HSE investigation of leukaemia and other cancers in the children of male workers at Sellafield.

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CONTENTS

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The investigation was carried out under the direction of Mr E J Varney, Deputy Chief Inspector, Nuclear Installations. The main epidemiological case-control study was designed by Mr J T Hodgson, and the project was controlled through a Steering Committee with members as follows:

Mr E J Varney — *Mr J T Hodgson* — *Dr J Osman*
Dr R McCaig — *Mrs S J Hutchings* — *Mr L G Williams*
Mr B J Furness — *Mr K Smith*

The work was carried out by the following:

Team A1: Identification of candidate cases and controls: analysis of radiation dose study

Dr R McCaig — *Mrs S J Hutchings*

Team A2: Matching of candidate cases and controls to the Sellafield workforces and preparation of dossiers

Mr J S Griffiths — *Mr J Sandford* — *Mr H K Robinson*
Miss J A Gibbs — *Mr I Johnson* — *Miss S Dee*
Miss M Jennings — *Mr D A Adams* — *Mr R Comaish*
Mr S A Bridge — *Miss L Blundell*

Team B: Assessment of external radiation dose for study subjects

Mr K Smith — *Mr L Bevington* — *Mr P Burrows*
Mr M Leach — *Mr D Brown* — *Mr I F Robinson*
Mr D Marshall

Team C: Assessment of potential chemical exposures

Dr M Tew — *Mr J Lindsay* — *Mrs J Rutherford*
Mr P Watson — *Mr D Daniels* — *Mr W Thompson*
Dr R Elliot

Team D: Data preparation and statistical analysis

Mr J Hodgson — *Miss K Naylor* — *Mr A Sweeney*
Miss G Grocott — *Mr S Clark* — *Miss V Boardman*
Mrs K Hall — *Miss A Turpin*

BACKGROUND TO HSE INVESTIGATION

1 In November 1983, Yorkshire Television broadcast a programme: "Windscale - The Nuclear Laundry". It suggested that in the village of Seascale, 3 km south of Sellafield, there was an excess of childhood leukaemia, and implied that this was due to the radioactive discharges from the plant.

2 Following the screening of the programme, the Minister of Health commissioned an independent advisory group chaired by Sir Douglas Black to investigate the claim. The Group published its findings[1] in 1984. These included a review of earlier work which indicated that there was an excess of leukaemia in children in Seascale, but that for West Cumbria as a whole, the mortality from childhood cancer was near the national average. It concluded, inter alia, that the calculated radiation doses to young people in Seascale did not support the view that the radioactivity released from Sellafield* was responsible for the observed incidence of leukaemia in Seascale and its neighbourhood.

3 The Group recommended that epidemiological studies and research should be carried out on the subject, and that a specialist body with significant health representation should be set up to advise on the control of permitted radioactive discharges. This led to the setting up by the Minister for Health of the Committee on Medical Aspects of Radiation in the Environment (COMARE) in November 1985. Its terms of reference were "to assess and advise government on the health effects of natural and man-made radiation in the environment and to assess the adequacy of the available data and the need for further research".

4 Professor Gardner, of the Medical Research Council Environmental Epidemiology Unit, was a member of Sir Douglas Black's Advisory Group, later becoming a member of COMARE: he was one of a number of people who followed up the Group's recommendation for further research. Professor Gardner set up a number of investigations including an epidemiological case-control study to examine the observed excess of childhood leukaemia and lymphoma near Sellafield in relation to certain behavioural or lifestyle variables (including those that might affect individual uptake of environmental radioactivity), and to radiation received during fathers' employment at the Sellafield nuclear plant.

5 Using a variety of sources, the study identified 52 cases of leukaemia and 22 cases of non-Hodgkin's lymphoma (NHL) in children who had been born and diagnosed of

* These discharges were later reassessed in a report[2] issued by COMARE

their illness in West Cumbria. Through the use of questionnaires and other methods, comparing the cases with other children as controls, the Gardner team examined the relative risks associated with various factors including paternal preconception radiation dose, maternal abdominal X-rays in pregnancy, paternal and maternal ages, maternal viral infection during pregnancy, family eating and children's play habits, paternal occupation and proximity of residence to Sellafield. The results of the study[3] were published on 15 February 1990. None of these potential explanatory factors showed any significant association with childhood leukaemia except fathers' pre-conception radiation dose.

6 Professor Gardner concluded that:

> "The raised incidence of leukaemia, particularly, and non-Hodgkin's lymphoma among children near Sellafield was associated with paternal employment and recorded external dose of whole body penetrating radiation during work at the plant before conception. The association can explain statistically the observed geographical excess."

The highest relative risks* recorded were of the order of sixfold for fathers with total radiation doses of 100 mSv or greater before the date of their child's conception, or doses of 10 mSv or greater during the six months before conception.

7 The publication of this report caused considerable public and political interest. Discussions were held between the Department of Health and the Health and Safety Executive (HSE) to determine what action should be taken. It was clear that the Gardner findings suggested a possible occupational cause which was a matter that HSE should pursue, and it was agreed that HSE would carry out an investigation into occupational factors arising at Sellafield which might shed further light on these findings. The Health Minister announced the start of this investigation on 15 February 1990[4].

8 A group was formed for this purpose with staff drawn from HSE's Nuclear Installations Inspectorate (NII) and the Epidemiology Unit of its Health Policy Division (which now forms part of the Technology and Health Sciences Division, THSD).

* The term "relative risk" in this report means the ratio of the probabilities that a case will occur in one group compared to another. In case-control studies, the relative risk is estimated by the "odds ratio" (OR): this is the ratio of the odds that a case will occur in one group compared to another.

9 The purpose of this report is to present the objectives, methodologies and findings of the various studies which comprise this investigation.

INTRODUCTION TO THE HSE STUDIES

Aims and contribution of each study

10 Since the results of Professor Gardner's report suggested that leukaemia and NHL in some children was related to paternal employment and in particular the fathers' exposure to external radiation, HSE decided to focus its investigation on Sellafield and the occupational histories of fathers. The investigation was planned to examine the fathers' exposure to external radiation* and a number of other employment factors not considered by Professor Gardner. These included exposure to internal radiation*, and to known or suspect carcinogenic and mutagenic chemicals. Additionally, fathers' job histories, ie where they worked, what type of occupation, and their involvement in known radiation or other incidents, were examined. The objective was to see if any of these factors could explain or clarify the association reported by Professor Gardner.

11 Because it was recognised that a full epidemiological study would take some years to complete, it was decided to split the investigation into 3 parts. ***The first part was to examine the occupational histories of those case fathers who had worked at Sellafield and who had been identified by Professor Gardner. This is referred to in this report as the case-only study.*** The intention was to see if any obvious common factors emerged which provided grounds for immediate action by HSE to protect further the health and safety of workers. The data used were the preconception external radiation dose† records, biological monitoring records, the occupational history records showing where each father worked and when, and records of radiological incidents. Potential exposure to selected chemicals was inferred from the above data.

12 ***The second part, referred to as the radiation dose study, was aimed at comparing the radiation dose histories of each of the case fathers with those of all other male Sellafield radiation workers of the same age as the case fathers when the children were conceived***, ie, if a case father were aged, say, 25 at the time of conception, his total radiation dose was compared with that of all other male workers up to the time

* The terms "external radiation" and "internal radiation" are defined in the Glossary.

† In this report the term "preconception external radiation dose" is generally abbreviated to "radiation dose", unless the context requires otherwise.

they were 25. Such a comparison would show whether the radiation doses of the case fathers were as unusual, in this extended comparison, as Professor Gardner's results (based on some 90 matched control fathers) implied.

13 ***The third and main part of the investigation was an epidemiological case-control study. It was based on children born in West Cumbria whose fathers worked at Sellafield. The cases were children whose fathers had worked at Sellafield at some time prior to the diagnosis of cancer in their children, the children being under 25 at the time of diagnosis. The controls were other children whose fathers had started work at Sellafield before the child's 25th birthday.*** In this context "working at Sellafield" means that the person concerned was directly employed at Sellafield by the United Kingdom Atomic Energy Authority (AEA), British Nuclear Fuels (BNFL) or the United Kingdom Atomic Energy Authority Constabulary, and does not include contractors who worked on the site. The study was designed to investigate not only the effects of exposure to internal and external radiation but also occupational history, exposure to chemicals and involvement in radiological or other incidents. In this respect the HSE investigation is different from Professor Gardner's study because it centres on Sellafield and the occupational histories of its workforce. At a late stage of the study, it was decided to see whether any of the available data supported Dr Kinlen's theory on population mixing.[5,6] He has suggested that there may be an infective basis for childhood leukaemia which could be enhanced by unusual patterns of people coming to live and work in the area from other parts of the country.

Development of investigation protocol

14 At a very early stage it was decided that HSE staff would not seek to interview any of the case or control fathers. Professor Gardner's study had addressed the possible role of personal risk factors of a sort that could only be established by direct interview, but had found no important associations. The focus of interest in the HSE study would be on workplace exposures and particularly on radiation exposures for which documentary records should be available. BNFL and AEA held the detailed records relating to the occupational histories of the Sellafield workforce, and they readily agreed to provide access subject to the agreement of the workforce. It was also necessary to know the names of the case fathers identified by Professor Gardner, and, for the epidemiological case-control study, to trace all other cases of childhood cancers related to Sellafield fathers. It was therefore necessary to have access to information held by the Office of Population Censuses and Surveys (OPCS) and through it, by the National Health Service Central Register (NHSCR).

15 Although the employers, having consulted with the workforce, were prepared to provide data from their files, neither Professor Gardner nor OPCS could release the

information required until the proper clearances had been obtained from the ethical authorities. A detailed protocol[7] explaining HSE's proposals was therefore submitted through OPCS to the British Medical Association Ethics Committee. The application accompanying the protocol also required HSE to confirm that it had the agreement and support of the workforce. The protocol described the studies planned, how the cases and controls were to be selected, and also the managerial and working arrangements, particularly those required to maintain confidentiality. A similar submission was made to the West Cumbrian Ethics of Clinical Research Committee.

16 To secure the necessary agreements, presentations were made both to management and workforce representatives. They gave their agreement on the condition that anyone who did not wish to be involved with the study should be given the opportunity to opt out. HSE formally submitted its application to OPCS on 20 September 1990. In order to advertise the investigation and provide the agreed opportunity to opt out, notices were placed in the BNFL and AEA newsletters and in a number of trade union journals. HSE's press office also notified BBC national radio, local TV stations and national press to ensure maximum coverage of the opt out procedure which people could use if they did not wish to have their records used in the study. A number of people wrote in but, following clarification, only 5 asked not to be included. Of these, only one proved to be a potential subject (a control), and the matching process for him was not pursued. Thus the study was not materially affected. The clearance to proceed with the studies was received from the ethical authorities by 18 December and work commenced early in January 1991.

Overall study management arrangements

17 The investigation, being made up of a number of distinct studies, required a management structure to ensure that the people who had access to the subjects' names were separated from those who were to do the epidemiological analysis. Similarly, the people who were collecting and collating the data had to be separate from those who knew the identity of the case and control fathers. This was to ensure the necessary confidentiality, both to limit access to the names of cases and controls on a 'need to know' basis, and to prevent the possibility of bias in the interpretation of data. For the main epidemiological case-control study, five teams were set up as shown in Table 1. The whole project was controlled by a steering committee to decide on policy and planning.

18 For the main case-control study the initial task was for Team A1 to obtain the birth certificates for those born in West Cumbria during the period 1950-1990 who were diagnosed prior to age 25 as having cancer. They separately obtained a sample of West Cumbrian birth certificates from OPCS for the same period. All of these birth

Table 1

Case-control study: Teams and their function

TEAM	FUNCTION[1]	
A1	(i)	Obtain from OPCS copies of the birth registrations for all children born in the study area (Allerdale and Copeland Districts) during the study period, who had been flagged on the NHSCR as having died from or diagnosed with cancer.[2]
	(ii)	Mix these with a sample of birth certificates of children born in the same study area and study period.
	(iii)	Transfer the birth certificates to Team A2 in a manner ensuring that Team A2 did not know which were diagnosed as cancer sufferers.
A2	(i)	Search the BNFL and AEA workforce files to determine whether children whose birth certificates had been transferred from Team A1 were those of fathers who had been employed at the Sellafield site.
	(ii)	Having identified children with fathers linked to Sellafield, prepare dosiers of occupational history and radiation exposure with identifying names and markings removed and replaced by a code.
	(iii)	Transfer these anonymised dossiers to Teams B & C.
B	(i)	Evaluate radiation dose data from film badge records in the dossiers provided by Team A2.
	(ii)	Extract relevant information and translate it into modern dosimetry units, resolve queries, and pass the translated information to Team D.
C	(i)	Using occupational histories provided by Team A2, assess each subject's potential for exposure to various chemicals.
	(ii)	Pass the information to Team D.
D	(i)	Using the completed anonymised dossiers, encode the data for computer analysis.
	(ii)	Evaluate the results.

[1] Further details of the methods used by each team are given in the Appendices.

[2] Individuals were candidates for inclusion as cases in this study where their diagnosis had been recorded on the National Health Service Central Register (NHSCR) by January 1992. Deaths up to 1990 and cancers registrations to 1987 had been recorded at that time.

certificates were passed to Team A2 without any indication of which might be a cancer case.

19 Team A2 then had the task of establishing which of these children could be directly linked to a father who was, or who had been, a member of the Sellafield workforce. They extracted from the Sellafield files details of the matching fathers' work histories and radiation records. This information was anonymised and included in a complete dossier for each subject under a code number. These anonymised dossiers contained the basic information which was used in subsequent parts of the study described later in this report.

20 Team B was given the task of producing the detailed interpretation of the external radiation dose histories for each subject. The collection of chemical exposure histories was the responsibility of Team C. In parallel with this "in house" HSE resource, the National Radiation Protection Board (NRPB) was contracted to carry out the internal dose assessment using relevant information on work histories and biological monitoring. Finally, Team D had the task of coding the anonymised information and carrying out the statistical analysis. (Details of the working methods used by the teams are given in Appendices 1 and 2).

THE CASE-ONLY STUDY

Objectives

21 It was decided to carry out an initial study of the occupational histories and radiation exposures of the 11 case fathers identified by Professor Gardner. Following clearance from the ethical authorities, Professor Gardner provided to HSE on a confidential basis the names of the Sellafield case fathers who had been included in his study. Team A2 carried out the investigation and reported its findings in June 1991. The results of this investigation were revealed to only a small number of people all within HSE: Teams B, C and D did not have access to them to ensure that no possibility of bias could be introduced to subsequent parts of the study.

22 The objective of the case-only study was to carry out a detailed examination of the case fathers' occupational histories at Sellafield to try to identify any factors which were common to this group. If any such factors were found, this might have implied a link with their children's illness indicating a need for further protective action for the workforce.

Working methods

23 The comparisons carried out in the case-only study were intended to be objective, but the information did not lend itself to the use of statistical or epidemiological techniques. Knowledge of the case fathers' identities was limited within HSE to specified members of Teams A1 and A2 who needed to know. The type of information obtained from BNFL records included data on external radiation doses, results of any biological monitoring, personnel records and involvement in incidents. Access was not provided to medical records, although some basic information which had been extracted by BNFL was examined to check whether any of these individuals had needed decontamination by Medical Centre staff. For each of the cases, a photocopy of each record type was prepared: the originals were returned to BNFL. From the photocopy, a second version was produced, the names of the case fathers and all other identifying features being removed and replaced by a code, to maintain anonymity.

24 A series of standard spreadsheets was developed covering an overview of the fathers' employment history up to the time of diagnosis of each child's illness together with information for the two years centred on the assumed date of conception. These were completed for each of the case fathers by at least two members of the team as a check for accuracy. A comparison was made of relevant aspects such as total whole body external radiation dose up to the date of conception, type and location of work, exposure to contamination, and involvement in incidents in an attempt to identify common factors. For the purposes of this analysis, the occurrence of the same feature in five or more of the cases was deemed to constitute a common factor.

Findings of the case-only study

25 It was noted that 7 out of the 11 case fathers were born or brought up in West Cumbria. This is not surprising as BNFL and AEA recruit locally.

26 The analysis of the dates of birth of the case fathers' children showed that the numbers of children born peaked between 1960 and 1964. The distribution showed 1 child born between 1950 and 1954, 2 between 1955 and 1959, 4 between 1960 and 1964, 2 between 1965 and 1969, 1 between 1970 and 1974 and 1 between 1980 and 1984.

27 Examination of cumulative totals in the film badge records showed that 4 out of the 11 case fathers had received a total cumulative whole body dose of external radiation greater than 100 mSv prior to the conception of the case children, 2 had received doses between 50 and 99 mSv, and 4 had received doses between 1 and 49 mSv; the

remaining case father did not have a radiation dose record. These figures confirm the numbers in each of the dose bands used by Professor Gardner*.

28 Examination of the records of doses received during the six months prior to conception showed only 2 of the fathers had received more than 10 mSv and 3 were in the range 5 to 9.5 mSv. This compares with the 4 fathers estimated to have received more than 10 mSv by Professor Gardner who used an approximate method of estimating the dose in this period by calculating proportionally from annual doses. No estimates of internal radiation dose were included in this case-only study.

29 Examination of information about the working locations of case fathers for the period prior to the conception of their children showed there were two locations where at least 3 of the case fathers had been employed for some period. (No conclusion was drawn from this: the topic of work locations is, however, dealt with in more detail in the case-control study reported later.)

30 Examination of the information on the chemicals to which case fathers could have been exposed prior to the conception of their children showed several chemicals to which 5 or more of the fathers could have been exposed, ie they worked in parts of the plant where these chemicals were in use. The chemicals included ammonia, beryllium, caustic soda, nitric acid and sodium hydroxide. Apart from beryllium, the other chemicals listed are still in common use at Sellafield. Examination of occupational histories also showed that 5 out of the 11 fathers could have been exposed to coal or graphite dust at some time prior to the conception of their children. It is not possible to say that these findings are significant: the observation is merely that the individuals worked in areas where these chemicals were in use, not that they were actually exposed to them.

31 Involvement of the case fathers in incidents associated with radioactive material was also considered. This showed that 6 had been involved in 1 or more such incidents prior to conception of their children, though none of these fell into the six month period immediately prior to the date of conception. In addition, 5 had been involved in 1 or more incidents in the period between conception and the diagnosis of their child's illness. However, in the absence of controls against which to judge this finding, no particular conclusions could be reached.

32 The findings of the case-only study were held in confidence, being withheld from Teams B, C and D to ensure that no possibility of bias could be introduced to the subsequent parts of the study.

* For one of the case fathers, the cumulative pre-conception whole body dose includes an estimate made by BNFL for two ocasions on which his film badge was lost.

RADIATION DOSE STUDY

Objectives

33 The Gardner report presented a prima facie case that fathers' external radiation doses prior to the conception of their children are causally associated with a raised risk of leukaemia and NHL in the children. Following on from the case-only study, it was decided to compare the cumulative pre-conception doses of the 11 case fathers identified by Professor Gardner, and the doses they received in the year of conception of the case children, with those of all other males of the same ages in the Sellafield workforce. The objective was to see how they compared, and whether the associations reported by Professor Gardner would be maintained when seen in the context of all available dose data.

Working methods

34 For this part of the investigation, the controls were all past and present male workers of ages matched to the case fathers at the time of conception. Annual and cumulative external radiation dose data were provided by BNFL for all males employed at some time during the period 1950-1985. The data for the leukaemia and NHL cases were plotted together with the pooled data for the controls in order to show whether the case fathers' radiation doses were typical. The relative risks of having a child who would develop these illnesses were estimated for men with recorded radiation doses at or above various levels, compared with those men who had received lower doses. Similarly the relative risks of case fatherhood for men with cumulative doses in a range of dose categories above 50 mSv were compared with those for men with a dose less than 50 mSv.

35 For comparison purposes, figures were initially plotted for each case father and his controls to show in percentile terms how the case father's cumulative radiation dose, and dose in the year of conception, related to other men of the same age. This data was then pooled: (i) for the cumulative dose; and (ii) for the dose in the year of conception, to produce figures 1 and 2 respectively. The x-axis represents the year (1950-1983), on a scale proportional to the numbers of age-matched controls employed at Sellafield at the time. The y-axis represents percentiles of this workforce. External radiation dose is represented in the body of the plot, and from the contours one can read off the y-axis the percentage of workers employed in the relevant year who had received a cumulative external radiation dose below the level indicated. Marked on these figures are the doses of the 11 case fathers against the year of their children's conception.

Figure 1 - Cumulative Dose Chart

The conception dates and pre-conception radiation doses for the 11 case fathers identified by Professor Gardner shown against the distribution of man years by year and cumulative radiation dose for all Sellafield employees of the same ages as the case fathers.

