U.P.)	Member
5.	**Dr. I.C. Verma** Prof. and Head, Dept. of Genetics & Paediatrics, All India Institute of Medical Sciences, New Delhi	Member
6.	**Dr. P.S.S. Sundar Rao** Director, Schiefflin Leprosy Research and Training Centre, Karigiri.	Member
7.	**Shri M. Das** Chief Engineer (HSE&PA), NPC	Member
8.	**Dr. S.K. Dave** Dy. Director, NIOH, Ahmedabad	Member
9.	**Shri V.K. Gupta** Head, Health Physics Division, BARC	Member

10.	**Dr. B.S. Arya** TAPS Hospital, Tarapur	Member
11.	**Dr (Ms) P.N. Notani** Honorary Consultant, TMH	Member
12.	**Dr. S.A. Pradhan** TMH	Member
13.	**Shri M.R. Sachdev** Nuclear Safety Group, NPC.	Member-Secretary

The terms of reference for this committee shall remain the same as given in the earlier Memorandum (Copy enclosed).

(Y.S.R. Prasad)

Distribution :

STAG Members :

i) Dr. (Ms) K.A. Dinshaw, Director, TMH, Chairperson
ii) Dr. A.N. Bhisey, Director, CRI, Member
iii) Dr. B.J. Shankar,, Head, Medical Division, BARC, Member
iv) Dr. Shyam S. Agarwal, Director, SGPGI, Member
v) Dr. I.C. Verma, Prof. & Head, Dept. of Genetics & Paedriatics. (AIMS), Member
vi) Dr. P.S.S. Sundar Rao, Director, SLR & TC, Member
vii) Shri M. Das, Chief Engineer (HSE/PA), NPC
viii) Dr. S.K. Dave, Dy. Director, NIOH, Member
ix) Shri V.K. Gupta, Head, Health Physics Division, BARC
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APPENDIX G

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