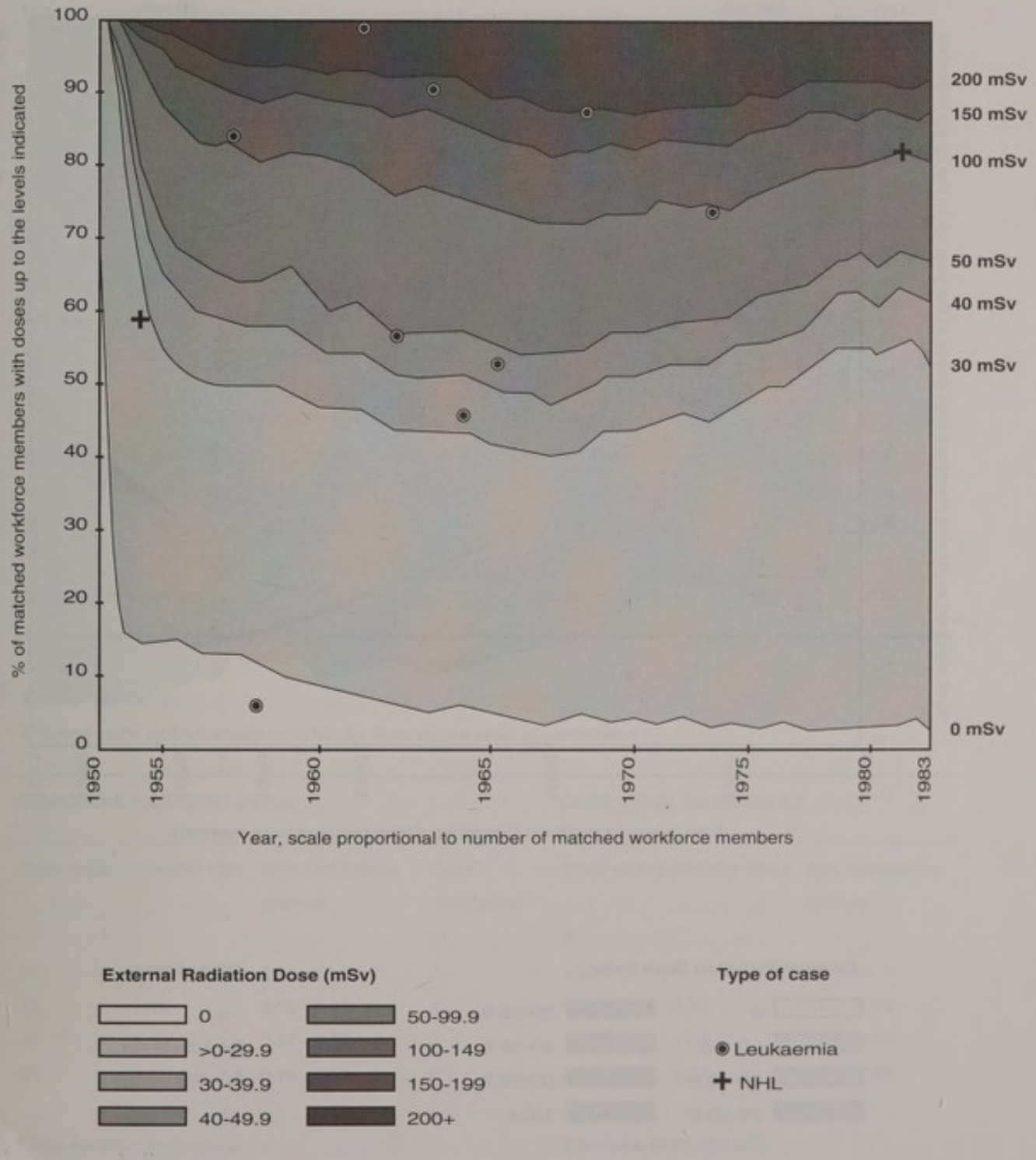
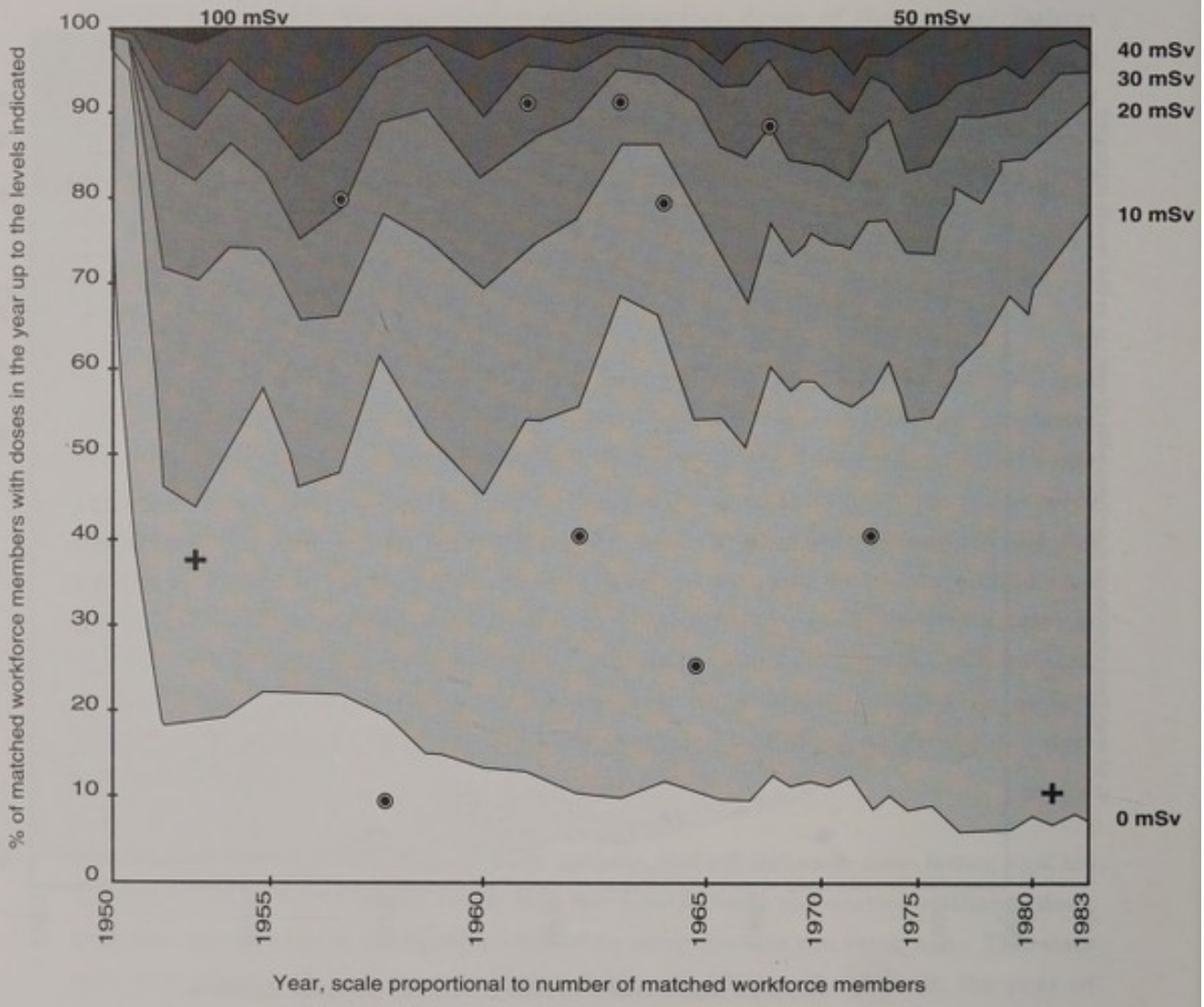
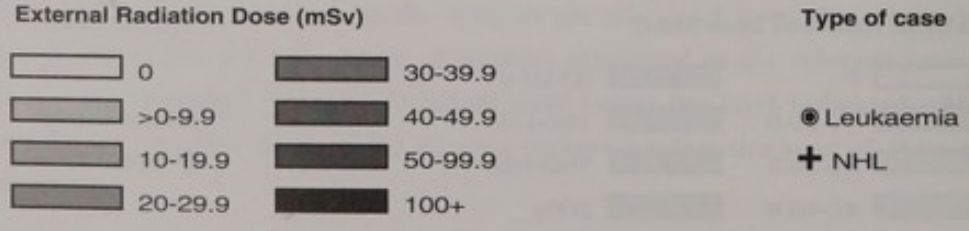


Figure 2 - Annual Dose Chart

The conception dates and radiation dose in the year of conception for the 11 case fathers identified by Professor Gardner shown against the distribution of man years by year and radiation dose in the relevant year for all Sellafield employees of the same ages as the case fathers.





36 Tables 2 and 3 show the relative risks derived from these data. Each table presents the risk in two ways, that headed "dichotomous dose levels" compares the relative risks above and below particular levels of dose; that headed "dose level categories" compares the risk from receiving a dose within a specified band prior to the date of

Table 2

Relative risks of leukaemia or NHL by lifetime pre-conception dose

DICHOTOMOUS DOSE LEVELS				DOSE LEVEL CATEGORIES		
Dose (mSv)	*Relative Risk*	*95% Confidence interval*	*Case Distribution*	*Dose (mSv)*	*Relative Risk†*	*95% Confidence interval*
			1*	0		
>0	0.84	0.11 - 6.54	0	>0 - 9		
10	4.35	0.53 - 35.9	0	10 - 19		
20	7.38	0.92 - 59.4	1	20 - 29		
30	5.21	1.06 - 25.6	1	30 - 39		
40	4.13	1.05 - 16.1	2	40 - 49		
50	2.25	0.68 - 7.46	2	50 - 99	1.65	0.32 - 8.51
100	2.30	0.65 - 8.14	1	100 - 149	1.81	0.21 - 15.8
150	2.84	0.72 - 11.2	2	150 - 199	6.34	1.20 - 33.4
200	1.23	0.15 - 9.84	1	200+	1.77	0.20 - 15.9

* Non-radiation worker

†Baseline dose <50 mSv

Table 3

Relative risks of leukaemia or NHL by dose in the year of conception

DICHOTOMOUS DOSE LEVELS				DOSE LEVEL CATEGORIES		
Dose (mSv)	*Relative Risk*	*95% Confidence Interval*	*Case Distribution*	*Dose (mSv)*	*Relative Risk†*	*95% Confidence Interval*
			1*	0		
>0	1.95	0.24 - 16.0	5	>0 - 9		
10	1.16	0.35 - 3.81	1	10 - 19	0.50	0.06 - 4.19
20	1.95	0.57 - 6.67	2	20 - 29	1.93	0.39 - 9.59
30	1.57	0.34 - 7.29	2	30+	1.58	0.32 - 7.83

* Non-radiation worker

†Baseline dose <10 mSv

the child's conception with that to individuals who have received less than 50 mSv for the cumulative dose, and less than 10 mSv in the year of conception.

Findings of the radiation dose study

37 From Figure 1 it can be seen that 3 of the 11 case fathers had cumulative radiation doses exceeding 150 mSv prior to the conception of their children. Nine out of the 11 received doses above the median.

38 The mean of the cumulative doses of the 11 case fathers was also compared in 20 trials to that of 999 randomly chosen sets of 11 controls. The case dose mean (106 mSv) occupied a position estimated by this method to lie with 95% confidence between the 88th and 91st upper centiles of the range of means of all possible sets of 11 doses of the age matched men in the workforce. The results suggest an association of case fatherhood with comparatively high cumulative radiation dose, the comparison being made with all other workforce males of similar age.

39 From the "dose level categories" side of Table 2, it appears that there is a trend of increasing risk at higher cumulative dose and a test for linear trend indicates that this relationship is significant at the 95% confidence level. However, in view of the wide confidence limits associated with the estimates, which are a reflection of the small number of cases involved, this data must be treated with caution. There is a suggestion in the estimate of a six-fold relative risk at doses of 150 mSv and above, which tends to support Gardner's observation of a significantly raised risk of fathering a child who developed leukaemia or NHL at cumulative doses in excess of 100 mSv.

40 Analysis of data from the "dichotomous dose levels" side of Table 2 suggests that risks may also be substantially raised at lower levels of dose, around 30-40 mSv. The association with dose is not monotonic when risks at these lower exposures are taken into account. It can be seen in Figure 1 that the case fathers cluster in two groups with respect to the dose category limits (and also with respect to the y-axis centile rankings). Three cluster in the 30-49 mSv band, and another 6 fall in the highest dose bands starting at just below the 100 mSv line. It is this pattern of clustering that explains the non-monotonic pattern of the risk ratios. Again it has to be emphasized that nearly all the estimated comparative risks involve wide confidence intervals so the results should be treated cautiously.

41 Figure 2 relates to the year of conception. Six out of the 11 case fathers had doses in the year of conception of less than 10 mSv, whilst 3 had doses between 10 and 30 mSv with 2 exceeding 30 mSv. Five out of the 11 lie above the median annual dose. The mean annual dose of the case fathers was 14 mSv, a value which lies with 95%

confidence between the 63rd and 70th centiles of all possible subsets of 11 age-matched men in the workforce. No clear pattern emerges from this ranking.

42 Table 3 suggests a raised risk of fathering a child with leukaemia or NHL for those with radiation doses of over 20 mSv in the year of conception which appears to represent about a doubling of the risk. This does not approach Professor Gardner's estimate of a four-fold raised risk for doses of 10 mSv or more in the six months prior to conception. Again the wide confidence intervals associated with these findings mean they should be treated cautiously.

THE MAIN CASE-CONTROL STUDY

Objectives and overall plan

43 This third, and main part of the HSE investigation was set up to examine a range of issues arising from Professor Gardner's work in relation to Sellafield fathers. The intention was, firstly, to include more case fathers and to extend his analysis using a more detailed assessment of radiation dose (including an estimate of internal radiation dose for each subject). Secondly, to examine the possible effects of other workplace factors, and thirdly, to see whether the risks of cancers other than leukaemia and NHL were raised in the children of workers with higher pre-conception radiation doses. Specific questions to be addressed were:

(a) In addition to external radiation dose, what other workplace exposures, or other features of job history (if any) are associated with leukaemia in workers' children?

(b) Do any of these factors provide an alternative explanation of the observations of excess leukaemia?

(c) Does the distribution in time of the workplace cases suggest any association of risk with particular calendar periods?

(d) Does the paternal radiation/childhood leukaemia association appear consistently across the observation period, or is there any additional association with particular time periods?

(e) Does the paternal radiation/childhood leukaemia association appear consistently both for births resident and non-resident in Seascale?

(f) Is the risk of cancer other than leukaemia and NHL raised among the children of Sellafield workers?

44 The investigation method chosen to address these issues was a case-control study. In this design, the cases arising in the target population are compared with a representative sample of non-cases (controls) from the same population. For the present investigation the population of interest is that of children born to men directly employed at Sellafield. The main difficulty in assembling an appropriate study population is that there is no way of directly identifying the members of this target group. The study population was identified by a two-stage process of first identifying "candidate" case and control children from the totality of births to mothers resident in a wide area around the Sellafield site (the current local authority areas of Allerdale and Copeland), and then identifying within the candidate groups which children had fathers who had worked at Sellafield.

Identification of cases and controls

Cases

45 The details of the methods used to identify case and control fathers are given in Appendix 1, and are summarised as follows: candidate case children were identified by searching the National Health Service Central Register (NHSCR) in the area currently known as Allerdale and Copeland for the period 1 January 1950 to 31 May 1990. This end date was chosen because it was the last date at which complete entry of deaths, regardless of their location, could be guaranteed. Although cases were sought amongst births registered up to 31 May 1990, September 1989 was the last date for which microfiche copies of birth records were available at the time of the extraction of the control series. No candidate cases were in fact identified amongst the registrations from October 1989 to May 1990, so the observation period for the study was taken as January 1950 to September 1989.

46 Copies of death registration information for all deaths in this group were obtained from OPCS and reviewed by two members of Team A1 independently, and all certificates indicating a malignant condition were noted. For the period 1971 onwards, cancer registrations have been marked on the NHSCR, and cancer registration details for the children of interest were extracted by OPCS. At the time of data extraction, the latest cancer details on the register were for 1987. By this method, 203 candidate cases were identified. For each case, a copy of the birth certificate was obtained from OPCS, and the data was entered on a computer file.

Controls

47 The candidate control children were a systematic random sample drawn from the same birth registers and in the same time period as the case children. Estimates based on the proportion of control subjects in the Gardner study who were linked to the Sellafield work force suggested that a sample of about 2% of births would safely

yield the desired number of controls. The same work also suggested that it would be necessary to over-sample controls with mothers resident in Seascale, if adequate numbers of Seascale controls were to be obtained to stratify the analysis by this factor. The extent of this over-sampling was determined after the first batch candidate controls had been matched* against the Sellafield personnel records.

48 In anticipation of the need to enhance the Seascale control sample, OPCS also extracted copies of all birth certificates in the same registries with registration numbers whose last two digits were in the range 11-25, and which mentioned "Seascale" on the register entry. The results of the first batch of matching showed that the Seascale controls would need a nominal 6% sample of births to achieve an adequate Seascale control sample. Accordingly, a randomly chosen 4/15ths of the additional Seascale sample of candidate controls was added to the basic 2% sample, after weeding out those certificates where the mention of Seascale on the certificate did not imply that the mother's residence was in the civil parish of Seascale.

49 In order to address the possibility of post-conception workplace effects, case children conceived before their fathers started work at the plant and diagnosed after that date were clearly of interest. However, large numbers of control children would naturally fall into this category, and if represented in the control series in their true proportion, would reduce the power available in the study to examine the effects of possible workplace pre-conception factors. It was decided to limit the numbers of control children whose fathers started work at Sellafield after their birth, but before their diagnoses, by taking a random 1 in 4 sample of the candidate controls who appeared at the initial stages of matching to fall into this category. A final total of 1482 candidate controls was available for matching from the Allerdale and Copeland registration districts.

Checks on control sample

50 The main candidate control sample should have automatically given something close to a 2% sample of live births, but the achieved sampling fraction was affected by cancelled register entries, and by registration books which did not contain whole hundreds of entries. The details of checks on the actual sampling fraction are described in Appendix 1. The final sampling scheme for controls resulting from these adjustments and from the over-sampling of Seascale controls and under-sampling of control fathers not employed at Sellafield before their child's conception is summarised in Table 4. (See also Tables 1 and 2 in Appendix 1).

* "Matched" in this context means the father named on the birth certificate could be identified with appropriate confidence in the Sellafield workforce file.

Table 4

Sampling fractions for control subjects in different study strata and time periods

POPULATION GROUP	TIME PERIOD	SAMPLING FRACTION (%) FOR COMPLETE 'CANDIDATE' SERIES		FRACTION USED IN MATCHING	FINAL SAMPLING FRACTION (%)
		nominal [1]	*actual*		
Birth resident in Seascale:					
Father at Sellafield before child's birth	1950 - 73	6	6.15	0.963[2]	5.92
	1974 - 89	6	6.00	0.958[2]	5.75
Child born before father's start at Sellafield	1950 - 73	6	6.15	1/4	1.54
	1974 - 89	6	6.00	1/4	1.50
Birth resident elsewhere:					
Father at Sellafield before child's birth	all	2	2.00	7/8	1.75
Child born before father's start at Sellafield	all	2	2.00	1/4	0.50

[1] For births to families resident in Seascale, the nominal sampling fraction comprises a 2% fraction from the main control series plus 4% from the additional Seascale controls.

[2] The combined effect of using 7/8 of the main (2%) control series plus 4% from the supplementary Seascale sample.

Matching children named on birth certificates to fathers on the Sellafield workforce file

51 Birth certificate data for the 203 candidate cases and 1482 candidate control children were passed to Team A2 in randomly chosen batches, with cases and controls mixed together. The information on the birth certificates was then used to establish which candidates' fathers had worked at Sellafield, by matching the available data to the personnel records held by BNFL and AEA. This was done by members of Team A2 at Sellafield, who were given access to the computerised personnel databases, and to the paper personnel files. Matches were scored on a pre-established scale of similarity based on the relative frequency of the values of matching items (surnames, forenames, addresses, jobs). A match was accepted at a score corresponding to a nominal false positive probability of 10^{-12}. All possible matches with nominal false positive probabilities between 10^{-8} and 10^{-12} were reviewed in detail for indirect or additional evidence for or against a true match. There were 25 potential matches in this score range, and 11 were accepted. The numbers of case and control children successfully matched and retained in the study are summarised in Table 4 of Appendix 1.

52 Because three members of Team A2 had worked on the case-only study, the identities of the 11 Sellafield case fathers identified by Professor Gardner, were known to them. For all other candidate cases or controls, the matching was performed without knowledge of whether the child concerned was a case or control. The review of borderline matches was performed entirely case-blind.

Extraction of information and production of dossiers

53 Appendix 2 describes the way in which information was extracted from files held by AEA and BNFL and was used to construct a dossier of employment history for each father included in the study. Access to information held by AEA and BNFL relating to employment history was provided at the Sellafield site in a way which ensured that no member of the employers' staff became aware of the names of the subjects.

54 For each of the 211 fathers in the investigation, a series of information dossiers was prepared. All information which might enable the individual concerned to be identified was removed. The dossiers contained the following information:

- ▼ External dosimetry — details of external radiation doses assigned by the employer from each film badge or thermo-luminescent dosemeter (TLD).
- ▼ Internal dosimetry — data from personal air samplers and from biological monitoring.

- Chemicals — potential for exposure to chemicals.
- Work Histories containing the following information or records:
  - Personnel — these were used to establish the types of work, the buildings and dates concerned.
  - Incident — involvement in incidents or occurrences on the site which might have affected people.
  - Contamination — information was provided by BNFL and AEA on people treated at the Medical Centre for contamination.
- Father's place of birth — birth of a father outside Cumbria was used as an indicator for population mixing.

External radiation doses

55 It became clear at a very early stage that since analyses covering various periods of time prior to conception were likely to be required, Team B should convert the dose data from the anonymised copies of the original dose records on a "badge-by-badge" basis, ie where possible, the dose recorded for each interval of time for which routine whole body dosemeters had been issued, would be addressed. The output from Team B would thus allow, for each individual, the assigning of radiation doses for various time periods prior to the date of conception as well as cumulative dose up to that date. It was decided, following consultation with various medical experts, that the immediate pre-conception period of interest would be taken as 12 weeks. Radiation doses in that period were evaluated for each of the subjects in the study. Appendix 2 explains the reasons for this choice of time period and describes the procedures used.

56 Much thought was given to deciding which components of external radiation should be addressed. It was considered unlikely that the beta radiation component would be a significant contributor to the dose and that within the accuracy of the study little would be lost by not including it. Only those recorded doses from X-, gamma, and neutron radiation therefore were translated. However, the dose records were not perfect and at times technical judgement had to be applied in deciding which dose figures to use. A panel of 3 health physicists arbitrated in particularly difficult instances. In a few cases where the dose records were particularly deficient, eg where there were unexplained gaps or where notional doses had been ascribed, imputation rules were developed (see Appendix 2).

Internal radiation doses

57 In addition to exposure to external radiation, workers in the nuclear industry, particularly in some locations at Sellafield, have the potential to inhale or ingest radioactive substances which give rise to additional radiation doses.

58 Access was provided by BNFL and AEA to the records of each individual's radioactive intake. This information was sent to the National Radiological Protection Board (NRPB), after anonymisation, for an estimate of internal radiation dose to be made.

59 Taking into account the objectives of the study and the range of radionuclides to be considered, it was decided to make the following assessments:

- integrated dose from the date of start of work to the date of conception;
- dose in the 64 days prior to conception (in the subsequent analysis this was extrapolated to 84 days: see Appendix 2);
- dose in 365 days prior to conception;
- dose in each calendar year from the start of work to the year before date of conception.

60 The results of the assessments carried out by NRPB for each subject for whom there was any record of intake of radioactive material were provided to HSE. In addition, NRPB prepared a full report of its work[8] which also summarised the main findings for the internal dose distribution within the study population.

Potential for exposure to chemicals

61 Information on the potential exposure of case and control fathers to selected chemicals was obtained by Team C. The list of relevant chemicals was derived from 3 sources. BNFL had provided for review by the Department of Health's Advisory Committee on Mutagenicity of Chemicals in Food, Consumer Products and the Environment (COM), a list of chemicals used in bulk in the site processes and a list of those used in smaller quantities in the laboratories, together with their International Agency for Research on Cancer (IARC) classifications[9]. This was supplemented by information provided by inspectors with experience of the site and by the results of an in-house review of the scientific literature on occupational exposures associated with cancers in the offspring. Interviews were then held with BNFL and AEA personnel who had experience of jobs comparable to those held by the case and control fathers. This provided information on whether or not a chemical had been in use at a given time, and how it was handled. From this qualitative data it was possible to produce

an exposure ranking for each job type against each of the 35 chemicals on the list. The job histories were used to determine the duration of such potential exposures. Appendix 2 gives the full list of chemicals and describes in more detail the way in which Team C produced exposure rankings.

62 In addition to the chemical substances it was decided to treat in the same manner a number of other factors which were not readily quantifiable. These were:

neutrons,
alpha-in-air,
polonium,
tritium and
beta/gamma-in-air.

Potential for exposure to these radiations and to the chemicals was rated on a seven point scale.

63 For each case or control father, and for each of his separately identifiable periods on a job, an exposure profile sheet was completed and sent to Team D for inclusion in the analysis. At that stage the sheets were separately checked to identify any time gaps, any overlapping data which appeared inconsistent or any misinterpretation of the job histories. Anomalies were cleared at a series of meetings between Teams C and D.

Work histories

64 In addition to the information covering radiation doses and potential for exposure to various substances and radiations, information on the job history of each individual was obtained.
This was:

(a) a history of jobs held, with (as available) job titles, cost centres and building numbers;

(b) records of visits to the Medical Centre for decontamination after contamination events*;

(c) a record of absences from work - either annual leave or sick leave - for each leave year;

* This information was contained in medical records and to preserve medical confidentiality it was provided in summary form by BNFL. Further details are given in Appendix 2.

(d) details of involvement in 'incidents' as recorded in the Sellafield incident database; and,

(e) a record of any medical restrictions on work in active areas.

Fathers' place of birth

65 Since information on the fathers' birthplaces was available, and to investigate further the Kinlen hypothesis, it was decided to construct a "migration index" as an indicator of population mixing. This was the ratio of the number of children of non-Cumbrian born fathers to the number of children of Cumbrian born fathers.

Coding of the data

66 The data supplied for analysis to Team D was abstracted from the dossiers, keyed and then checked back against the original source to clear errors. The dossiers were also reviewed a second time to ensure that all relevant information had been abstracted. Throughout this stage, all of those involved in the encoding process were unaware of whether the dossiers being handled referred to cases or controls. The information thus input to the computer formed the basic data set for the statistical analysis.

Statistical methods

67 The details of the statistical methods used in this report are given in Appendix 3. Two kinds of analysis have been made, the first being "internal" comparisons in which the characteristics of the cases are compared with those of controls within the study population (for example, the proportion of cases resident in Seascale at birth compared with the proportion of controls resident in Seascale at birth). The results of these internal comparisons are reported as "odds ratios" (ORs). An OR is calculated as the ratio of the odds that a case will occur in one group compared to another. The second kind of analysis used takes advantage of the fact that the controls represent a known proportion of the total population of children whose fathers worked at Sellafield. Because of this, the control numbers, together with known national rates for the cancers of interest, can be used to estimate the number of cases that would be expected to occur in this population. The number of cases observed can then be compared with the number expected, to give a direct measure of the relative incidence in the study population compared to the national average. The comparison of observed and expected cases is measured by their ratio, referred to as the O/E ratio.

68 The calculation of expected cases needs to take account of the varying length of follow-up of individuals covered by the study. For example, a child born in 1950 will have had a full 25 years potential follow-up, while one born in 1980 will have had around 10. The calculation also has to take account of the fact that while the NHS Central Register

(which was the source for case ascertainment) records deaths for the entire study period, cancer registrations are only recorded from 1971. When the NHS Central Register was searched to ascertain the cases for this study, cancer registrations for 1987 were not complete, and registrations for subsequent years had not been recorded. The probability of becoming a case is higher for those subjects whose follow-up includes time after 1970 than for those with earlier follow-up. Expected case numbers were calculated using national cancer death rates for the periods 1950 to 1970 and 1988 to 1990, and national cancer registration rates for the period 1971 to 1987.

Confidence intervals and p-values

69 Both ORs and O/E ratios are measures of the underlying risk of disease in the study population relative to a comparison group. Odds ratios always compare 2 sub-groups of the study population - for example, Seascale residents to non-Seascale residents, or children born after 1970 with children born before that date. The O/E ratios compare the study population (or its sub-groups) with the national average. Both types of estimate of relative risk are subject to statistical uncertainty, and the extent of this uncertainty can be indicated by a "confidence interval" or by a "p-value". A 95% confidence interval indicates the range of values for a risk estimate which has a 95% chance of containing the true value; it provides an indication of the precision of the estimate. A p-value gives a measure of the probability of the observed results occurring if the "true" relative risk were one, ie if there were no difference between the compared groups.

70 It should be remembered that confidence intervals and p-values are themselves estimates, subject to uncertainty, and dependent on the choice of an underlying statistical model. These measures should be seen as giving general guidance to the understanding of the data, by distinguishing those contrasts which are statistically more or less extreme. The convention used in this report is that of denoting associations with p-values of 0.05 or less as "statistically significant", and those for which p-value is greater than 0.05 as not "statistically significant". (This wording should be regarded as convention only. In reality, a result for which $p = 0.051$ has the same implications as one for which $p = 0.049$.)

71 Continuous variables, such as external radiation dose, can be treated either continuously or in a grouped fashion. Treating these variables as continuous clearly uses the most detailed available information. When this information is accurate, the form of the relationship between the variable and the outcome can be accurately specified. This provides the most powerful treatment of the available information. When these conditions are not fulfilled however, treatment as a continuous variable may be misleading. In particular, individuals with extreme values of the variable may have an undue influence on its assessed significance. For this reason, all continuous variables have also been analysed as grouped forms in two ways:

(a) in three groups: unexposed/exposed below average/exposed above average (the two exposed groups made up of subjects with values above and below the median of all non-zero values of control subjects for the variable in question); and

(b) in a two group version, simply comparing the zero value subjects with positive value subjects.

Explanatory variables

72 Table 5 lists the main potential explanatory variables available within the study. For some the underlying definitions are obvious, for those discussed in the findings appropriate explanations are given. More information is provided in Appendix 3.

Table 5

List of potential explanatory variables

Variable code	*Variable name*	*Factor/ Variate*	*Level definitions/variate units*
DOBQ	Childs' date of birth	f	5 year periods
DOSQ	Date at start at Sellafield	f	5 year periods
QUIQ	Sellafield quit date	f	5 year periods
SEX	Childs' sex	f	Male/Female
FAGE	Father's age at child's conception	f	<25/ 25 - 35/ >35
SEAS	Seascale resident mother	f	No/Yes
JOBC	Job class	f	Industrial/non-industrial
TIME	Years from start at Sellafield to child's conception (or Sellafiald quit, if earlier)	v	years
Measured and assessed radiation exposure			
XG	External radiation (X & gamma)	v	mSv
NEUT	Days in any neutron job	v	days
NHI	Days in any high neutron job	v	days
IT	Internal radiation (all nuclides)	v	mSv
IA	Internal radiation (alpha emitters)	v	mSv
ITRI	Internal radiation (tritium)	v	mSv
Assessed exposure to chemicals and other workplace exposures			
C1	Aniline	v	Weighted days exposed
C2	Anthracene	v	Weighted days exposed

C3	Arsenic & compounds	v	Weighted days exposed
C4	Benzene	v	Weighted days exposed
C5	Benzidine & compounds)	v	Weighted days exposed
C6	Beryllium (dust)	v	Weighted days exposed
C7	Butex/di-n-butyl ether (used/degraded)	v	Weighted days exposed
C8	Chromates/di-chromates	v	Weighted days exposed
C9	Formaldehyde/formalin	v	Weighted days exposed
C10	Graphite dust	v	Weighted days exposed
C11	Hydrazine	v	Weighted days exposed
C12	Hydroflouric acid	v	Weighted days exposed
C13	Kerosene (used/degraded)	v	Weighted days exposed
C14	Lead and compounds	v	Weighted days exposed
C15	Mercury	v	Weighted days exposed
C16	Phosphoric acids	v	Weighted days exposed
C17	Picric acid	v	Weighted days exposed
C18	Decontaminant type SDG3	v	Weighted days exposed
C19	Tetrabromoethane	v	Weighted days exposed
C20	Chloroform	v	Weighted days exposed
C21	Tetrachloroethane	v	Weighted days exposed
C22	Dichloroethane	v	Weighted days exposed
C23	Trichloroethylene	v	Weighted days exposed
C24	Carbon tetrachloride	v	Weighted days exposed
C25	Sulphamic acid	v	Weighted days exposed
C26	Thiophenyl-trifluoroacetone	v	Weighted days exposed
C27	Ortho-Toluidines	v	Weighted days exposed
C28	Zinc and compounds	v	Weighted days exposed
C31	Alpha-in-air (Pu)	v	Weighted days exposed
C32	Alpha-in-air (U)	v	Weighted days exposed
C33	Beta/gamma (only) in air	v	Weighted days exposed
C34	Tritium	v	Weighted days exposed
C35	Polonium	v	Weighted days exposed

Actual and potential contamination

NDCN	Total decontamination visits	v	number
NALP	Number of alpha contaminations	v	number
NBEG	Number of beta/gamma contaminations	v	number
HEAV	Number of 'heavy' contaminations	v	number
CLEA	Number of 'not cleared' contaminations	v	number
CON1	Days in most contaminating jobs	v	days
CON2	Days in anydays in most contaminating jobs	v	days

FIRE	Involved in Windscale fire	f	No/Yes
IN57	In workforce on 10/10/57 (Windscale fire)	f	No/Yes

Work areas and jobs

1	R&DD - Chemical	vf	
2	R&DD - Mechanical	vf	
3	Decontamination	vf	
4	High level waste	vf	
5	Waste management	vf	
6	Effluent plants	vf	
7	Windscale piles & B29	vf	
8	Calder	vf	
9	Ponds West	vf	
10	Pond 5 - SIXEP	vf	
11	Oxide ponds	vf	
12	Reprocessing (old)	vf	
13	Reprocessing (new)	vf	
14	North Group	vf	
15	THORP	vf	
16	Fuel plants	vf	
17	Windscale Nuclear Labs	vf	
18	Advanced Gas-cooled Reactor	vf	
19	Main workshop	vf	
20	Graphite workshop	vf	
21	Maintenance - separation area	vf	
22	Maintenance - non active	vf	
23	Plumbers	vf	
24	Painters/joiners	vf	
25	Maintenance - electrical/instruments	vf	
26	Changerooms	vf	
27	Health physics monitors	vf	
28	Stores	vf	
29	Training	vf	
30	Site transport	vf	
31	Police/firemen	vf	
32	Draughtsmen & other office workers	vf	
33	Chemical plumbers	vf	

Recorded as factors (codes PJi): >5% *of time in job (N/Y)* for total pre-conception analyses;
as variates (codes JBi): *days in job* for analyses of 12 week pre-conception period

Grouping of cancer types

73 A COMARE working group[10, 11] proposed the following classification for childhood cancer cases for use in studies relating to the issue of radiation and childhood cancers.

A - Lymphatic leukaemia and non-Hodgkin's lymphoma
B - Other leukaemias
C - Hodgkin's disease
D - Brain and spinal tumours
E - Other cancers

Professor Gardner's West Cumbria case-control study covered cases in groups A and B combined. The numbers of cases in the present study broken down by the full categorisation above are 12, 4, 3, 4, 9 respectively. In the results reported here 3 case groups have been used: group A of the above categorisation (sometimes abbreviated in what follows to LLNH); the combined groups A and B (abbreviated LNHL); and all other cancers (OCAN). Table 7 in Appendix 1 gives details of the different diagnoses within each of these categories A to E.

Findings of the case-control study

74 The full results of the analyses are given in the tables in Appendix 3. The tables provide information on the statistical importance of the association between the occurrence of childhood cancers and the variables of interest. The main findings of interest arising from this study have been extracted from the tables in Appendix 3 and are presented in the following paragraphs. It should be noted that in all of the analyses, the date of conception has been taken to be 266 days prior to the date of birth.

Exposure to external radiation

75 Extracts from Tables A-5 to A-7, and A-56 to A-58 are given in Table 6. Table 6 shows the statistical associations for radiation doses to the fathers and the occurrence in the case children of:

(a) lymphatic leukaemia and non-Hodgkin's lymphoma (LLNH);

(b) all leukaemia and non-Hodgkin's lymphoma (LNHL) and

(c) other cancers (OCAN).

Table 6 includes results for both the cumulative pre-conception radiation dose and the 12 week pre-conception dose. Table 7 provides typical details of the grouped analyses for LLNH.

Table 6

Statistical significance and sign of association between the various cancers (LLNH, LHNL and OCAN) and external penetrating radiation (XG): results are shown for both the cumulative pre-conception dose and the dose in the 12-week pre-conception period.

Cancer type	Continuous analysis		Three group analysis		Two group analysis	
	p	sign	p*	sign	p	sign
Lymphatic leukaemia & NHL (LLNH)						
Cumulative dose	0.01	+	0.17		0.29	
12 weeks pre-conception dose	0.96		0.34		0.20	+
All leukaemias & NHL (LNHL)						
Cumulative dose	0.01	+	0.28		0.63	
12 weeks pre-conception dose	0.58		0.31		0.32	
Other cancers (OCAN)						
Cumulative dose	0.05	–	0.09	–	0.67	
12 weeks pre-conception dose	0.34		0.35		0.14	–

This table contains extracts from Tables A-5 to A-7 in Appendix 3. The sign of associations is only indicated if $p \leq 0.2$.

* In the three group analysis, values shown are p for trend (see Tables A-56 to A-58 in Appendix 3).

76 Radiation dose (XG) is significantly associated ($p = 0.01$) with LNHL and LLNH when fitted as a continuous variable but not when grouped. The significance when analysed as a continuous variable is produced by a single case father who had a dose in excess of 500 mSv. Without this individual, this significance disappears ($p = 0.38$). This suggests that in the study population as a whole, there is only fragile evidence that dose is associated with an increased risk of these cancers. A different picture emerges, however, when Seascale is examined separately.

77 For other cancers (OCAN) there is a significant negative association in both the continuous ($p = 0.05$) and 3 group analysis ($p = 0.02$), ie the risk decreases with increasing dose (see Tables A-7, A-29 and A-58 in Appendix 3).

78 For radiation dose in the 12 week pre-conception period, there are no statistically significant associations for the study population as a whole for any of the cancer types. This finding contrasts with Professor Gardner's observation of an association with

Table 7

Lymphatic leukaemia & NHL (LLNH): Observed and expected numbers with relative risks for cumulative pre-conception radiation dose (XG).

Grouped analysis (3 groups) p = 0.17	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
Unexposed	35	2	1.23	1.62		
Exposed - low half*	72	3	1.19	2.52	1.52	0.24 - 9.83
Exposed - top half*	72	7	1.58	4.43	2.84	0.54 - 14.84
Grouped analysis (2 groups) p = 0.29						
Unexposed	35	2	1.23	1.62		
Exposed	144	10	2.77	3.61	2.25	0.47 - 10.72

* Median dose 33.2 mSv: Exposed - low half, doses less than 33.2 mSv
Exposed - top half, doses greater than 33.2 mSv

This table contains extracts from Table A-15 in Appendix 3.

paternal radiation doses in the six months prior to conception. But again a different picture emerges when Seascale is examined separately.

79 Tables A-5 to A-7 in Appendix 3 show no significant effect in terms of the time spent in jobs involving potential exposure to neutrons (NEUT and NHI), another component of strongly penetrating radiation.

80 Tables A-5 to A-7 in Appendix 3 also show that there is no significant association for internal radiation doses from intakes of all nuclides (IT) or alpha emitters (IA). In general the internal radiation doses received by the study population were extremely small in comparison to external whole body doses.

Seascale

81 For both LLNH and LNHL, residence in Seascale at the time of the child's birth is highly significant (p = 0.008 and 0.0005 respectively). This is shown in Tables 8 and 9, and, in effect is confirmation of the Seascale "leukaemia clusters" reported by earlier researchers[11]. For all other childhood cancers (OCAN), Table 10 shows there is no significant association (p>0.5).

Table 8

Lymphatic leukaemia & NHL (LLNH): Observed and expected numbers with relative risk by residence in Seascale (SEAS).

Seascale residence p= 0.008	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
No	140	8	3.73	2.15		
Yes	39	4	0.28	14.44	6.97	1.98 - 24.59

This Table contains extracts from Table A-12 in Appendix 3.

Table 9

All leukaemias & NHL (LNHL): Observed and expected numbers with relative risk by residence in Seascale (SEAS).

Seascale residence p= 0.0005	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
No	140	10	5.39	1.86		
Yes	39	6	0.41	14.81	8.67	2.9 - 25.91

This Table contains extracts from Table A-57 in Appendix 3.

82 In Tables 8, 9 and 10, the expected numbers of cases have been estimated on the basis of national incidence rates for the relevant disease groups. The observed to expected ratios therefore indicate the relative frequency of the illnesses compared to the national average. For children born to families resident in Seascale at the time of the birth, the rates of both LLNH and LNHL of the study are some fourteen times the national average ($p = 0.00046$ and $p = 0.000013$ respectively). For non-Seascale residents the corresponding rates are around twice the national average but this excess is not statistically significant ($p = 0.078$ for LLNH and $p = 0.10$ for LNHL). Part of the excess outside Seascale is due to cases arising in children conceived before the father started work at Sellafield (O/E ratio 3/1.43). For Seascale there was one other cancer (OCAN) case, compared with 0.85 expected.

83 A joint analysis of the effects of cumulative pre-conception external radiation dose (XG) and Seascale residence is given in Table 11 for LLNH. The full details are given in Table A-35 in Appendix 3. There is a clear difference between the association with external radiation dose for Seascale and non-Seascale subjects. The statistical test of

Table 10

Other cancers (OCAN): Observed and expected numbers with relative risk by residence in Seascale (SEAS).

Seascale residence p= >0.5	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
No	140	15	11.21	1.34		
Yes	39	1	0.85	1.18	0.75	0.10 - 5.85

This table contains extracts from Table A-58 in Appendix 3.

Table 11

Lymphatic leukaemia & NHL (LLNH): Joint analysis for Seascale residence (SEAS) and cumulative pre-conception external penetrating radiation dose (XG)

PRE-CONCEPTION EXTERNAL DOSE GROUP (mSv)	SEASCALE RESIDENCE *NO*			*YES*		
	O	*E*	*O/E*	*O*	*E*	*O/E*
None	2	1.2	1.65	0	0.02	0
0.01 - 49	4	1.3	3.11	0	0.2	0
50 - 99	1	0.6	1.55	2	0.04	47.3
100+	1	0.6	1.72	2	0.03	71.6

This table contains extracts from Table A-35 in Appendix 3.

this difference - the significance of the interaction between the variables - indicates a strong effect (p = 0.009). Table 11 shows that for non-Seascale residents, the association with external radiation dose is similar to that shown in Table 7 for the total study population. In contrast, for Seascale subjects, the 4 cases all fall in the upper two dose groups, and are greatly in excess of the expected numbers. For the wider case definition, LNHL, there is a very similar pattern: within Seascale all 6 cases fall in the upper 2 dose bands and the test for an interaction between the variables shows an even stronger effect (p = 0.0004). Thus there is evidence of a very strong statistical association between the cumulative radiation dose received by Seascale resident fathers employed at Sellafield and the incidence of leukaemia and NHL in their children.

Table 12

Joint analysis of birth residence and father's 12-week pre-conception radiation dose

Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

EXTERNAL RADIATION DOSE IN THE 12 WEEKS BEFORE CONCEPTION (mSv)	SEASCALE RESIDENT AT BIRTH					
	NO			*YES*		
	O	*E*	*O/E*	*O*	*E*	*O/E*
0	3	1.68	1.78	0	0.040	0
0.1 - 2.4	2	0.99	2.03	2	0.17	11.4
2.5 - 4.9	1	0.42	2.36	1	0.042	24.0
5+	2	0.63	3.15	1	0.020	48.9
p for trend:			>0.5			0.18

This table contains extracts from Table A-52 in Appendix 3.

Table 13

Joint analysis of birth residence and father's 12 week pre-conception radiation dose

Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

EXTERNAL RADIATION DOSE IN THE 12 WEEKS BEFORE CONCEPTION (mSv)	SEASCALE RESIDENT AT BIRTH					
	NO			*YES*		
	O	*E*	*O/E*	*O*	*E*	*O/E*
0	5	2.51	2.0	0	0.054	0
0.1 - 2.4	2	1.35	1.5	2	0.26	7.8
2.5 - 4.9	1	0.63	1.6	1	0.062	16.0
5+	2	0.89	2.2	3	0.033	89.7
p for trend:			>0.5			0.005

This table contains extracts from Table A-52 in Appendix 3.

84 When Seascale residence is considered in combination with external radiation dose received over the 12-week pre-conception period, there is a consistent positive trend in the O/E ratio with dose category for both LLNH and LNHL: for the latter, this trend is statistically significant (p = 0.005). This is shown in Tables 12 and 13 respectively.

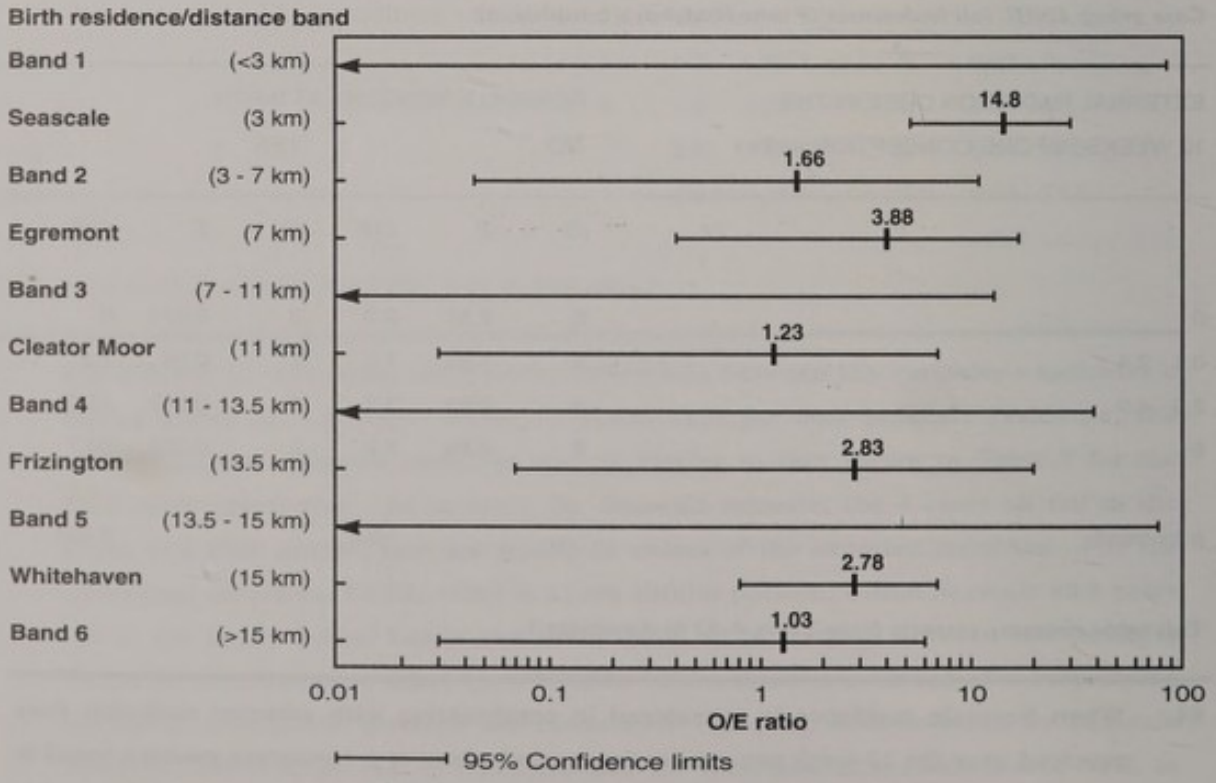
Table 14

Joint analysis of all leukaemia & NHL cases (LNHL) by cumulative and 12 week pre-conception radiation dose, for Seascale subjects only

EXTERNAL RADIATION IN THE 12 WEEKS BEFORE CONCEPTION (mSv)	CUMULATIVE PRE-CONCEPTION DOSE <50 mSv			50+ mSv		
	O	E	O/E	O	E	O/E
<2.5 mSv	0	0.230	0	2	0.080	25.1
>2.5 mSv	0	0.069	0	4	0.027	146.3
All 12 week doses	0	0.298	0	6	0.107	56.1
p for trend:			>0.5			0.033

This table contains extracts from Table A-54 in Appendix 3.

Figure 3 - Observed/expected case ratio for LNHL by distance of birth residence from plant and main population centre



The data for this Figure are shown in Table A-13 in Appendix 3.

85 Table 14 shows a joint analysis of the O/E ratio for cumulative and 12-week dose categories for the Seascale subjects only. In this sub-group, the positive associations for these two variables are independent. In other words the O/E ratio for all Seascale subjects with greater than 50 mSv cumulative pre-conception dose is 56: when this group is sub-divided by 12-week pre-conception dose, those with less than 2.5 mSv have an O/E ratio of 25, whereas those with more than 2.5 mSv have an O/E ratio of 146.

Locations other than Seascale

86 The observed to expected (O/E) ratios of LNHL cases at various distances from Sellafield were calculated both for population centres which include Seascale, Egremont, Cleator Moor, Frizington and Whitehaven, and for the more rural sectors between these centres.

87 The O/E ratios derived from the data are shown in Figure 3. Individually considered, only Seascale shows a significant excess of cases. There are only 2 cases in the generally less populated bands between the main centres of population; one case in band 2 (3-7 km) and another in band 6 (greater than 15 km). If the bands and the population centres are ranked by O/E ratio, the 5 population centres take the first 4 and the 6th positions. Even allowing for the fact that the expected numbers are generally higher for the population centres, this contrast is statistically significant ($p = 0.03$). If the observed and expected numbers are totalled separately for population centres (excluding Seascale), and for intermediate bands, the resulting O/E ratios are 2.6 (8/3.1) for population centres and 0.9 (2/2.3) for the intermediate bands.

88 The data in Figure 3 show some suggestion of a gradient by distance from the plant, with a high O/E ratio in Seascale close to the plant, and the most distant band having an O/E ratio of almost exactly unity. The apparent association with distance is solely dependent on the data for Seascale.

89 The incidence of other cancers (OCAN) by area shows some similarity with the pattern for leukaemia and NHL. The rates for population centres are generally higher, but Seascale is not exceptional, in contrast to the findings for leukaemia and NHL. The combined O/E ratio for the population centres was 1.9 (14/7.3) and for the intermediate bands was 0.4 (2/4.8) (see Table A-30 in Appendix 3).

Population mixing

90 Figure 4 shows the relationship of O/E ratio to migration index for the 11 population bands. The population centres have O/E ratios that seem to fall in a very convincing linear relationship, and the zero values for the other bands have particularly wide confidence intervals. However, with Seascale omitted from the 11 population bands, the correlation with O/E ratio and migration index is not significant ($p = 0.44$).

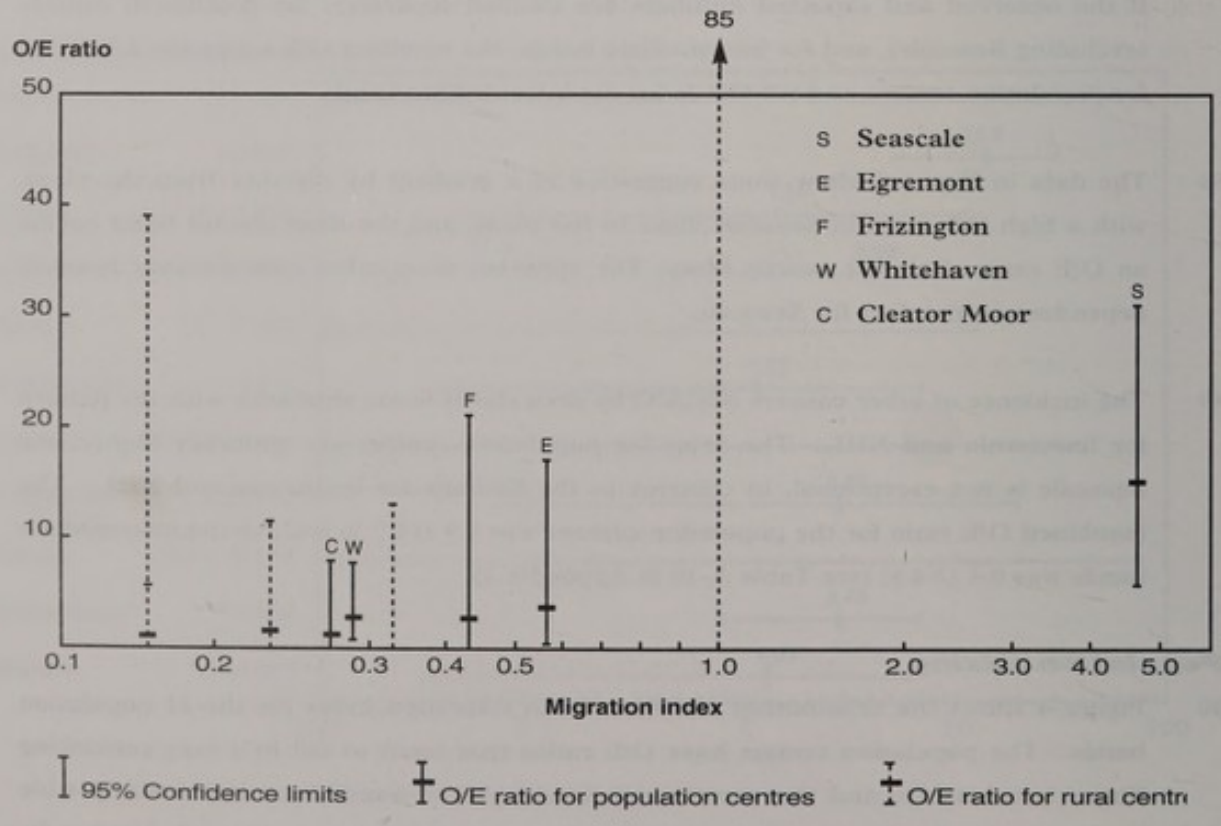
It remains non-significant if the analysis is restricted to the population centres other than Seascale ($p = 0.48$). With Seascale included there is a strong association ($p = 0.0005$).

Time distribution of cases

91 The pattern of risk by child's date of birth in Table A-8 of Appendix 3 shows some tendency towards higher risk in the early periods, but without any strong trend. The most significant dichotomy of the 8 periods is at 1970, the risk in the earlier years being about double that since 1970. In terms of absolute risk however, both periods show an excess when compared to the national incidence of childhood cancers; for LLNH the observed/expected ratios are 3.86 before 1970, and 1.80 after, and for LNHL the corresponding ratios are 3.25 and 1.91. The difference between these periods is, however, not statistically significant ($p>0.2$).

92 In relation to diagnosis date, the highest rates are seen in the 1960s and 1970s: there were no cases diagnosed before 1960. Between 1960 and 1979, the O/E ratio was

Figure 4 - Observed/expected case ratio for LNHL by migration index of birth residence



The data for this Figure are shown in Table A-13 in Appendix 3.

Table 15

Lymphatic leukaemia & NHL (LLNH): Observed and expected numbers with relative risks by father's date of start at Sellafield (DOSQ)

Grouped analysis (8 groups) p= 0.12	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
1950-54	43	3	1.11	2.70		
1955-59	29	3	0.72	4.15	1.66	0.30 - 9.11
1960-64	13	4	0.42	9.60	5.05	0.93 - 27.54
1965-69	12	0	0.25	0	0	0.00 - 5.52
1970-74	22	0	0.56	0	0	0.00 - 2.44
1975-79	38	2	0.74	2.71	1.03	0.16 - 6.76
1980-84	11	0	0.12	0	0	0.00 - 11.06
1985+	11	0	0.08	0	0	0.00 - 18.19
Grouped analysis (2 Groups) p=0.038						
1950-64	85	10	2.25	4.44		
1965+	94	2	1.75	1.14	0.23	0.05 - 0.92

This Table is also shown in Table A-9 (upper half) in Appendix 3.

around 4 for LLNH and around 3.5 for LNHL. From 1980, the O/E ratio has been around 2. The contrast between these time periods is not statistically significant.

93 There are stronger patterns for risk in relation to the father's start date at Sellafield. This is shown in Tables 15 and 16 for LLNH and LNHL respectively. Again, the higher risks are in the earlier period. The most significant cut point is at 1965 and the comparison of the periods before and after this date is significant for LLNH ($p = 0.038$). The excess risk is almost entirely concentrated in the period from 1950 to 1964, with the observed to expected case ratio being 10/2.25 for LLNH, and 13/3.56 for LNHL.

94 For other cancers (OCAN) in relation to child's date of birth and father's date of start at Sellafield, there is a hint of the pattern seen for leukaemias, with slightly higher rates for subjects with earlier dates on both variables (Table A-28 in Appendix 3). However, the strongest two-group contrasts for OCAN do not have the same cut-off as for the leukaemias. Also, for OCAN it is the two-group contrast for child's date of birth which is (just) significant while the father's date of start contrast is far from

Table 16

All Leukaemias & NHL (LNHL): Observed and expected numbers with relative risks by father's date of start at Sellafield (DOSQ)

Grouped analysis (8 groups) p= 0.15	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
1950-54	43	6	1.82	3.3		
1955-59	29	3	1.14	2.62	0.78	0.17 - 3.53
1960-64	13	4	0.6	6.66	2.63	0.59 - 11.82
1965-69	12	0	0.31	0	0	0.0 - 3.61
1970-74	22	0	0.72	0	0	0.0 - 1.55
1975-79	38	2	0.92	2.18	0.61	0.11 - 3.38
1980-84	11	1	0.17	5.98	2.12	0.18 - 25.11
1985+	11	0	0.12	0	0	0.0 - 9.65
Grouped analysis (2 Groups) p=0.063						
1950-64	85	13	3.56	3.65		
1965+	94	3	2.23	1.34	0.32	0.09 - 1.18

This Table is also shown in Table A-9 (lower half) in Appendix 3.

being statistically significant. For leukaemias the situation was reversed. There is no indication of any systematic variation in risk by diagnosis date.

95 For all leukaemias and NHL a strong pattern is also seen for father's date of leaving Sellafield (Table 17). Here the risk is seen in subjects who left the workforce most recently, ie after 1975, or who are still employed. This comparison is significant ($p = 0.04$).

96 The variable TIME, the duration of the period from the date of the father's starting work at Sellafield to the conception of his child (or his leaving Sellafield if this is earlier), is quite strongly related to LLNH when measured as a continuous variable, but not in either grouped form (see Table 18). Examination of the risk estimates for the 3 Group version of this variable shows a J-shaped pattern, with the risk dropping in the middle category and then rising quite considerably for the longest duration subjects, though these differences are not significant. This pattern is similar to that shown for external radiaton as a continuous variable, and is, in fact, highly correlated

Table 17

All Leukaemias & NHL (LNHL): Observed and expected numbers with relative risks by father's date of leaving Sellafield (QUIQ)

Grouped analysis (8 groups) p= 0.13	*Controls*	*Cases*	*Expected*	*O/E*	*OR**	*95% Confidence interval*
1950-54	6	1	0.21	4.66	1.32	0.13 - 13.1
1955-59	5	0	0.29	0.00	0.00	0.00 - 3.4
1960-64	12	0	0.69	0.00	0.00	0.00 - 1.4
1965-69	10	1	0.39	2.54	0.65	0.07 - 5.8
1970-74	8	0	0.43	0.00	0.00	0.00 - 2.3
1975-79	13	3	0.51	5.93	2.03	0.44 - 9.3
1980-84	20	1	0.56	1.79	0.43	0.05 - 3.7
1985+	105	10	2.71	3.69		
Grouped analysis (2 Groups) p=0.037						
1950-74	41	2	2.01	1		
1975+	138	14	3.78	3.7	4.19	1.11 - 27.1

This Table is also shown in Table A-10 in Appendix 3.

* OR values in the 8 group analysis are calculated relative to the data for the 1985+ period.

with it. After allowing for the effect of XG, the variable TIME provides no additional explanatory power.

97 An analysis of father's age (FAGE), (see Table 19 based on the FAGE element of Table A-12) shows a significant effect due mainly to the fact that there are no cases among children born to fathers under 25. The risks for the 2 older fathers' age groups, (25-34 and 35+) are similar.

98 Tables 20 and 21 show the joint analysis for external radiation and fathers' date of start in 2 categories divided at 1965. This data shows that a positive relationship with external radiation holds only for subjects with date of start before 1965, the difference between the periods in this respect being quite clear. This difference is statistically significant ($p = 0.025$). The pattern is the same whether LLNH or LNHL are examined.

Table 18

Lymphatic leukaemia & NHL (LLNH): Observed and expected numbers with relative risks by father's time at Sellafield prior to child's conception (TIME)

Note: Main data in tables is for lymphatic leukaemia & NHL, numbers of non-lymphatic leukaemias (additional to those shown) are indicated in parentheses.

Grouped analysis p for trend = 0.18	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
Unexposed	24	2(1)	0.96	2.07		
Exposed - low half*	78	3(1)	1.6	1.87	0.83	0.13 - 5.49
Exposed - top half*	77	7(2)	1.43	4.88	2.36	0.44 - 12.73
Grouped analysis (2 Groups) p=0.6						
Unexposed	24	2(1)	0.96	2.07		
Exposed (>0)	155	10(3)	3.04	3.29	1.53	0.31 - 7.65

* Median time 4.01 years: Exposed - low half, time less than 4.01 years
Exposed - top half, time greater than 4.01 years.

This table contains extracts from Table A-14 in Appendix 3.

Table 19

Lymphatic leukaemia & NHL (LLNH): Observed and expected numbers with relative risks by father's age at child's conception (FAGE).

Note: Main data in table is for lymphatic leukaemia & NHL, numbers of non-lymphatic leukaemias (additional to those shown) are indicated in parentheses.

Grouped analysis (3 groups) p= 0.04	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
35+	33	4(2)	0.84	4.79		
25-34	109	8(2)	2.3	3.48	0.70	0.19 - 2.56
<25	36	0(0)	0.85	0	0	0 - 0.91

This table contains extracts from Table A-12 in Appendix 3.

Table 20

Lymphatic leukaemia & NHL (LNHL): joint analysis of father's date of start and external radiation dose

EXTERNAL RADIATION EXPOSURE GROUP (mSv)	FATHER'S DATE OF START					
	before 1965			*from 1965*		
	O	*E*	*O/E ratio*	*O*	*E*	*O/E ratio*
Nil	1	0.54	1.84	1	0.69	1.46
1 - 49	3	0.75	4.03	1	0.73	1.37
50 - 99	3	0.49	6.11	0	0.20	0
100+	3	0.47	6.35	0	0.14	0

This table contains extracts from Table A-43 in Appendix 3.

Table 21

All leukaemias & NHL (LNHL): Joint analysis of father's date of start and external radiation dose

EXTERNAL RADIATION EXPOSURE GROUP (mSv)	FATHER'S DATE OF START					
	before 1965			*from 1965*		
	O	*E*	*O/E ratio*	*O*	*E*	*O/E ratio*
Nil	2	0.96	2.09	2	0.91	2.2
1 - 49	3	1.15	2.61	1	0.91	1.1
50 - 99	4	0.76	5.27	0	0.24	0
100+	4	0.69	5.77	0	0.17	0

This table contains extracts from Table A-43 in Appendix 3.

Work areas and jobs

99 Only one work area variable showed a significant effect when analysed for the cumulative pre-conception period: working in the Calder area of the site is significantly and positively associated with both LLNH and LNHL (see Tables 22 and 23 respectively). All five cases are of lymphatic leukaemia and the odds ratio for this diagnosis is 12.6 (95% confidence inverval 3.24 to 49.2).

Table 22

Lymphatic leukaemia & NHL (LLNH): Observed and expected numbers with relative risks by father's working in the Calder area of the site prior to child's conception.

Grouped analysis (2 groups) p= 0.0007	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
<5% of time in job	164	7	3.68	1.9		
>5% of time in job	15	5	0.32	15.48	12.63	3.24 - 49.23

This table contains extracts from Table A-12 in Appendix 3.

Table 23

All leukaemias & NHL (LNHL): Observed and expected numbers with relative risks by father's working in the Calder area of the site prior to child's conception.

Grouped analysis (2 groups) p= 0.003	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
<5% of time in job	164	11	5.34	2.06		
>5% of time in job	15	5	0.45	11.0	7.92	2.20 - 28.5

This table contains extracts from Table A-57 in Appendix 3 (see PJ8).

Exposure to chemicals

100 Examination of potential for chemical exposure in the cumulative pre-conception period showed significant positive associations for some chemicals (tritium, chromates/di-chromates, formaldehyde/formalin, hydrofluoric acid, picric acid and trichlorethylene). Chromates and di-chromates are mutagens in animals. Of the 4 cases potentially exposed to chromates/di-chromates, 3 were resident in Seascale at birth, and the association with Seascale accounts for the association with chromates/di-chromates but not vice versa. Of the remaining associations, only those for tritium and trichloroethylene are strong enough to merit detailed consideration.

Exposure to tritium

101 The association for LLNH and LNHL with the potential for exposure to tritium is shown in Tables 24 and 25 respectively. There is a strong positive relationship for the continuous measure ($p<0.00001$) and for both grouped measures with a positive trend in risk for the 3 group analyses.

Table 24

Lymphatic leukaemia & NHL (LLNH): Observed and expected numbers with relative risks by father's assessed exposure to tritium prior to child's conception.

Grouped analysis p for trend = 0.0018	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
Unexposed	87	5	2.13	2.35		
Exposed-low half*	8	2	0.13	14.97	8.29	1.26 - 54.7
Exposed-top half*	7	3	0.15	20.29	15.9	2.52 - 100.6
Grouped analysis (2 groups) p=0.0059						
Unexposed	87	5	2.13	2.35		
Exposed (>0)	15	5	0.37	13.54	7.77	1.91 - 31.5

* Median weighted days exposed 136.4 days

Exposed - low half, weighted days less than 136.4 days

Exposed - top half, weighted days greater than 136.4 days.

This table contains extracts from Table A-20 in Appendix 3.

Exposure to trichloroethylene

102 The associations between LLNH and LNHL and potential exposure to trichloroethylene are shown in Tables 26 and 27 respectively. All but 2 of the cases fall in the highest of the 3 exposure groups, and for LNHL the contrast of this group with the other 2 groups is statistically significant (p = 0.011).

Overlap of tritium and trichloroethylene exposure potential

103 Table 28 shows a joint analysis of LNHL cases by potential exposure to tritium (ever/never exposed) and trichloroethylene (highest group/others). All the cases with potential tritium exposure also lie in the highest trichloroethylene exposure group. The associations of these two exposures cannot therefore be statistically separated with any certainty.

Potential for contamination

104 No consistent pattern emerged from the analysis of variables related to potential or actual pre-conception exposure to radiation contamination incidents. For the study population as a whole, children of fathers with at least one recorded beta/gamma

Table 25

All leukaemias & NHL (LNHL): Observed and expected numbers with relative risks by father's assessed exposure to tritium prior to child's conception.

Grouped analysis p for trend = 0.026	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence Interval*
Unexposed	128	11	4.15	2.65		
Exposed-low half*	11	2	0.27	7.40	3.17	0.57 - 17.63
Exposed-top half*	11	3	0.28	10.77	5.61	1.18 - 26.66
Grouped analysis (2 groups) p=0.014						
Unexposed	128	10	4.15	2.41		
Exposed (>0)	25	6	0.67	8.93	4.71	1.46 - 15.13

* Median weighted days exposed 136.4 days

Exposed - low half, weighted days less than 136.4 days

Exposed - top half, weighted days greater than 136.4 days.

This table contains extracts from Table A-57 in Appendix 3 (see TRI 2 and TEN 2).

contamination incident have an odds ratio of 3.2 for LNHL compared to fathers with no such contaminations (p = 0.04), but no trend is seen in the three-group analysis, nor is there a positive association with "heavy" contamination. A significant association between LNHL cases and failure to completely clear the contamination before discharge from the Medical Centre is based on two cases only. "Time in any contaminating job" is significantly associated with LNHL in the continuous analysis, but there is no consistent trend and "Time in most contaminating jobs" does not show any positive association. (Tables A-21 to A-23 in Appendix 3 illustrate these points.) No strong interpretation can be placed on these patterns. Within the Seascale subset, statistically significant associations were found for LNHL and the number of visits to the Medical Centre for decontamination in the continuous (p=0.0002, Table A-55) and grouped analysis (p = 0.0071, Table A-53). No other consistent findings were evident for the Seascale subset. There are no positive findings for other cancers (OCAN) in relation to involvement in contamination incidents.

Cancers other than leukaemia or NHL

105 The associations for other cancers (OCAN) with work areas, chemicals and contamination potential are given in detail in Appendix 3. None were strongly significant, or involved more than a small number of cases. Making allowance for the

Table 26

Lymphatic leukaemia and NHL (LLNH): Observed and expected cases with relative risks for potential exposure to trichloroethylene.

Grouped analysis p for trend = 0.15	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
Unexposed	13	1	0.21	4.71		
Exposed - low half*	37	1	0.82	1.22	0.24	0.01 - 4.29
Exposed - top half*	37	6	0.79	7.63	1.83	0.19 - 17.5
Grouped analysis (2 groups) p=0.055						
Unexposed and exposed - low half	50	2	1.03	1.94		
Exposed - top half	37	6	0.79	7.60	4.66	0.86 - 25.1

* Median weighted days exposed 450.5 days

Exposed - low half, weighted days less than 450.5 days

Exposed - top half, weighted days greater than 450.5 days.

This table contains extracts from Table A-56 in Appendix 3.

large number of variables examined, none of these associations were judged strong enough to merit detailed consideration.

Post-conception period

106 A number of contamination incident variables are associated with leukaemia and NHL, and with other cancers, but there is no association with the variables of most interest in this context, ie that relating to whether the contamination had been cleared at the time of discharge from the Medical Centre (see Tables A-59 to A-61 in Appendix 3). None of the other variables studied show a significant association with any cancer grouping.

Age distribution of cases

107 Examination of the LNHL cases shows that all were diagnosed either before reaching $7^{1}/_{2}$ years old or after reaching the age of $17^{1}/_{2}$, five of the cases being in the older group. The small number of cases limits the scope for separate analyses of the older group. Comparison of analyses using all cases with those for the young cases only, showed that the older case group contributed to the Seascale and tritium associations (mainly through a single case) but not to the external radiation and Calder associations.

Table 27

All leukaemias and NHL (LNHL): Observed and expected cases with relative risks for potential exposure to trichloroethylene.

Grouped analysis	*Controls*	*Cases*	*Expected*	*O/E*	*OR*	*95% Confidence interval*
p for trend = 0.035						
Unexposed	13	1	0.34	2.98		
Exposed - low half*	37	1	1.11	0.90	0.28	0.02 - 4.94
Exposed - top half*	37	8	1.12	7.16	2.97	0.32 - 27.5
Grouped analysis						
(2 groups) p=0.011						
Unexposed and						
exposed - low half	50	2	1.45	1.38		
Exposed - top half	37	8	1.12	7.16	6.75	1.37 - 33.4

* Median weighted days exposed 450.5 days

Exposed - low half, weighted days less than 450.5 days

Exposed - top half, weighted days greater than 450.5 days.

This table contains extracts from Table A-18 in Appendix 3.

Table 28

All leukaemias and NHL (LNHL): Observed and expected cases by potential exposures to tritium and trichloroethylene.

Trichloroethylene exposure	Tritium exposure		
	No	Possible	Unknown
	O/E	*O/E*	*O/E*
Unexposed and exposed - low half	2/ 1.19	0/ 0.12	0/ 0.14
Exposed - top half	2/ 0.44	6/ 0.37	0/ 0.31
Unknown	6/ 2.52	0/ 0.18	0/ 0.52

This table contains extracts from Table A-47 in Appendix 3.

DISCUSSION

108 HSE's interests in having these investigations carried out centred on answering the question of whether the observed excess of leukaemia among young people in Seascale arose from an occupational cause, such as that suggested by Professor Gardner. If this were found to be the case then further measures to protect the health and safety at work of the population at risk would have to be considered. The 3 parts of HSE's investigation were devised to contribute to the knowledge required to answer this question.

The Case-only Study

109 It was recognised that without controls for comparison, the Case-only Study would be unlikely to provide strong grounds for action unless there were obvious common factors. None of the areas investigated showed such obvious factors.

110 Examination of the radiation dose histories of the case fathers generally confirmed the data used by Professor Gardner, but at the time the Case-only Study was completed, the evidence was not clear enough as to the connection between the fathers' pre-conception radiation doses and risk of leukaemia and NHL in their children. However, it was noted at the time that the majority of the cases (10 of 11) had occurred prior to 1974 and that there had been substantial reductions in average and peak radiation doses at Sellafield since that date.

111 In addition to looking at the radiation dose records of the case fathers, work location, job type and the potential for exposure to certain chemicals was also examined. Nothing was identified which could have been regarded with any confidence as being a common factor. Some of the fathers could have been exposed to a variety of chemicals, but the evidence was insufficient to indicate possible exposure levels or, indeed, whether exposure occurred at all. The observations were merely that they had worked in locations or jobs where such chemicals were, or might have been expected to be in use.

The Radiation Dose Study and the main Case-control Study

External pre-conception radiation doses

112 Both the Radiation Dose Study and the Case-control Study provided an opportunity to examine the suggestion that there is an association between a father's cumulative and short-term pre-conception external penetrating whole body radiation dose and the chance of his child contracting leukaemia or NHL.

113 The Radiation Dose Study showed that the Gardner case fathers as a group had incurred a relatively high average cumulative radiation dose compared with groups of Sellafield men of similar ages. There also appeared to be a trend of increasing risk with radiation dose. The wide confidence intervals relating to these analyses indicated that the results should be treated with caution.

114 The Case-control Study only showed a significant association with cumulative pre-conception external radiation dose when it was treated as a continuous variable, but not when relative risks were analysed in terms of exposure groups. However, the continuous variable association was solely dependent on one case father who had a very high dose: the significance of the association is removed if the data is analysed without that case. When the findings for exposure to external radiation and those for residence in Seascale (see below) are taken together, coupled with the strong influence which the Seascale cases had in the radiation dose study, the evidence that cumulative paternal pre-conception radiation exposure alone is linked to an increased risk of leukaemia and NHL in the children is fragile.

115 In the Radiation Dose Study the short-term pre-conception external radiation dose was taken as the dose in the year of conception. In this study there was a suggestion of a raised risk of a child developing leukaemia or NHL for fathers with radiation doses of over 20 mSv in the year of conception. Again the wide confidence intervals associated with the findings mean they should be treated cautiously. For the Case-control Study no association was found for external radiation dose in the 12 week pre-conception period for the study population as a whole. But there was a positive association for the Seascale subjects. Furthermore, this association was statistically independent of that for cumulative pre-conception dose. These findings resemble those of Professor Gardner, but on the basis of our data, apply only to the Seascale subset. In considering the possibility of any short term pre-conception effect, a 12 week period is biologically more appropriate than the 6 months used by Gardner, since this is the likely time span in which a specific effect on spermatozoa as opposed to germ cells could occur. However, a direct effect on spermatozoa was perhaps the least plausible component of Professor Gardner's hypothesis based on current understanding of radiobiology.

116 Although there is an excess of other cancers in the children of the fathers studied, the excess is small and not statistically significant. The only significant associations with radiation related variables are a negative association with paternal pre-conception radiation dose and a positive association with post-conception contamination incidents. The positive association for post-conception contamination incidents is not thought to be important in the context of the possibility of direct contamination of the

child, since there is no positive association for incidents "not cleared of contamination on discharge from the Medical Centre", and because there is no association with work in areas with higher contamination potential.

117 It is clear that the pattern of associations for other cancers is quite distinct from that seen for leukaemias and NHL. There is no evidence of excess associated with Seascale or with father's pre-conception radiation dose. Indeed, the other cancer case fathers had significantly lower average pre-conception radiation dose than control fathers. This means that if there is a real effect for leukaemias and NHL involving Seascale and paternal pre-conception radiation, it must be due to mechanisms specific for these cancers, or for these cancers and a limited range of other cancer types occurring in this age group (too few in number for this study to detect). There is no evidence of any effect across all cancer types.

Seascale

118 Residence of the family in Seascale at the date of the child's birth appears from this study to be important for leukaemia and NHL. (Only one case of a cancer other than leukaemia or NHL was born in Seascale.) Over the whole study period, the ratio of observed to expected cases of LLNH and LNHL in the children of the Sellafield workforce born in Seascale was about fourteen whilst for the children of the workforce with non-Seascale residence the ratio was about two. The latter ratio is not statistically significant and is partly based on 3 cases born before their fathers started work at Sellafield.

119 A further peculiarity of these Seascale cases is that they have strikingly higher radiation doses than other Seascale subjects. In other words, the data support the "Gardner" association within the Seascale-resident part of the Sellafield workforce. In addition, the Seascale case fathers were more likely to have been involved in contamination incidents than Seascale control fathers. The relationship with radiation in the non-Seascale part of the study population is at best weak, and arguably non-existent, and there are no consistent relationships with contamination incidents involving fathers resident outside Seascale.

120 The hypothesis put forward by Kinlen that the incidence of childhood leukaemia may be raised in areas where there has been a recent inflow of non-local people may be relevant here. It is certainly the case that Seascale has an unusually high immigrant (non-Cumbrian born) proportion of fathers. Estimated from present data, the ratio of non-Cumbrian born to Cumbrian born fathers is 4.5 among the Seascale fathers and 0.24 in the rest of the population on which the study is based. If Kinlen's hypothesis is correct, it could explain why the leukaemia rate at Seascale is raised.

121 It is not clear whether the non-significant excess of leukaemia and NHL identified in those Sellafield workers' children not born in Seascale could be taken as evidence of an effect of population mixing (at a lower level) in the other population centres. The association between leukaemia rate and migration index is not statistically significant without the Seascale data. Furthermore, the published evidence suggests that the effect on childhood leukaemia rates is expressed quite rapidly after the relevant population movements[5, 12], whereas the excesses seen in this study persist over at least 20 years. The concentration of cases in the population centres may be consistent with an infective process but it should be noted that the higher rates of cancer in these centres were also seen in this data for cancers other than leukaemia and NHL, for which no link with population movements has been suggested.

Time distribution of cases

122 The analyses of father's date of start and child's date of birth show similar patterns, with the higher risks in the earlier periods (before 1965 for father's date of start, before 1970 for child's date of birth). Taken individually, father's date of start shows the stronger contrast between its two periods. Thirteen out of the 16 case children were born to fathers who started work at the site before 1965. The absolute excess risk is almost entirely concentrated in this group.

123 This observation has two implications. Firstly, the fact that the strongest time comparison is based on a measure of the fathers' employment timing (rather than the child's diagnosis, or birth date, for example), provides some evidence for a paternally mediated effect of some kind. Secondly, the absence of any apparent excess among the children of fathers first employed at Sellafield since 1965 suggests that if workplace factors are involved, they relate to conditions that no longer apply (and, indeed, have not applied for over 25 years).

124 In relation to diagnosis date, no cases of leukaemia or NHL were diagnosed in the 1950s. The excess appears in the 1960s and 1970s, and is slightly higher in the latter period. This pattern does not seem to be consistent with a population mixing effect, at least in its simplest form, since the initial influx into the area (and especially Seascale), took place in the 1950s. It is difficult to see how an unusual infective environment could persist - and remain isolated - through a twenty-year period.

125 In considering the evidence for a population mixing effect, it should also be noted that the children of Cumbrian born fathers and of non-Cumbrian born fathers shared the excess risk of leukaemia and NHL about equally.

126 It seems difficult to attach a substantive interpretation to the significant association of leukaemia and NHL rates with fathers' date of leaving Sellafield (with the excess

limited to children of fathers leaving the workforce from 1975 onwards - including men still employed there). The numbers of expected cases for children born to fathers with early leaving dates are low, and evidence from the matching process (see Appendix 1) suggests that fathers who left the workforce in the 1950s are under-represented in the study, but there is no reason for this under-representation to affect cases and controls differently.

Work areas and jobs

127 The analyses of work areas were based on the assignments of individuals who had spent more than 5% of their time in a particular work area prior to the conception of their children. From this type of analysis, work in the Calder group of buildings is significantly and positively related to the incidence of LNHL and LLNH. A total of five cases of lymphatic leukaemia were associated with this work area. Although two of the cases also had mothers resident in Seascale, the Calder and Seascale associations are independent and the Calder workplace association is difficult to explain on the basis of present knowledge.

Exposure to chemicals

128 In considering the potential for exposure to chemicals it was recognised that the quality of the data was unavoidably weaker than those data which could be quantified, such as recorded radiation doses, or those which could be considered as factual, such as places of residence and dates. Consequently, the statistical power to detect any real effects of chemical exposures is less than it would be if accurate measurement of these factors was available. However the data were gathered in a systematic and consistent fashion, and assessments were made without knowledge of the case/control status of the subjects involved.

Potential exposure to tritium

129 Assessment of potential exposure to tritium was carried out in the same manner as for the other chemicals considered in the study. Strong positive statistical associations are shown with work where exposure to tritium might have occurred, both when analysed as a continuous variable and when analysed by exposure group.

130 This might imply that paternal pre-conception exposure to high levels of tritium could be associated with the incidence of childhood leukaemia. However the data on which the analyses are based suffer from the weaknesses already described. Further, if paternal exposure to tritium were to be taken as a strong candidate for a cause of some of the cases, it would imply that the employers at the time were unaware of tritium's importance as a radiological hazard, and that they were not monitoring either the workplace or the workers who could have been exposed, ie that substantial individual exposures could have passed unnoticed. The evidence available for

Sellafield suggests that this was not the case - with records showing both environmental and biological monitoring taking place as far back as the mid-1950s.

131 The Canadian study[13] of the occupational exposure of fathers to ionising radiation included reference to exposure to tritium. The number of fathers in that study with a recorded non-zero pre-conception exposure to tritium was 14, none of whom was a case. There is no suggestion in the Canadian work that pre-conception tritium exposure (at the levels experienced in that study population) was associated with childhood leukaemia.

Potential exposure to trichloroethylene (TCE)

132 Variables assessing potential exposure to chlorinated solvents were included in the study because these substances had been widely used at Sellafield and because of limited evidence in the literature of an association between paternal exposure to them and childhood leukaemia. A non-significant positive association with TCE has been reported[14]. The positive association between leukaemia and NHL and some measures of potential TCE exposure in this study cannot be separated statistically from potential exposure to tritium. In view of this and in the absence of strong independent supporting data, the evidence of an effect of TCE in this study is considered weak.

133 It is possible that the potential for exposure to tritium, work in the Calder area, and potential for exposure to TCE are markers for some other, more relevant exposure that was not assessed in this study. If that is so, then it remains the case that if such a workplace cause contributes to the excess of leukaemia and NHL in Seascale, it appears to be no longer exerting an effect.

Other chemicals

134 Positive associations for pre-conception exposure to chromates/di-chromates, formaldehyde/formalin, hydrofluoric acid and picric acid with one or both of the leukaemia/NHL case groups are identified in this study. These associations are not as strong as those for tritium and trichloroethylene and are not generally consistent in the various analyses done. They become non-significant when allowance is made for the multiple comparisons undertaken. Chromates and di-chromates are recognised animal mutagens, but in this study the association with chromates/di-chromates is accounted for when the analysis is controlled for residence in Seascale at birth.

Implications for workplace regulation

135 Since publication of Professor Gardner's report, the nuclear industry, in consultation with the workforce, has increased its efforts to restrict whole body radiation doses to less than 15 mSv. Also, in April 1991, HSC issued the 4th Part to its Approved Code of Practice[15] supporting the Ionising Radiations Regulations 1985. This came into effect

in July 1991: it calls on employers to review past decisions on exposure levels in the light of evidence that risks to workers might be 2 or 3 times as great as previous estimates, and is intended to trigger an additional investigation for any employee whose radiation dose reaches or exceeds 75 mSv in any 5 consecutive calendar years after 1 January 1988. HSE has also prepared non-statutory guidance[16] setting out a framework within which managers can take decisions on keeping doses as low as reasonably practicable. HSE's NII has recently issued its revised Safety Assessment Principles[17] which, inter alia, included a tightening of those principles relating to the control of radiation doses.

136 Records of whole body radiation doses for Sellafield personnel (including Calder Hall) from 1988 to 1992 reveal that actions to reduce both average doses and the numbers of staff in the higher dose categories have been successful. Average doses have been reduced from 4.6 to 2.4 mSv per annum whilst the numbers of persons receiving doses above 20 mSv per annum have been reduced from 126 to zero. Numbers in the dose band 15 to 20 mSv have shown a decline from 277 in 1988 to 6 in 1992. These reductions have been achieved against a reduction in collective dose (man-Sieverts) for the Sellafield site from 30.2 in 1988 to 16.0 in 1992.

137 If other sites are taken into consideration, the information provided by approved dosimetry services to HSE's Central Index of Dose Information[18] shows that between 1986 and 1991 there was a 10-fold reduction in the proportion of classified radiation workers who received a whole body dose greater than 15 mSv per year. Less than 200 out of about 60 000 classified persons received doses greater than 15 mSv in 1991, and more than 95% had doses of less than 5 mSv.

138 In the light of these findings and in view of the success of the actions already taken both by the industry and HSE, there is no need for any urgent regulatory action at present. The subject of ionising radiation exposure is one which HSE keeps under continuing review and will be dealt with in line with requirements arising through the revised Euratom Directive: this will lead, in due course, to revised UK Regulations under the Health and Safety at Work Act. Doses currently received by classifed workers are such that no substantial changes to present working practices will be needed to meet the requirements of the revised Euratom Directive, and revised UK regulations on radiation protection which are expected to take account of the latest recommendations[19] of the International Commission on Radiological Protection, ICRP 60.

139 The findings of the investigation into potential exposure to chemicals have not led to any conclusive results. Effective control of the known risks from hazardous substances should be achieved by compliance with the Control of Substances Hazardous to Health Regulations 1988. The introduction of these Regulations mean that no additional legal measures in relation to chemicals are required.

CONCLUSIONS

140 The first two parts of this HSE investigation, the Case-only Study and the Radiation Dose Study, were concerned with the 11 case fathers who had worked at Sellafield identified by Professor Gardner. These studies were associated with children born, and diagnosed as suffering from leukaemia or NHL, in West Cumbria. The third part, the main Case-control Study, was a full epidemiological study which sought to identify all cases of cancer diagnosed before the age of 25 and where the children concerned had been born in West Cumbria to fathers who had been directly employed at Sellafield. The search for diagnosed cases included the whole country and the period covered was from January 1950 to September 1989. In all, 16 cases of leukaemia and NHL, and 16 cases of other cancers were identified.

141 The purpose of the first two parts was to determine whether any of the information available at an early stage suggested a need to take action to further protect the health and safety of Sellafield employees in particular, or radiation workers in general. Nothing emerged from these parts to suggest such a need although the results of the Radiation Dose Study did provide some weak support for the associations found by Professor Gardner between pre-conception radiation dose to the fathers and the risk of leukaemia and NHL in their children.

142 This result was not surprising since the fathers of the cases identified by Professor Gardner were merely being re-examined against a different set of controls. It was considered that more reliable findings would emerge from the Case-control Study, which would include additional cases, more comprehensive radiation dose data, a study of the potential exposure to other substances and an enhanced statistical analysis.

143 From the Case-control Study, the main conclusion is that there was a clear distinction between the risk of leukaemia and NHL for the children of Sellafield workers resident in Seascale when the child was born, compared with those resident elsewhere. The rate of leukaemia and NHL was about 14 times the national average for the Seascale children born to Sellafield fathers, and about twice the national average for the children of Sellafield fathers resident in locations other than Seascale.

144 Thirteen out of the sixteen leukaemia and NHL case children were born to fathers who started work at Sellafield before 1965, whilst only 3 were born to fathers who started work at Sellafield after that date. The excess in these illnesses is almost entirely concentrated in children whose fathers started work in the period from 1950 to 1964, with the observed to expected ratios being 10/2.25 for lymphatic leukaemia and NHL, and 13/3.56 when considering all leukaemias and NHL. If there was a workplace-

related cause contributing to the observed incidence, the indications are that since about the middle 1960s, it has either ceased or has very substantially reduced.

145 The association of all leukaemias and NHL, (and more specifically lymphatic leukaemia and NHL) with cumulative pre-conception external radiation dose to the fathers identified in the main Case-control Study is weak. The estimates are associated with wide confidence intervals and are strongly influenced by the Seascale cases. Consequently it is concluded that there is only fragile evidence that cumulative pre-conception external radiation dose alone is linked to an increased risk of leukaemia and NHL among young people. The present study also considered other forms of cancer, ie those other than leukaemia and NHL, and identified 16 cases: there was no association between these other forms of cancer and the father's exposure to radiation.

146 In considering the immediate pre-conception external radiation dose, and the possibility of a direct effect on the father's sperm, the important period is the 12-weeks prior to conception. It is concluded that for the study population as a whole, there is no statistical significance for any of the cancer types when examined against the radiation dose received during this 12 week pre-conception period, or any other of the variables studied. This finding contrasts with Professor Gardner's observation of an association between paternal external penetrating radiation doses in the six months prior to conception and leukaemia and NHL.

147 An important finding in considering potential mechanisms for inducing these illnesses is the absence of an effect on other cancers. Had excesses of other cancers been found, showing the same pattern of associations as seen for the leukaemias and NHL, this would have provided strong evidence for a hereditable effect of the type hypothesised by Professor Gardner. No such pattern was seen and the fathers of cases of other cancers actually had lower than average paternal pre-conception radiation doses. This implies that any genetic mechanism involving radiation that might be postulated for the excess of leukaemia and NHL in children born in Seascale would have to be specific for these, and conceivably a limited range of other cancers.

148 For the Seascale cases, there is a strong association with fathers' cumulative pre-conception radiation dose, and a weaker association in the 12-week period before conception. Because these observations are linked with residence as stated on the children's birth certificates, and thus with the assumed early residence of the children in Seascale, it is possible that they can be explained by a combination of causes, including paternal radiation exposure prior to conception and population mixing. In this respect the observation of a high degree of population mixing in Seascale may be important.

149 For the other factors examined in the Case-control Study, it is concluded that fathers' assessed pre-conception internal radiation doses, potential neutron and alpha exposures, exposure to chemicals of various kinds and involvement in radiological incidents do not seem to have been important, though the latter factor did show some statistical association for the Seascale cases.

150 Three factors which did produce significant associations, independently of external radiation and residence in Seascale, were potential exposure to tritium, potential exposure to trichloroethylene and employment in the Calder part of the site. In these cases the associations are strong, but for potential exposure to tritium and trichloroethylene, the associations are largely based on non-numerical data and the same cases are involved in both associations. Thus the two relationships cannot be separated. As far as tritium is concerned, we understand that the employers at the time were aware of the hazards and carried out monitoring both of the workplace and of individuals. Also, there is no suggestion in the Canadian study that pre-conception tritium exposure was associated with childhood leukaemia. Independent evidence of a paternally mediated risk from trichloroethylene is weak. We conclude, therefore, that both these associations should be treated with caution.

151 The association found for Calder is difficult to explain. There is some overlap of cases in that 2 of the Seascale case fathers worked in the Calder part of the plant. However, the cumulative pre-conception radiation doses received by the Calder case fathers were not unusual relative to their controls. Neither can the Calder association be explained by exposure to tritium. In conclusion, no convincing explanation for this association can be found.

152 No single factor so far advanced seems capable of explaining all the features of these cases. It seems difficult to deny some role for population mixing, even if the precise way this operates is still unclear, (and the present data suggests that its effect bears equally on the native and incoming populations). Population mixing alone, would not explain the strong correlation within Seascale between father's cumulative pre-conception radiation dose and leukaemia/NHL in his children. On the other hand, evidence has recently been published[6], showing that for cases diagnosed while resident in Seascale, there is an excess even if all cases whose fathers had known pre-conception radiation doses are excluded.

153 The main interest of the Health and Safety Executive in having this work carried out has been to determine whether there is any evidence from a study of the Sellafield workforce to suggest that further preventative action is required to protect the health and safety of radiation workers in general and those at Sellafield in particular. It is concluded that the evidence obtained from the work suggests that none is necessary other than that already taken.

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GLOSSARY OF TERMS AND ABBREVIATIONS

Absorbed Dose: The fundamental *dose* quantity. It is the energy absorbed per unit mass of material.

AEA: See UKAEA.

AECB: Atomic Energy Control Board of Canada.

Alpha-in-air: A term used when referring to air borne *contamination* by radioactive materials (such as plutonium or uranium) which emit alpha radiation.

Beta-in-air: A term used when referring to airborne *contamination* by ratioactive materials (such as strontium-90, caesium-137 and other fission products) which emit beta, and in some cases, gamma radiation.

Biological Monitoring: The measurement of radioactivity in urine and faecal samples as a means of estimating *internal radiation dose* from radioactive material taken into the body.

BNFL: British Nuclear Fuels plc.

Case-control study: A type of epidemiological study in which the occurrence of possible explanatory factors for a disease is compared between those with the disease ("cases") and a representative sample of non-cases ("controls") from the same population.

CIDI: Central Index of Dose Information. The *HSE's* national database of occupationsl exposure to radiation. It is operated on an agency basis by *NRPB*.

Classified worker: See *classified person*.

Classified person: A person designated as such by his employer under *IRR85* Regulation 9. Employees who are likely to receive *doses* in excess of 3/10 of any relevant dose limit set out in IRR 85 are required to be so designated.

COM: Committee on Mutagenicity.

Confidence interval:	A 95% confidence interval is a range of values that has a 95% chance of containing the true value; it provides an indication of the precision of the estimated *odds ratio*.
COMARE:	Committee on the Medical Aspects of Radiation in the Environment.
Committed Effective Dose:	The *dose* to individual organs when radioactive material is taken into the body is seldom uniform and is spread over time. The sum of the *doses* to individual organs, suitably weighted to allow for the radiosensitivity of each organ and integrated over time is the committed effective dose.
Conception date:	See *Date of conception*.
Contamination:	Radioactive material in particulate, gaseous or liquid form present in places where it should not be.
Continuous variable:	Data (variable) with a potentially infinite number of possible values along a continuum (eg height, weight).*
COSHH:	Control of Substances Hazardous to Health.
Date of conception:	Estimated for this study to be 266 days before the date of birth.
Dose:	See *Radiation Dose*.
Effective dose:	A quantity derived from *equivalent dose* to represent the combination of *doses* to different organs and tissues in a way which is likely to correlate well with the total of the *stochastic effects*. It is the sum of the weighted *equivalent doses* in all tissues and organs of the body, where the weighting represents the relative contribution of the organ or tissue to the total detriment due to the *stochastic effects* resulting from uniform whole body irradiation.

* These terms are as defined in Last J M. *A Dictionary of Epidemiology*, Oxford University Press, 1988 or are modified from definitions in that volume.

Environmental monitoring:	The measurement of radioactivity (in air samples mainly) to give confidence that radiation and *contamination* conditions in working and other areas are satisfactory.
Equivalent dose:	The *absorbed dose* averaged over a tissue or organ and weighted by a factor depending on the type and energy of the radiation.
External Radiation Dose:	*Dose* which is received by an individual as a result of exposure to sources of radiation from outside the body.
Factor:	A variable the values of which fall into or have been allocated to discrete categories (eg place of residence, date of birth in 5 year periods).
Film badge:	One of the devices used for estimating *external radiation dose*. It consists of a photographic film in a holder and is normally worn on the front of the body. Processing of the film allows estimation of the dose received by the wearer.
HSE:	Health and Safety Executive.
IARC:	International Agency for Research on Cancer.
ICD:	International Classification of Diseases.
ICRP:	International Commission on Radiological Protection.
Interaction:	Difference in the effects of one or more explanatory variables according to the level of the remaining explanatory variables*
Internal Radiation Dose:	*Dose* which is received by an individual as a result of radioactive material inside the body.

* These terms are as defined in Last J M. *A Dictionary of Epidemiology*, Oxford University Press, 1988 or are modified from definitions in that volume.

Migration index:	In this study, the ratio of the number of children of non-Cumbrian born fathers to the number of children of Cumbrian born fathers.
Millisievert:	A unit of *equivalent dose* and *effective dose* (= 0.001Sv).
mSv:	*Millisievert.*
Neighbouring dose:	A concept used in the development of 'rules' which allowed values and variants to be entered into the HSE database of external radiation dose information when dose record information was uncertain or absent. It refers to recorded doses for the periods surrounding the period in question.
NHL:	Non-Hodgkin's Lymphoma.
NHSCR:	National Health Service Central Register.
NII:	HM Nuclear Installations Inspectorate. Part of *NSD.*
Notional dose:	A value entered into a *dose* record for a period when a *film badge* or other personal dose measuring device has been damaged or lost and where investigation has not produced an estimate of a likely dose. It is normally a pro rata figure based on the appropriate annual *dose* limit.
NRPB:	National Radiological Protection Board.
NSD:	Nuclear Safety Division of *HSE.*
Observed/Expected ratio:	Ratio of the number of cases of disease observed in a study population to the number expected had the *risk* of disease in that population been the same as in the general population. Abbreviated to O/E ratio.
OCCR:	Oxford Childhood Cancer Registry.
Odds ratio:	The ratio of the odds that a case will occur in one group compared to another. In this study the *odds ratio* is a measure of *relative risk.*

O/E:	See *Observed/Expected ratio.*
OPCS:	Office of Population Census and Surveys.
OR:	See *Odds ratio.*
p - value:	Probability (of a given result being produced by chance).
Paternally mediated:	In this study, a possible effect on a child of an occupational exposure occuring indirectly through the father is described as paternally mediated.
PBE:	pre-birth exposure.
Radiation Worker:	A person working with radioactive materials. Often used to mean *classified person.*
Radiation Dose:	A general term, often shortened to 'dose', for a measure of exposure to ionising radiation. In this report unless otherwise stated, the term *Radiation Dose* refers to the pre-conception *External Radiation Dose.*
Relative Risk:	The ratio of the probabilities that a case will occur in one group compared to another.
Replacement film badge:	A *film badge* issued and worn when a *routine film badge* has been lost or damaged or which has been withdrawn for processing because an abnormal *dose* to the wearer is suspected.
Risk:	The probability that an event will occur (eg that a case will appear within a defined population group)*
Routine film badge:	A *film badge* issued to be worn on the front of the body and used as the basis of statutory *dose* measurements.

* These terms are as defined in Last J M. *A Dictionary of Epidemiology*, Oxford University Press, 1988 or are modified from definitions in that volume.

Sievert:	A unit of *equivalent dose* and *effective dose*.
Special film badge:	A film badge issued and worn when (perhaps because of non-uniform radiation fields) it is believed that a *routine film badge* alone will not give an acceptable measurement of dose to the wearer.
Statistically significant:	Shown by statistical testing to be unlikely to have arisen by chance. An arbitrary probability (usually 0.05 by convention) is chosen to indicate the likelihood that the study finding, or a more extreme finding, will not have occurred by chance.
Stochastic effects:	Those radiation effects (such as cancer induction) where it is the probability of the effect occurring which depends on the *dose*, rather than the severity of the effect.
Strongly Penetrating Radiation:	A term defined by the International Commission on Radiation Units and Measurements in ICRU Report 39(1985). For the present report it can be taken to mean radiation which is sufficiently energetic that, if incident on the body, will irradiate deep organs, including male and female gonads.
Study population:	All the subjects included in the study. In this investigation the study population is all the cases and controls.
Sv:	*Sievert*.
Thermo-luminescent dose meter:	One of the devices (there are several designs) used for estimating *dose*. Energy stored in the material by exposure to ionising radiation can be released as light when the material is heated in a "reader". The amount of light emitted is a measure of the *dose* received by the wearer.
THSD:	Technical and Health Sciences Division of *HSE*.
TLD:	Thermo-luminescent dosemeter or dosimetry.

Translation sheets:	The documents containing the results of the work to convert information from the *BNFL dose* records into a form suitable for entering into the *HSE* database of *external radiation dose.*
Tritium:	A radioactive isotope of hydrogen. It emits low energy beta radiation and has a radioactive half-life of 12.3 years.
UKAEA:	United Kingdom Atomic Energy Authority.
Variable:	A quantity that varies. Any attribute, phenomenon or event that can have different values.*
Whole body dose:	A term used to represent *dose* from approximately uniform irradiation of an individual, and to distinguish it from *dose* to particular body organs and tissues. In this report, depending on the context, the term "whole body dose" means the *effective dose* from external radiation or the sum of the *effective dose* from external radiation and the *committed effective dose* from intakes of radioactive material.
Variate:	In this study, variate is synonymous with *continuous variable.*

* These terms are as defined in Last J M. *A Dictionary of Epidemiology*, Oxford University Press, 1988 or are modified from definitions in that volume.

APPENDIX 1

Case-control study - identification of cases and controls

Stage 1: Identification of "candidate" Case and Control children

1 The source population from which the candidate case and control children were drawn, and therefore for whom fathers were to be sought, consisted of all children born and therefore entered in the birth registers covering the present geographical areas of Allerdale and Copeland in West Cumbria between 1 January 1950 and 30 September 1989. Although cases were sought among births registered up to 31 May 1990, the quarter from July to September 1989 was the last for which draft entries on microfiche were available at the time of the extraction of the control series. No candidate cases were in fact identified amongst the registrations from October 1989 to May 1990, so the observation period for the study was taken as January 1950 to September 1989.

2 A search was made on the National Health Service Central Register (NHSCR) for all deaths and cancer registrations recorded against this cohort of births. The main part of this search was completed in July/August 1991 with checks in some of the small closed registers continuing through to January 1992. Copies of the draft death registration entries and details of cancer registrations (available from 1971 up to 1986, with some, but not all, recorded for 1987 at the date of search) were supplied by the Office of Population Censuses and Surveys (OPCS) and the General Register Offices in Scotland and Northern Ireland where appropriate. 2057 deaths, 176 cancer registrations and 78 with both a death certificate and cancer registration were notified in total. A count of numbers emigrated was also supplied: there were 1103 in all, for whom no death or cancer registrations would be available. 351 children had been adopted: although death and cancer notifications were obtained for this group, the candidate cases identified were not included in the study as no original birth registration details could be supplied.

3 The certificates were reviewed by two members of Team A1 independently, and all cancers occurring in children and young people up to the age of 25 were noted. Any cancer mentioned on the death certificate as the underlying or associated cause of death was included. Copies of draft birth registrations were obtained for this group from OPCS. After exclusion of adoptees (there were 2), this group was accepted as the set of candidate cases, 203 in all. Independent confirmation of cancer type or of cause of death was obtained from the appropriate cancer registry for successfully matched cases at a later date (see paragrgraphs 41 - 46 of this Appendix).

4 The candidate control children were identified as a randomly seeded systematic sample of births drawn from the same birth registers, covering the same time period as the case children. These were identified at OPCS by entry number in the registry books. A 2% sample was estimated to be sufficient to yield about 150 matched control fathers; this number of controls was considered adequate to optimise the statistical power of the study at reasonable cost.

5 The nominal 2% sample consisted of all entry numbers ending in a 53 or 63 for registrations after March 1969, which were supplied by OPCS as photocopies of the single sheet microfiche entries. For the earlier period where 5 registrations in general appeared per sheet, sheets containing an entry number ending in 53 were extracted. The first and last entries on each of these sheets, usually (but not always) ending in a 51 or 55, were actually used to make up the 2% sample.

6 An additional nominal 15% sample, consisting of registrations with an entry number ending in the digits 11 to 25 and with a mention of Seascale anywhere on the entry was also obtained. This sample was drawn from the same registers, covering the same observation period as the 2% sample extraction. From this sample, births to families resident in Seascale parish were identified.

7 Information from the birth registration photocopies was entered onto computer files. Data was keyed through a double entry system for validation purposes, and a further thorough check was made of all fields entered against the photocopied originals.

8 A nominal 2% systematic sample had also been drawn at the outset from the birth registries in Carlisle and Barrow-in-Furness. One quarter of these (604) were submitted for matching, resulting in a single successful identification of a father employed at Sellafield (of a child registered in Barrow). This control father was excluded from the study, as no attempt had been made to identify candidate cases from these two registration districts in the light of the very low success rate of the matching of birth certificate fathers from these more distant registries.

9 After exclusion of duplicates and entries with incomplete information, a total of 4025 candidate controls were available for matching from the 2% sample series (including one duplicate of a case, and two re-registrations of pre-1950 births). 2389 of these were from the Barrow and Carlisle registries. 174 additional registrations were available from the Seascale 15% 'boost' sample (one again a case duplicate).

10 Registrations cancelled due to adoption were excluded from the candidate control series. There had been a total of 14 adoptions amongst the 2% sample extraction from the Allerdale and Copeland area registries. Where a cancelled birth registration had

Table 1

Birth registrations available for matching by registration district and address

	CANDIDATE CASE CHILDREN		CANDIDATE CONTROL CHILDREN		
			Main series (2%)		*Seascale boost (15%)*
Address	*Seascale*	*Other*	*Seascale*	*Other*	
Birth Registration District					
Whitehaven	8	96	8	1007	170*
Millom	0	8	0	23	0
Cockermouth	0	68	0	541	4
Wigton	0	23	0	57	0
Total Allerdale & Copeland	8	195	8	1628	174
Barrow & Carlisle	-	-	0	2389	-

* These figures each include one duplicate of a case

been replaced by an updated copy of the original entry under the same entry number, it was retained in the sample with the revised details (for example change of name). Some re-registrations using the original NHS number allocated, but forming part of our 2% sample due to their location in the register pages, were also included. Cancellations in our 2% sample series, subsequently re-registered under a different entry number, were excluded. No cancelled registrations were found in the 15% Seascale boost control series.

11 Table 1 shows the numbers of birth registrations for the candidate case and control children, which were available for matching, by registration district and address.

Checks on completeness of the candidate Control series

12 Extensive checks were made on the completeness of the 2% Control series. Missing sample entries in entry number runs, missing books as represented by NHS codes

which had been allocated to the various birth registries, and missing birth sub-registration districts where these had ceased to exist before the end of the study period were identified and the missing registrations were obtained. Lists of sub-registries and books which had been a source for the control series and for potential cases were cross-checked with one another to ensure that all had been searched for both candidate cases and controls.

13 As a further check, numbers in the 2% main series and 15% Seascale boost control groups were compared to numbers of births counted to mothers resident in the Allerdale and Copeland areas and in Seascale for the relevant period. These numbers would not be expected to be exactly the same, since births are registered in the area in which the birth takes place, while the published birth statistics are based on the mother's residence. The main point of this comparison was to see if there was any evidence of sampling variation over time. The number of registrations in the 2% candidate control series was about 20% less than the number of births to mothers resident in the area, consistently for all time periods. There was no overall deficit of births in the 15% Seascale boost (see Table 2), but the data shows an upward trend in the proportion sampled from about 12% in the 1950s to about 18% in 1975-83 (the comparison for 1984-89, 21%, is based on a different data source from the earlier years, and may differ for other reasons).

14 Four sources of 'leakage' or loss of births could be identified which were due to the choice of birth registries as a source of births to Sellafield fathers and to sample selection within these registries[1]. These were:

(a) a family resident in the Allerdale and Copeland area but the birth registered elsewhere;

(b) registrations missed in the OPCS search;

(c) choice of entry number for the systematic samples, with short, and early closure of, registration books;

(d) cancellation of registrations, particularly due to adoption.

There was a clear pattern suggesting a consistent proportion of births to residents being registered outside the study area in all periods, mostly from the Wigton and Millom registration districts, presumably to the Carlisle and Barrow registries respectively because of the siting of the relevant maternity hospitals. However, all but one of the registrations successfully matched to a Sellafield father were from the inner area registries, namely Whitehaven and Cockermouth, for which this leakage factor

Table 2

Seascale boost

			CANDIDATE CONTROLS:		
			Sampled		
Year of birth	*Seascale birth cohort*	*15%*	*As proportion of 15% of total Seascale births*	*submitted 4%*	*matched*
1950 - 54	176	19	0.720	7	3
1955 - 59	182	25	0.916	6	6
1960 - 64	222	39	1.171	10	6
1965 - 69	169	23	0.907	6	5
1970 - 74	140	15	0.714	4	4
1975 - 79	89	16	1.199	5	5
1980 - 84	104	20	1.282	5	4
1980 - 89*	78	17	1.453	4	3
Total	***1160***	***174***	***1.000***	***47***	***36***

* Seascale "birth cohort" of Gardiner et al BMJ 3/10/87, additional years from 'Newcastle data'

Main series

Year of birth	*Allerdale & Copeland birth cohort*	*2%*	*As proportion of 2% of total Seascale births*	*submitted 1.75%*	*matched*
		1		1	
1950 - 54	14180	234	0.825	202	12
1955 - 59	14593	231	0.791	204	18
1960 - 64	15409	253	0.821	218	24
1965 - 69	13906	223	0.798	194	15
1970 - 74	11757	199	0.838	174	17
1975 - 79	9775	159	0.803	142	15
1980 - 84	10525	182	0.850	163	19
1980 - 89*	9859	154	0.781	137	25
Total	***99999***	**1636**	***0.814***	***1435***	***145***

* estimated to September 1989

was of no importance. Seascale births were also not affected. The loss of births due to missed registrations and to adoptions was also negligible. Although assessed on the basis of the candidate control data, all these factors would affect case and control births equally. The comparisons did not therefore indicate that adjustments to any of the sampling fractions would be necessary for different years or areas covered in the study. The early closure of registration books could also operate in either direction on the real sampling fractions, assuming that the point of closure would occur at random, and therefore this factor was not adjusted for either.

15 However, the choice of entry number did have an effect on the nominal sampling fractions for Seascale births, leading to a need to adjust the probabilities of selection of these candidate control children in the study. Where a registration book contained only 250, instead of the usual 500 or 1000 entries, the choice of entry number for the 2% sample (51,53,55 or 63) would result in the sampling fraction being 1.6% for these short books, and for the 15% sample (11-25) 18%. Nearly half (44%) of the Seascale births were registered in the Egremont, then Ennerdale sub-registries whilst these operated; they closed on 30 September 1957 and 31 March 1974 respectively. Thirteen of 14 books covering the period from 1950 to closure in these registries contained 250 entries, the 14th contained 500, representing a 1.65% nominal sampling fraction for these registries for the main series (17.6% for the Seascale boost) and therefore a true sample fraction (ignoring the effects of cancellations and adoptions) for the period up to 31 March 1974 of 1.85% for the main series and 16.14% for the Seascale boost. The sampling fractions for Seascale births up to 1 April 1974 were adjusted accordingly and are given in Table 4 of the main report. Full details of the calculation of the selection probabilities is given elsewhere[2]. The effect of short books on the sampling fractions for non-Seascale residents in the main sample series was negligible, and no adjustment to selection probabilities was therefore necessary.

Stage 2: Matching to the Sellafield workforce files

16 The following details were extracted from the birth registrations for use in matching to the Sellafield workforce file:

(a) child's date of birth;
child's forenames;
child's surname (available after March 1969 only);
child's sex;

(b) father's forenames and surname;

(c) father's place of birth (available after March 1969 only);

(d) father's job;

(e) mother's forenames;

(f) mother's surname;

(g) mother's maiden name;

(h) Mother's address (available after March 1969), or informant's address and relationship to child (available up to March 1969).

17 The above details for the candidate case and control children were supplied electronically in a series of mixed batches to Team A2, for the second stage of the case and control identification process. No indication of status as a case or control was given in the batches. Controls and cases were allocated an identifying code and sequential number as they became available for batching. They were then allocated to the batches in a randomly seeded systematic fashion, so that each batch contained sufficient numbers and birth date spread of controls and cases to obscure the identities of both. It was also possible to identify which of four original notional batches the control and case candidates would have been allocated to had all registrations been available at the outset of the matching procedure, by the sequential numbering system. In this way it was possible to restrict the matching process for an identifiable subset of the registrations submitted for matching when new rules were applied (see paragraphs 23 and 25 of this Appendix), while ensuring that all such subsets formed a sample representative of and based on similar selection methodology as the original birth register extractions.

18 The fathers' and other details from the birth registrations were matched to Sellafield employees on the computerised databases maintained by the BNFL and AEA personnel departments. These records contain the employment details of over 20 000 workers employed by BNFL, AEA and UKAEA Constabulary. They do not however cover workers employed by outside contractors, who were therefore excluded from the study. If a potential match or matches was identified on one of these databases, ie a man between the ages of 16 and 65 at the time of the child's birth with the correct surname and at least one matching forename, the man's paper personnel records would also be consulted. Should the man have transferred to another site this would also be noted at this stage. A match was considered to be successful if the sum of the scores awarded for each matching criterion (father's name, wife's details, address, job information) exceeded a pre-determined threshold, which had been fixed (at 12) so that the theoretical chance[3] of a single mistaken match occurring (over the entire matching process) would be limited to the order of 1 in about 6 000.

19 The scores for father's surname and mother's maiden name were based on the relative frequency of occurrence of those names in the local telephone directory. Forename and initial scores were based on national frequencies. Scores for an exact match on job were based on national frequencies of occurrence of occupations (at chapter level of the Standard Occupational Classification), with an additional score awarded for mention on the birth registration of Sellafield employment. Scores were also allocated for an exact or close match on mother's (or pre-April 1969, father's) address. Items (a), (b) and (c) listed in paragraph 16 were not scored in the matching process.

20 Cognisance was also taken of any contradictory evidence against a match. Evidence which might suggest a family relationship other than as father of the child would also be an indication of mismatch, in spite of a high score. For example, a brother or grandfather of the birth certificate child sharing a common family name and a common address would present a situation where the independence assumption used in the probability calculation for determining the cut-off score would not be valid.

21 The match scores were concentrated above and below a band defined by the scores of 8 and 12, with very few falling within this band. All potential matches with scores from 8 to 12 were re-assessed anonymously by an independent arbitrator. Three additional scorable criteria were as a result added to the above list. These were:

(a) For a mention of Sellafield work on the birth registration, plus a contemporary job record matching that on the birth certificate and no other potential matches in the database - include in matched set;

(b) For a 'spread' of at least two independent scorable items in addition to name - score additional 0.5;

(c) For a close similarity of job descriptions from different time periods - score additional 0.5;

22 One Gardner case scored 10.8 after taking account of all the above criteria. However in the original study by Gardner, fathers' dates of birth had been known, and were used to identify which case fathers had worked at Sellafield. Because of this, it had been decided (before any matching had been attempted) that an additional score of four* should be counted for each of the 11 Gardner cases. The case was therefore retained in the study.

* Based on there being approximately 10^4 possible birth dates in the 40-year span covered by the study

Table 3

Birth registrations submitted for matching by year of child's birth

CANDIDATE CASE CHILDREN			CANDIDATE CONTROL CHILDREN			
			Main series (2%) Allerdale/Copeland (1.75%)		Barrow/Carlisle	***Seascale boost (4%)***
Address	*Seascale*	*Other*	*Seascale*	*Other*		
Year of birth						
Pre 1950*	0	0	0	1	0	0
1950 - 54	2	40	1	201	74	7
1955 - 59	2	34	2	202[1]	75	6
1960 - 64	1	52	0	218	81	10[1]
1965 - 69	1	24	2	192	79	6
1970 - 74	1	26	1	173	88	4
1975 - 79	0	13	0	142	58	5
1980 - 84	1	5	1	162	78	5
1985 - 89[2]	0	1	1	136	71	4
Total	*8*	*195*	*8*	*1427*	*604*	*47*

[1] Includes one control who was also a case

[2] up to September 1989

* Re-registered after 1950

23 The original target for control numbers was 150, of which 30 should be Seascale residents. The 2% sampling fraction for the main control series was determined before the matching process started on the basis of the proportion of Sellafield workers among the controls in Professor Gardner's study. The additional sampling for Seascale residents was determined after the first 0.5% of the main control series had been matched. After 4/15 of the additional Seascale controls, and 7/8 of the main control series had been matched, both these targets had been reached (41 Seascale controls and 141 other controls). It was therefore decided that it was unnecessary to match the final 7/8 of the main control series or the remaining additional Seascale controls.

24 It will be noted from Table 3 that the numbers of candidate case children fall from 1965 onwards. After this date the length of follow-up during which a child could become a case, a maximum of 25 years, was shortened, so progressively reducing the pool of candidate case children born in these years.

25 As explained in the main report, case fathers whose children were born before the father's date of start at Sellafield, but diagnosed of their cancer after that date, were included in the study in order to contribute to the assessment of the possible effect of post-conception factors. The corresponding control fathers (fathers with a child aged under 25 on the father's Sellafield start date), were under-sampled in relation to other controls in the ratio 1:4. This was done by including all matched control fathers in the first two of the 0.25% batches, and in subsequent batches excluding control fathers whose date of start post-dated the relevant child's date of birth. Since the allocation of the control series to batches was done randomly, this control sub-group is a 1 in 4 sample of such control fathers in the full 2% sample amongst the additional Seascale controls.

26 In Table 4 of the main report are summarised the final sampling fractions achieved for the different population groups in the study. The probability of selection of each candidate matched for the study is derived directly from these sampling fractions.

27 Thirty-nine candidate cases and 182 controls, including 36 from the supplementary Seascale boost (one also a case) and one from the Barrow-in-Furness registry, were successfully matched to fathers who had at some time been employed on the Sellafield site. Table 4 in this Appendix shows the numbers successfully matched, by time period of the child's birth, address (Seascale or otherwise) and pre-birth exposure (PBE) status.

28 As noted earlier, separate probabilities of selection (sampling fractions) were applicable to those resident in Seascale or elsewhere, and to fathers who had worked on the Sellafield site before their child's birth as opposed to those who had not. In Tables 4 and 5, residence in Seascale implies a father of a child whose birth registration indicated a home address within Seascale parish, whether that registration came from the 2% or 15% boost control series or from the candidate cases. This classification and that of PBE status in tables 4 and 5 determines the allocation of selection probabilities to the study subjects. Those fathers classified as having no pre-birth exposure have been allocated to this category according to the decision made at the time of first matching of the birth registration to the workforce computerised database. At this time potential matches to candidate registrations were not followed up (whatever score was achieved) if the potential match father had a date of start after the child's birth and the registration was not part of the pre-defined subset of

Table 4

Birth registrations successfully matched by year of child's birth, address and pre-exposure status

	CASE CHILDREN				CONTROL CHILDREN			
Address	**Seascale resident[1]**		**Other**		**Seascale resident[1]**		**Other**	
Pre- birth Exposure Rule applied[2]	Yes	No	Yes	No	Yes	No	Yes	No
Year of child's birth								
1950 - 54	1	0	4	2 (1)	3	0	10	2
1955 - 59	2	0	2	0	8	0	14	2
1960 - 64	1	0	8	3	6[3] (5)	0	21	3
1965 - 69	1	0	2	1	7 (6)	0	9	4
1970 - 74	1	0	2 (1)	2 (0)	4	0	11	6
1975 - 79	0	0	1	2 (1)	5	0	12	3
1980 - 84	1	0	1	1 (0)	4	0	19	0
1985 - 89[4]	0	0	1 (0)	0	4[5]	0	24[6] (23)	1
Total	7	0	21 (19)	11 (6)	41 (39)	0	120 (119)	21

[1] Resident within Seascale parish according to mother's/father's address on birth certificate

[2] See paragraph 28

[3] Includes one control also a case

[4] Up to September 1989

[5] Includes two siblings matched to one father

[6] Includes one control from the Barrow registry, subsequently excluded from the study

( ) Numbers in parentheses are those retained in the study after exclusion of rejected cases and controls, and of the control who was also a case.

candidates to whom this restriction was not to be applied. A father's date of starting work could be revised subsequently however, in the light of additional information, so that it might become apparent for example that a no PBE father had indeed worked on the site before the birth (or vice versa). His probability of selection for the study, however, was determined by the decision made at the outset of the matching process, so no re-allocation to the other category is appropriate for the calculation of the selection probabilities.

Table 5

Birth registrations successfully matched by Registration District, address and pre-birth exposure status

	CASE CHILDREN				CONTROL CHILDREN			
Address	**Seascale resident[1]**		**Other**		**Seascale resident[1]**		**Other**	
Pre- birth[2] Exposure Rule applied?	Yes	No	Yes	No	Yes	No	Yes	No
Birth registration district								
Whitehaven	7	0	19 (17)	10 (6)	41[3] (39)	0	113	17
Millom	0	0	0	0	0	0	1	0
Cockermouth	0	0	2	1 (0)	0	0	5	4
Wigton	0	0	0	0	0	0	0	0
Total: Allerdale & Copeland	7	0	21 (19)	11 (6)	41 (39)	0	119	21
Barrow & Carlisle	-	-	-	-		0	1	0

[1] Residence within Seascale parish according to mother's/father's address on birth certificate

[2] See paragraph 28

[3] Includes one control also a case, and two siblings matched to one father

( ) Numbers in parenthesis are those retained in the study after exclusion of rejected cases and controls, and of the control who was also a case.

29 In Table 5 are the numbers of candidate case and control birth registrations which were successfully matched to Sellafield fathers, by birth registration district and address.

30 Seven cases which had been successfully matched were subsequently excluded from the study. Three of the fathers were found not to have been employed on the Sellafield site prior to their child's date of diagnosis of cancer. The other four were found on confirmation of diagnosis not to have had a malignancy.

31 All the matched control children were successfully traced on the NHSCR. Five were found to have died before the age of 25 (no cancers), of which one, who died very shortly after birth was excluded entirely from all further analyses. Dates of death of the others were noted. Two candidate control births were of siblings, matched successfully to one Sellafield father. One candidate birth which was successfully matched had been selected as a control in the Seascale boost but was also a case. Two successfully matched control fathers and one case father had worked on site for just two, three and five days respectively. These were retained in the study.

Checks on the representativeness of the matched controls

32 Numbers matched by date of child's birth and by father's start and leaving dates and staff category (staff or industrial) were monitored during the matching process. No major deficits in any of the strata were apparent. A further comparison was made of matched numbers from the main series 2% control sample against numbers of births which might have been expected amongst this workforce. Expected births for the study observation period were estimated from national (England and Wales) birth rates, for births with father recorded on the birth registration and adjusted for the slight excess of births in the Northern region, applied to various subsets of the total of men employed at any time on the Sellafield site up to 1991. Expected numbers of births were calculated separately for the periods before, during and after employment.

33 Best matching rates were achieved for fathers employed at the time of the birth of the child to whose registration they were to be matched. For these men, numbers successfully matched represented 70% of the expected numbers, based on the 1.75% sample of local births which were submitted for matching. For fathers starting at Sellafield only after the birth of their child, 40% were matched (based on 0.5% of local births submitted for matching), while only 12% were matched for births to fathers who had left their employment at Sellafield. The main explanation of these last two rather poor rates of matching is likely to be that many of these (expected) births will have occurred outside the Allerdale and Copeland districts and therefore would not have been available for matching in this study. In addition, even when the child was born in the area, matching information - wife's names, address at child's birth and occupation at that time, would also be less likely to match to the BNFL records when the father was not an employee at the time.

34 An explanation for the 30% deficit of births to fathers during their employment can be sought in the quality of the BNFL/AEA personnel records among different groups. Matching rates were less good for fathers who had left Sellafield employment before 1970, than for those leaving after this date or those still employed.

35 Various categories of missing data in the BNFL personnel records could be identified which would be responsible for this early period deficit. A very few (4 out of the 136 candidate case and control children, mostly from births registered in the early period of the study, who had a mention of Sellafield work on the birth certificate - 3%) had no potential match on the BNFL or AEA computerised databases. This suggests that only a very small loss of potential matches in this early period was due to incompleteness of the computerised records - the first step in the matching process.

36 A higher proportion of potential matches with early leaving dates had missing paper archive records - about 28% of the pre-1960 leavers, or nearly seven times as many as those with later dates of leaving or the still employed, had no archive personnel records at Sellafield or at other sites operated by BNFL or AEA.

37 Partly as a result of the absence of paper personnel records, a higher proportion of the early (especially pre-1960) leavers had missing data items from their records, which would have been used for matching. To alleviate this problem, other record sources in other archives (including AEA) and at other nuclear sites to which records had been transferred were also searched for information on potential matches, and a number of those with missing paper archive records were in fact successfully matched. All available employment and radiation exposure history was included in the subject's dossier.

38 However it was not possible to adjust the candidate control mix to overcome the deficit of pre-1970 leavers which remained. Some consideration was given to increasing the numbers of control fathers who had left the workforce at an early date. This could have been accomplished by submitting additional candidate control births from all time periods and registries for matching, subject to a restriction that only potential matches among pre-1970 leavers would be included in the study. However the distribution of matched cases across leaver categories was similar to that of controls, as would be expected, and as no such enrichment of the matched set of cases was possible, the enrichment of the controls was considered inappropriate.

39 It was also the case that significantly higher matching rates were achieved for industrial than for staff worker categories, and for radiation than for non-radiation workers (defined as ever or never a radiation worker respectively). However there were few (only 6 matched) non-radiation workers included in this analysis. The availability of matching information in the personnel records was not better for industrial than for staff employees. Radiation dose records were available for the radiation workers, but matching information obtainable from this source was not scored in the matching process.

40 As the matching was done blind to case/control status, the factors mentioned above which led to differential matching rates among the workforce, ie timing of the child's birth with respect to a father's dates of starting and leaving employment, status as a staff or industrial employee, and as ever a radiation worker or otherwise, would apply equally to the matching of cases and of controls. A fuller description of the results of the analysis of matched versus expected birth numbers is given elsewhere[4].

Confirmation of case diagnosis

41 For the 39 successfully matched cases, and for 1 case that was expected to be matched, but for which the required information could not be found, independent confirmation of the date and nature of the diagnosis was sought. For each case, the following identifying details were assembled:

(a) name;
(b) date of birth;
(c) place of birth;
(d) NHS number;
(e) diagnosis;
(f) anniversary date;
(g) date of death, if relevant.

A list with this information was submitted to the Oxford Childhood Cancer Registry (OCCR) with a request for an indication whether the cases were held on that register.

42 Detailed information, site and type codes for each relevant edition of the International Classification of Diseases (ICD)[5] was provided by the OCCR for those cases confirmed. Of the 40, a total of 19 were identified on the register. Of these, however, 3 were recorded as non-neoplastic. One of these 3 had been diagnosed as myelofibrosis, which is not considered to be neoplastic in the 9th revision of the ICD and was rejected on that basis.

43 A list comprising those cases for whom the OCCR could give no help was then submitted to Professor Craft at Newcastle, with the same request for advice. Of the 21 cases submitted, information was available on 13, and again, site and type codes were supplied. One case of anaemia had been included in the case list on the basis that this may have been secondary to leukaemic disease not specifically recorded, but there was no evidence to confirm the original suspicion.

44 At this stage, 7 cases remained with no confirmation. These were all cases which had been diagnosed outside the NHS Northern Region and in all of whom the diagnosis had been made at or over the age of 16 years (16, 19, 20, 22 and 24 x 3). From the

cancer registration form, the register which held the original information on each case was identified and approached to seek confirmation that the data on the OPCS registration form was accurate. Data was held on the following registries:

(a)	North Western	2
(b)	Mersey	2
(c)	Thames	1
(d)	Oxford	1
(e)	South Western	1

45 For all these cases the individual registers confirmed that the corresponding data was held by them. For the two cases on the Mersey register, minor differences in the anniversary dates were noted which were related to the definition used. For one case on the North Western Registry, further confirmation of the diagnosis was considered necessary. This was obtained through the records officer at the treating hospital.

46 For the case registered with the Thames Registry there was an apparent conflict of diagnosis between the cancer registration form, the death certificate and the information from the registry. This was resolved by discussion with the registry staff and contact with the consultant concerned.

47 Once this process of confirmation was complete, the total list of 40 potential cases was reviewed. At this point, it was determined that 3 of the cases had been diagnosed prior to the father's start of work at Sellafield, and that in one case, a sufficient matching score had not been obtained (it had been thought that information from personnel records at another nuclear site would confirm matching). The number of cases matched and confirmed was thus reduced to 32 with cases dropping out for the following reasons:

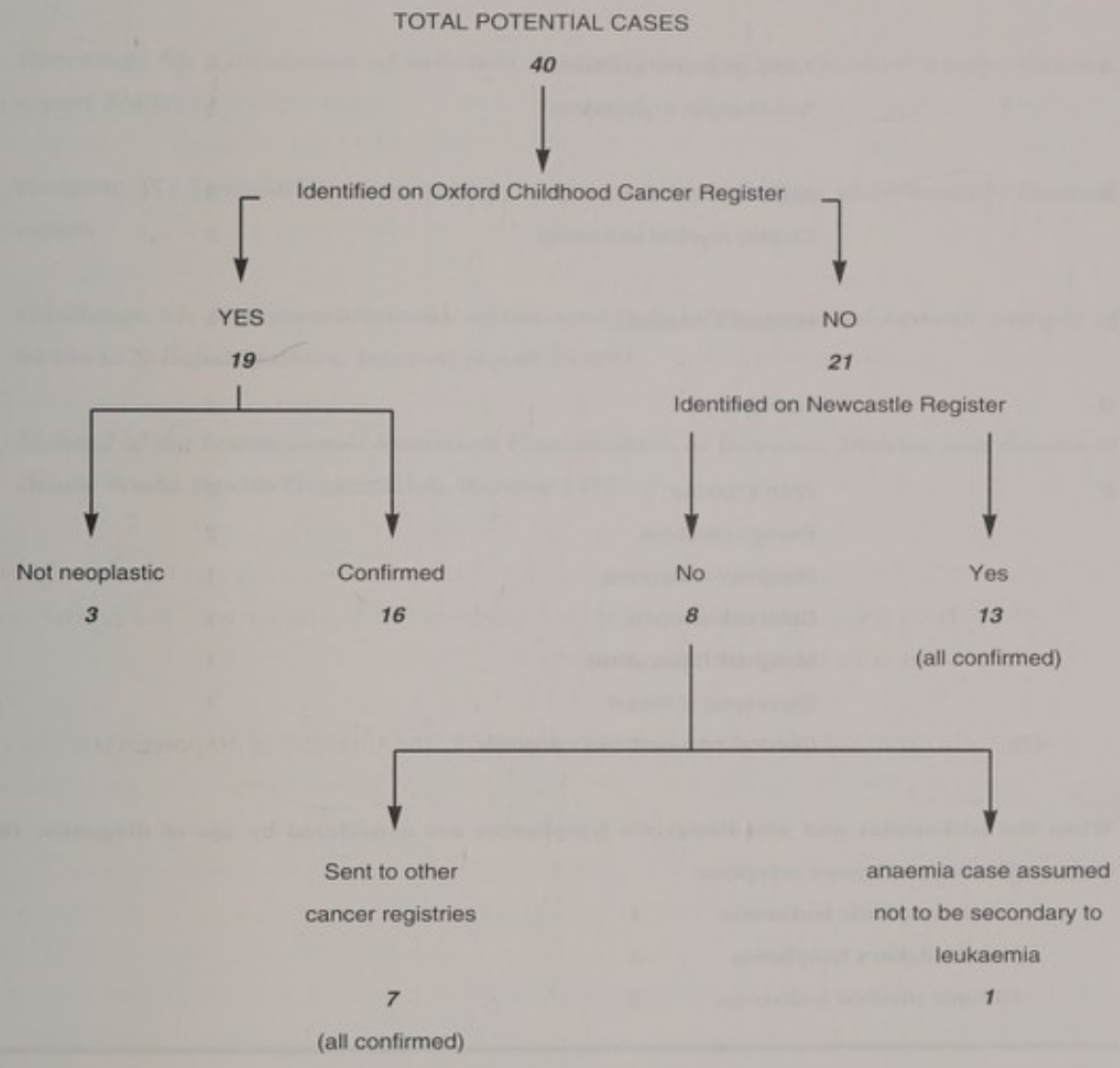
(a)	diagnosis not malignant tumour	4 (3+1)
(a)	diagnosis before father's employment	3
(a)	matching not achieved	1

The process is summarised in Table 6.

48 The diagnostic classification of the cases of leukaemia, non-Hodgkin's lymphoma and other cancers and their allocation to the categories for epidemiological analysis recommended by a COMARE working group, and used in this study, are shown in Table 7.

Table 6

Summary of confirmation process for case diagnosis



Total confirmed diagnoses,			*36*
of which	-	not matched	*1*
	-	diagnosed before father's Sellafield employment	*3*
Total included in study			*32*

Table 7

Grouping of cancer types using classification recommended by COMARE working group

Group	*Diagnosis*	*Number of cases*
A	Acute lymphatic leukaemia	9
	Non-Hodgkin's lymphoma	3
B	Acute myeloid leukaemia	2
	Chronic myeloid leukaemia	2
C	Hodgkin's disease	3
D	Astrocytoma	4
E	Wilm's tumour	2
	Ewing's sarcoma	2
	Malignant melanoma	1
	Clear cell sarcoma	1
	Malignant histiocytosis	1
	Carcinoma of breast	1
	Cervical intra-epithelial neoplasia	1

When the leukaemias and non-Hodgkin's lymphomas are considered by age of diagnosis, those diagnosed over age 15 years comprise:

Acute lymphatic leukaemia	1
Non-Hodgkin's lymphoma	2
Chronic myeloid leukaemia	2

REFERENCES TO APPENDIX 1

1 Hutchings SJ: *Investigations into the representativeness of the 2% and 15% samples.* Internal report 2/06/93.

2 Hutchings SJ: *Calculation of selection probabilities for the Gardner study.* Internal report 22/06/93.

3 Hodgson JT: *Calculation of matching scores and probabilities of mismatch.* Internal report

4 Hutchings SJ: *Representativeness of the nominal 1.75% matched control sample of births to Sellafield fathers.* Internal report 15/6/93.

5 *Manual of the International Statistical Classification of Diseases, Injuries and Causes of Death*: World Health Organisation, Geneva 1977

APPENDIX 2
Data extraction

Information collection and dossier production

1 Access to information held by BNFL and AEA relating to employment history was provided at the Sellafield site in a way which ensured that no member of the employers' staff became aware of the names of the subjects. For each of the 211 fathers who formed part of the investigation, a series of information dossiers was prepared. The dossiers contained the following information:

- ▼ External dosimetry — details of external radiation doses assigned by the employer from each film badge or thermo-luminescent dosemeter (TLD).
- ▼ Internal dosimetry — data from personal air samplers and from biological monitoring
- ▼ Personnel — these were used to establish the types of work, the buildings and dates concerned.
- ▼ Incident — involvement in incidents or abnormalities on the site which might have had affected people.
- ▼ Contamination — information was provided by BNFL and AEA on people treated at the Medical Centre for contamination.

2 For each of these categories of information, two photo-copies were made and the original was returned to the employer. On one of the photo-copies, all identifying features were obliterated and this was then re-copied to produce an anonymised version. The anonymised version was incorporated in the dossiers used in the study. The non-anonymised version was held under strict security as confidential to Team A2 to assist in resolving any queries.

3 To ensure that good document control was exercised, a number of quality assurance procedures were prepared and audits carried out of the working methods. This approach ensured that the actual documents used were appropriate and consistent for each case. The final information dossiers were re-checked to ensure anonymity before transfer to Team B.

External radiation doses

4 The remit of Team B was to select relevant information from anonymised copies of the original external dose records (provided by Team A2) to convert the dose data into modern dosimetry units, and to transfer the converted dose information to Team D statisticians in a suitable form for input to their computer. The team was required to operate within a procedure designed to preserve appropriate standards of security and confidentiality and to ensure that its members did not know the identities of the individuals concerned nor whether they were Cases or Controls. Some preliminary work was done to establish the extent and difficulty of the task and to ensure that the team understood the conventions used in the past for recording doses on the site. To this end, relevant scientific papers on dosimetry were sought and studied and discussions were held with the Approved Dosimetry Service used by BNFL Sellafield, to gain historical information on dose monitoring and record keeping on the site. An examination was undertaken of copies of a few external dose records provided by Team A2 to determine the quality and quantity of information likely to be available, and the difficulties likely to be met in interpreting and analysing the data.

5 It was established that the film badge was the main device used at Sellafield for demonstrating compliance with dose limits and had evolved from a crude unscreened dental X-ray film (in the early 1950's) incapable of discriminating between radiation of different types and energies, through a simple badge where half of the film was screened with lead, to the multifilter badge currently used. This has good radiation type and energy discrimination features.

6 Nowadays radiation is characterised as either "weakly penetrating" or "strongly penetrating", a concept reflected in current arrangements for personal dose monitoring and in the terminology used. X-, gamma, neutron, and high energy beta radiation are normally considered as components of the latter group which irradiates deep organs including male and female gonads.

7 There was only a limited amount of neutron dose information in the records. Indeed, there seem to have been no measurements of personal neutron dose prior to 1960, although some measurements were taken on plants to determine whether neutrons posed a significant problem with respect to worker exposure. At one stage, personal neutron doses were estimated by applying neutron to gamma dose rate ratios from instrument measurements, to gamma doses measured with film badges. Although neutron dose records were not as comprehensive as those for X- and gamma radiation, Team B decided to include neutron doses in the extraction and translation work where they were available.

8 With regard to beta radiation, again the records were less comprehensive than those for X- and gamma radiation. Discussion with dosimetry staff at Sellafield, however, indicated that beta radiation was unlikely to make a significant contribution to the dose of interest so Team B decided that little would be lost by not including it. Only those recorded doses from X-, gamma, and neutron radiation therefore were extracted from the records and translated, and for the most part these were doses measured by the statutory film badges. However, the dose records were not perfect and at times technical judgement had to be applied to decide on the dose figures to use. These technical judgements were supported by decisions made by a panel of three health physicists.

9 From the preliminary work it was clear that interpretation of the earlier external dose records would give problems. There would be the obvious difficulty of deciphering the numbers in the records, difficulties in determining which doses to include in the "strongly penetrating" group, determining which radiation dose units had been used and deciding which factors Team B should employ when converting the numbers to doses in milliSieverts. It was also clear that uncertainties from, for example, incorrect recording of results, the leaving of gaps, or the use of *notional doses* for lost and damaged films, would have a bearing on confidence limits in the statistical analysis. Guidance for the statisticians would have to be developed. It was evident too that the early dose records would be more difficult to translate than later ones, and that dossiers would differ in ways which would have implications for the translation work and resources. It was observed, for example, that some dossiers contained 20 years of dose records while in others there were only 3 to 4 years. It was clear that a pilot programme would be needed to properly identify the likely difficulties and for this purpose 5 typical dossiers covering size and temporal variations were selected, and considered in detail.

10 The pilot programme confirmed the difficulties suggested by the preliminary work, allowed resource needs to be established and led the way to the development of technical and administrative arrangements and procedures for the dose data extraction and translation work of Team B. An important feature of the arrangements was the communications interface with Team A2 so that additional information relating to the copies of the dose records could be acquired without compromising the anonymity requirements. The pilot programme allowed the foundations to be built for a quality assurance system which would ensure that the dose records in the dossiers were worked upon in a controlled way, and the output properly checked. These QA arrangements were refined as the main translation work proceeded.

11 The pilot programme also confirmed that Team D would need to be given clear indications of, and advice about, the uncertainties in the data[1], established the Team D

preference for receiving translated information on a "badge-by-badge" basis, and allowed development of the pro forma for the "translation sheets" by means of which the dose data and the other information would be passed to Team D. It also allowed a start to be made on the setting of criteria for converting recorded doses (some of which were in units as imprecise as "fractions of a weekly tolerance dose") into modern units.

12 The main data extraction and translation work was performed "badge-by-badge" in two stages. The first stage dealt with the two years immediately prior to the end of the year of conception, and the second stage with the remainder of the period before then. Team A2 provided, for each dossier of dose records, information on the year in which conception occurred.

13 Some 40 000 dose record entries were extracted, translated and recorded during this part of the work. Reference 2 describes in detail how Team B carried out its work and highlights the uncertainties, the shortcomings and other points of interest related to the data.

14 To indicate to the HSE statisticians where there was potential for uncertainty in the dose values, additional to the inherent measurement errors, Team B "annotated" the information provided to Team D and during the statistical analysis provided supplementary advice on dealing with the annotated entries eg gaps and *notional doses*. A data review group was formed with health physicist representation from Team B and statistician representation from Team D to consider the issues and to decide on the numbers which should be entered into the database.

15 The outcome of the discussions within this group was the development of a set of "imputation rules" which allowed Team D to enter numbers into its database where neither the dose record nor the judgements of the panel referred to in paragraph 8 could provide dose values. Most of the rules use the concept of *neighbouring dose* where the numbers entered into the database are based on the dose record information for the periods shortly before, or shortly after, the period of interest. Compromises were made between using information relating to the periods closest in time to the period of interest, and casting the net wider.

16 The algorithmic definition adopted was that for a piece of dose information to be included in the *neighbouring dose* calculation, it must relate to a period between 5 and 31 days in length, and which had a start date within 180 days of the start or end of the period of interest. Furthermore, in deriving the *neighbouring dose*, the pieces of dose information were taken in order (starting with that nearest to the period of interest) from the immediately preceding period, until at least 3 pieces of dose information had been found with a total coverage of at least 3 times the duration of the period of

Table 1

Derivation of variant values when there was no information from special film badges for the period

CATEGORY	*Recorded dose*	*Low*	*Central*	*High*
Short (<30 days) unexplained gap	0	0	0	0
Long unexplained gap	0	0	individual review	
Notional dose entries	ND	0	min (N, ND)	max (N, ND)
Estimated entries				
zero	0	0	0	N
non-zero	X	min (N, X)	X	max (N, X)
Lost/damaged badges				
up to 1958	0	0	N	max (N, ND)
	X(>0)	min (N, X)	X	max (N, X)
after 1958	0	0	0	N
	X(>0)	min (N, X)	X	max (N, X)
Zero dose replaced badges with no explanation	0	0	0	R
Blank entries	0	0	0	N

Notation

X The X-gamma dose in the Team B translation of the original dose record

N The "neighbouring" dose

ND Notional dose - 4.2 mSv/month or 1 mSv/week

R Number calculated by applying the dose rate indicated by the replacement badge to the period from the date of issue of the replaced badge to the date of issue of the replacement

interest. A similar procedure was applied for the period following the period of interest, and the number to be entered into the database was derived by applying to the period of interest the average dose rate over the selected neighbouring periods, taking account of the length of the period of interest.

17 The application of the rules to each relevant entry in the dose record, eg where there were gaps or where *notional doses* had been entered, gave 3 numbers - a low, a high and a central value. The central value was the one used in the principal analyses, the low and high variants being used in sensitivity studies. Table 1 shows how the *neighbouring dose* concept, and other information, was used to generate the variant values.

Table 2

Derivation of variant values in cases where special film badges were worn in the period

CATEGORY	Recorded dose	Variant values used in analysis		
		Low	*Central*	*High*
Short (<30 days) unexplained gap	0	P	P	max (P, N)
Notional dose entries	ND	P	max (P, min) (N, ND)	max (P, N, ND)
Estimated entries				
zero	0	P	P	max (P, N)
non-zero	X	P	A	max (N, A)
Lost/damaged badges				
up to 1958	0	P	max (P,N)	max (P, N, ND) max (N, A)
	X(>0)	P	A	
after 1958	0	P	P	max (P, N)
	X(>0)	P	A	max (N, A)
Zero dose replaced badges with no explanation	0	P	P	max (P, R)
Blank entries	0	P	P	max (P, N)

Notation

X The X-gamma dose in the Team B translation of the original dose record

N The "neighbouring" dose

A Value adjusted for overlapping special badge entries

P The "parallel" dose - the total dose from special badges overlapping with the routine film badge

ND Notional dose - 4.2 mSv/month or 1 mSv/week

R Number calculated by applying the dose rate indicated by the replacement badge to the period from the date of issue of the replaced badge to the date of issue of the replacement

18 The data review group referred to in paragraph 14 considered that where the dose records contained information from additional film badges for the period in question, a slightly different rule should be used. Table 2 indicates how the central and variant values were derived in these cases.

19 The particular features of the dose record output from Team B which led to the need to generate the variant values are set out together with the imputation rule as follows:

Short (less than 30 days) unexplained gaps

The meaning of *unexplained* in this context is that the documents produced by Team B contained no explanation for the missing data. The low and central values were taken to be zero and the high value was taken to be the *neighbouring dose* as described in paragraph 16.

Long unexplained gaps

Again the meaning of *unexplained* in this context is that the documents produced by Team B contained no explanation for the missing data. An individual review was made of the personnel and dose records for the period surrounding the gap. On the basis of this, one of three decisions was taken by the data review group:

(a) there was probably no dose received during the period, so zero should be entered on the database for the central value and for the high and low variants;

(a) it was reasonably plausible that there could have been no dose received during the period, and the rule applying to *short gaps* should be applied, or

(c) it was unlikely that no dose had been received, so the central value should be taken to be the *neighbouring dose* and the low and high variants should be derived separately from the dose rates in the 6 months before and the 6 months after the gap.

Two special cases did not fit these general rules. In one, for the period following the gap, there were a few very large recorded doses. The central value for this instance was taken as the *neighbouring dose* calculated with the high values removed, the low variant was zero and the high variant was the *neighbouring dose* including the high doses. In the second case there was strong evidence, from detailed descriptions of the work undertaken, to support the view that the *neighbouring dose* was a good basis for the database numbers covering the period of the gap. The *neighbouring dose* was entered on the database for the central value and the high and low variants.

Notional doses (see Glossary)

The central value was taken as the smaller of the *neighbouring dose* and the *notional dose*. Almost always this was the *neighbouring dose*, and reflects the site practice of overestimating where there was doubt, since the purpose of personal dose monitoring was to demonstrate compliance with dose limits. The low variant was taken as zero and the high variant as the larger of the *notional* and *neighbouring dose*s.

Estimated record entries

For other entries in the dose record where the dose had been estimated, the low variant was taken as the smaller of the *neighbouring dose* and the recorded dose estimate, the central value was taken as the recorded dose estimate and the high variant as the larger of the *neighbouring dose* and the recorded dose estimate.

Entries relating to lost/damaged film badges

These were treated differently according to date. It was known from the preliminary work of Team B that up to 1958, zero was generally entered on to the dose record in such cases. Where the dose record prior to 1958 showed a zero dose for a lost/damaged film badge, the central value was taken as the *neighbouring dose*, the low variant as zero and the high variant as the larger of the *neighbouring dose* and the pro rata *notional dose*. All other dose entries relating to lost/damaged film badges were treated in the same way as for *estimated record entries*.

Zero entries (where replacement film badges had been issued)

In a number of instances where a routine film badge had been replaced, the dose for the period prior to the replacement had been recorded as zero. In the absence of explanation in the documents produced by Team B, the low variant and central value were taken as zero in such instances: a high variant was calculated by applying the dose rate for the replacement film badge to the period from the date of issue of the original film badge to the date of issue of the replacement.

Blank entries (ie where there were only one or two consecutive missing entries)

These were treated in the same way as the *short unexplained gap*, the low variant and central values being taken as zero and the high variant as the *neighbouring dose*. However, where some special film badges had been worn during a period where there was a gap in the routine film badge record, the values taken were not less than the doses recorded by the special badges (see Table 2).

Overlapping entries

When special film badges had been worn during a period, the recorded doses were sometimes different from those measured by the routine film badge for the same period. The data review group discussed at great length the reasons for this and decided to adopt imputation rules based on:

(a) the recorded dose on the routine issue badge (X);

(b) the duration of the routine badge (D);

(c) the total overlap period for all special issue badges (n);

(d) the total dose recorded on all special issue badges (P - the "parallel dose").

20 The calculation depends on the relationship of these four quantities as illustrated in Figure 1. Where the period covered by special badges was short in relation to the routine issue badge, and where the dose on the special issue badge was substantially less than that recorded on the routine issue badge (this situation corresponds to point "a" on the figure), no adjustment was made. Where the period covered by the special badge or badges was short, but the dose recorded by them was greater than that recorded by the routine badge ("b" on the figure) then it was decided to use the sum of the P and X. Where the total period covered by special badge or badges was the same as that covered by the routine badge ("c" on the figure), it was decided to use the larger of P and X. There were relatively few instances of this type.

21 Somewhat arbitrarily, it was decided to extend the application of the adjustments described above to the shaded areas shown on the figure and to make a linear interpolation for badge combinations whose parameters fell in the unshaded area of the figure.

22 Figure 2 illustrates the effect of these adjustments on all total pre-conception doses in the study. In this figure the adjusted dose totals are plotted against the dose totals that would be reached by simply adding up the whole body doses from the Team B translation of the original records. The figure also indicates the area in which the adjusted dose total lies within 20% of the dose as recorded. The adjustments produced no major changes in the dose ranking. No subjects change dose category on a grouping with cut-points at 50 and 100 mSv. The 4 subjects with the largest absolute change are marked by a letter on the figure: the dose estimates for subjects A, B and C are raised because they wore large numbers of special badges; subject D because there were three long gaps in his dose record totalling 5.3 years, and a value of 53 mSv was imputed for these missing periods.

23 Figure 3 shows a similar plot for doses received in the 12 weeks prior to conception. Here the relative changes in dose estimate are greater, and 4 subjects change dose category (with cut-points at 5 and 10 mSv). The reasons for the largest absolute changes are as follows: subject A had a two-week routine film badge which recorded 7.26 mSv, and in 2 days in the same period wore 2 special badges which recorded a total dose of 9.68 mSv. For subject B there was a similar situation with a single special badge recording 9.22 mSv. Subject C had a 9 day gap in his routine dose record during which he wore a special badge which recorded a dose of 3.6 mSv. Subject D had a 6 month gap in his dose record, but other available information

Figure 1

Diagram showing the circumstances in which the dose recorded on routine monitoring badges was modified because of high doses recorded on special issue badges worn during the same period (see text)

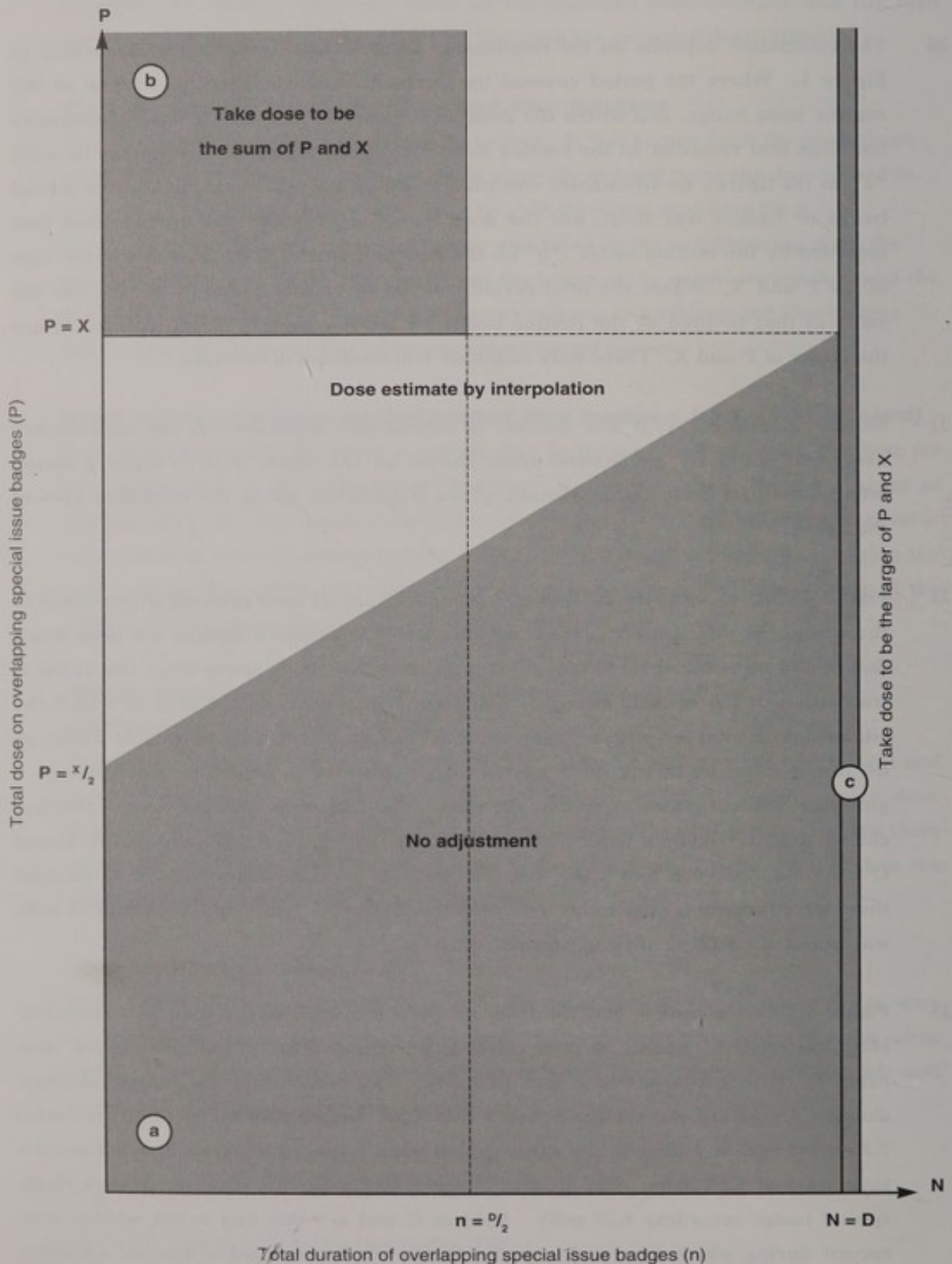


Figure 2

Comparison of the adjusted and as-recorded external radiation dose totals for the complete pre-conception periods

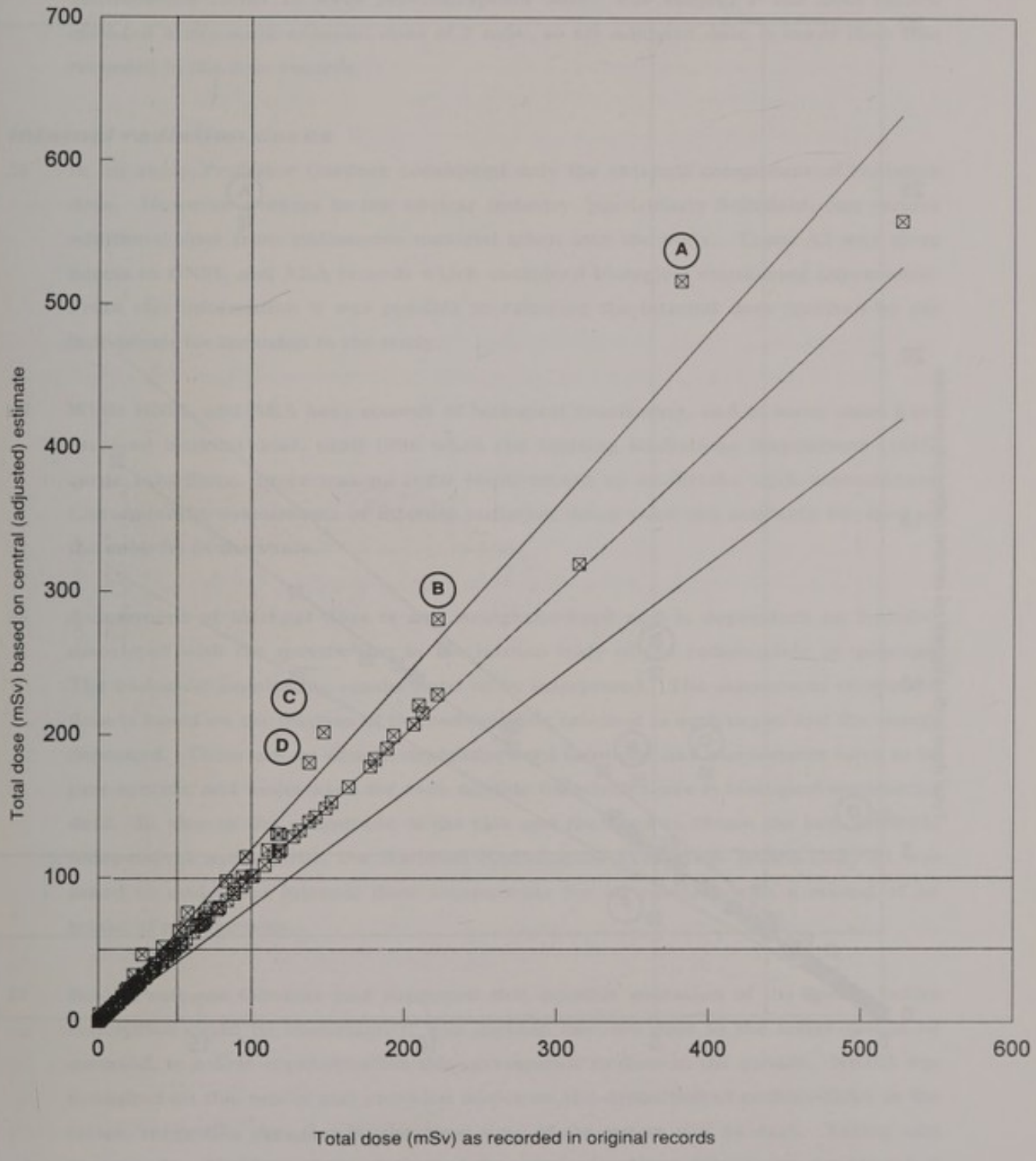
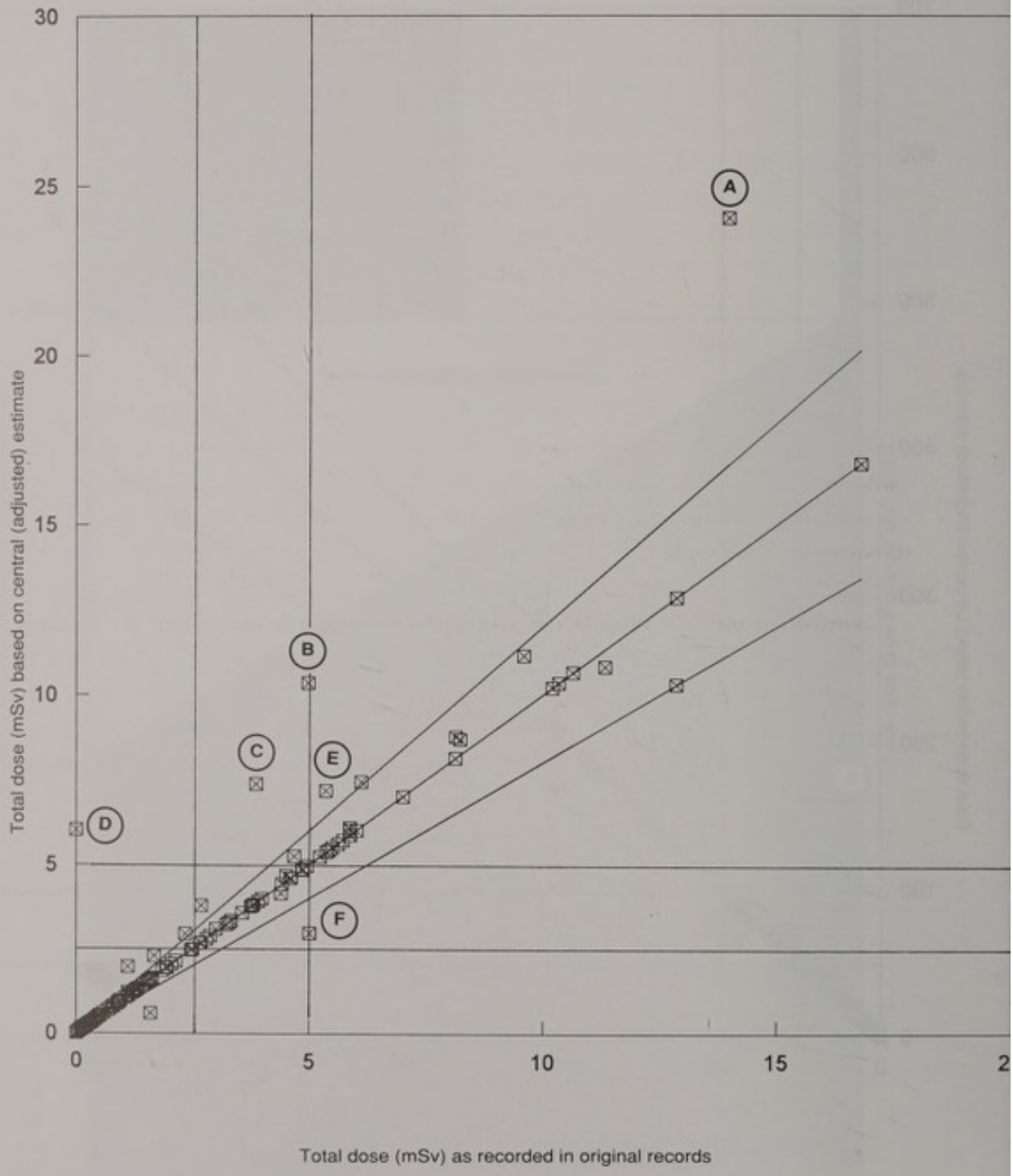


Figure 3

Comparison of the adjusted and as-recorded external radiation dose totals for the 12 weeks pre-conception periods



implied that his work in this period was similar to that in preceding and following periods. The 6 mSv is an imputed value. Subject E also had a 5 month gap partly overlapping with the 12 pre-conception weeks, leading to an imputed 0.27 mSv contribution to his 12 week pre-conception dose. For subject F the dose record included a two-week *notional dose* of 2 mSv, so his adjusted dose is lower than that recorded in the dose records.

Internal radiation doses

24 In his study Professor Gardner considered only the external component of radiation dose. However workers in the nuclear industry, particularly Sellafield, can receive additional dose from radioactive material taken into the body. Team A2 was given access to BNFL and AEA records which contained biological monitoring information. From this information it was possible to calculate the internal dose received by the individuals for inclusion in the study.

25 While BNFL and AEA have records of biological monitoring, and in some cases have assessed internal dose, until 1986 when the Ionising Radiations Regulations (1985) came into force, there was no legal requirement to undertake such assessments. Consequently, assessments of internal radiation doses were not available for most of the subjects in the study.

26 Assessment of internal dose is not straightforward and is dependent on features associated with the metabolism in the human body of the radionuclide in question. The biological monitoring results have to be interpreted. The assessment of internal dose is based on the fraction of the radionuclide retained in each organ and the energy deposited. There are no simple straightforward formulae and assessments have to be case-specific and undertaken for each nuclide for which there is biological monitoring data. In view of the magnitude of the task and the need to obtain the best available independent assessment, the National Radiological Protection Board (NRPB) was asked to undertake internal dose assessments for all subjects with a record of an intake of radioactivity.

27 Since Professor Gardner had suggested that possible mutation of the sperm before conception could be important, it was decided that the dose to the testes should be assessed: to a first approximation this corresponds to dose to the gonads. NRPB was consulted on this aspect and provided advice on the deposition of radionuclides in the testes, suggesting that the development time of the sperm was 64 days. Taking into account the objectives of the study and the range of radionuclides to be considered, it was agreed that the following assessments would be made.

(a) integrated dose from the date of start of work to the date of conception;

(b) dose in the 64 days prior to conception;

(c) dose in 365 days prior to conception;

(d) dose in each calendar year from the start of work to the year before date of conception.

28 The results of the assessments carried out by NRPB for each subject for whom there was any record of radioactive intake were provided to HSE. In addition NRPB prepared a full report of their work[3] which also summarised the main findings for dose distribution within the study population. In general the main contributor was plutonium.

29 In addition to the derivation of a numerical value of dose, work was undertaken to look at the range of uncertainties within the dose assessment. One particular aspect which was examined in some detail was variation in dose within the "sensitive" period prior to conception.

30 In order to define this period during which developing sperm may be exposed to internal ionising radiation prior to conception, it is necessary to have an estimate of the time taken for the process of spermatogenesis in the body of the testes and for the transport, maturation and storage of sperm in the epididymis.

31 Based on the work of other researchers,[3, 4, 5, 6] the range for the period of interest varies from 71 days at one extreme to 99 days at the other. On the basis of advice from a reproductive physiologist, a period of 84 days was chosen as the best estimate of the average duration. This is in the mid-point of the range and is equivalent to a period of 10 weeks for spermatogenesis and 2 weeks for epididymal transit. There will be uncertainties involved in the use of any single figure, and for practical purposes there will be no significant difference between the 84 days which we have selected and that of 90 days used in another similar study.

32 In view of the decision to use 84 days as the immediate pre-conception period of interest, the results for each of the study population were examined and the 64 day to 365 day ratio determined. This analysis indicated that the variation in dose for periods between these limits could, in all but one subject, be assumed as linear. The subject in question had been exposed to tritium, and for him, NRPB recalculated the dose for the 84 days prior to conception. For all other subjects, the 64 day dose was extrapolated linearly to calculate the 84 day dose.

Potential for exposure to chemicals

33 In addition to the main study of radiation doses to members of the workforce, HSE had also planned to undertake a study of chemicals in use on the site in the past. This was to see whether any of them might be related to the incidence of the observed cancers. This study covered both the BNFL and AEA areas of the Sellafield site. To undertake this work a separate team, Team C, was established: none of the members of this team had been involved in any other work associated with the studies.

34 The first task was to compile a list of appropriate chemicals, where they had been used, and to devise a ranking scheme to classify different levels of potential exposure to each chemical. A job history for each of the anonymous subjects was supplied by Team A2.

35 A starting point in identifying the chemicals was a list, provided in 1989 by BNFL to COMARE, of all chemicals present at Sellafield together with their International Agency for Research on Cancer (IARC) classifications. From this list were selected those substances with classifications 1, 2A, 2B and 3, ie ranging from "known carcinogen" to "suspect carcinogen". This selection was reviewed by an HSE toxicologist who added a number of chemicals used on site which had been either;

(a) identified as being worth further investigation by the members of Team A2 who had conducted the original Case-only Study; or

(b) identified by THSD as meriting further examination.

36 To be able to link a potential for exposure to chemicals to any individual in the study, the team needed to determine, as a function of time, between 1949 and 1991, the locations and methods of usage of each of the chemicals on the final list. Records which were searched in an attempt to build up this complex picture included:

(a) site archives - these held some data relating to radioactivity levels, but there was little information of use to this study;

(b) a manual of hazardous materials used at site, compiled in 1961, which gave some useful historical information about where various substances were used in the late 1950's;

(c) site incident database - by using as keywords the list of chemicals, approximately 100 incident reports were extracted. These were used to supplement information on the location of chemicals, and they also provided some indication of the method of usage.

37 Records of the location of chemicals, and method statements of how they were handled and used, from the mid 1970's to the present time were available. However the further back in time, the less data was available, other than those sources noted in the previous paragraph. Since its inception, the nuclear industry has monitored and recorded radiation doses and levels of radioactivity in working areas: in common with other industries, however, there has been little or no quantitative monitoring of the levels of chemicals in the working environment.

38 This general lack of quantitative data on chemical exposures restricted the exposure classification scheme which was finally arrived at. In deriving the ranking system, assistance was provided by Mr B Pannett, a member of the MRC Epidemiology Unit at the University of Southampton, who has had extensive experience of conducting studies into exposure to substances in the environment. Since prediction or knowledge of absolute exposure levels was going to be impossible, the ranking system concentrated on patterns of exposure for groups of workers doing a similar range of jobs.

39 A set of definitions was generated to enable job types to be ranked in probable exposure order.

Code	*Description*
1	Unexposed
	Some potential exposure with:
2.1	up to $^1/_3$ of such workers exposed;
2.2	$^1/_3$ to $^2/_3$ of such workers exposed;
2.3	more than $^2/_3$ of such workers exposed
3	All such workers exposed
4	All such workers heavily exposed
9	Exposure status unknown

The codes were assigned taking into account exposure control measures, such as the use of local extract ventilation or respirators.

40 It was decided that the most effective use of resources would be to identify each job type represented in the study and then to derive exposure rankings specific to that job. In addition to the original list of chemicals, it was decided to treat a number of other factors which were not readily quantifiable in the same manner. These were neutrons, alpha-in-air, tritium, polonium and beta/gamma-in-air. The objective was to include a judgement of exposure to these factors for which there was only sparse data in the records for the 1950s and 1960s. The overall list of chemicals and radiological factors is shown in Table 3.

Table 3

List of chemicals and other agents considered in the study

CHEMICAL	CHEMICAL or AGENT
Aniline	Solvents:
Anthracene	a. $(CHBr_2)_2$ (tetrabromoethane)
Arsenic (and Compounds)	b. CH_3CCl_3 (chloroform)
Benzene	c. $(CHCl_2)_2$ (tetrachloroethane)
Benzidine (and compounds)	d. $(CH_2Cl)_2$
Beryllium (dust)	e. $CHClCCl_2$ (trichloroethylene)
Butex/di-n-butyl ether (used/degraded)	f. CCl_4 (carbon tetrachloride)
Chromates/dichromates	Sulphamic acid
Formaldehyde/formalin	Thiophenyl - trifluoroacetone
Graphite dust	0-Toluidines
Hydrazine	Zinc and compounds
Hydrofluoric acid (HF)	Fast neutrons
Kerosene (used/degraded)	Other neutrons
Lead (dust/compounds)	Alpha (Pu etc) in air
Mercury	Alpha (U) in air
Phosphoric acids	Beta/gamma (only) in air
Picric acid	Tritium
Decontaminant type SDG3*	Polonium

* SDG3 is a proprietary decontaminant based on a mixture of decontaminating agents and sequestrants. It is supplied as a dry powder which is dissolved in water for use. The main constituents are Sodium sulphate, Citric acid, a detergent, and EDTA (ethylene diamine tetra-acetic acid)

41 It was also necessary to identify the jobs undertaken on site by the individuals in the study. The amount of relevant information varied considerably from case to case. For some individuals it was relatively straightforward to identify jobs and timescales quite accurately. In the majority of cases, however, only a resume was available in which the only information on a job was a BNFL cost centre number. and an abbreviated (and often generic) job title. A copy of the BNFL/AEA report on cost centre numbers. between 1951 and 1991 was available which enabled the numbers to be de-coded. However a significant proportion of the numbers were found to be invalid codes for the time period specified.

42 As the protocol precluded interviews with actual case or control fathers, the only effective way of progressing the study was through interviews with other BNFL/AEA

personnel and retirees, who were doing or had done similar jobs. Through their recollections it was possible to:

(a) obtain positive confirmation of whether or not a particular chemical had been in use at that time;

(b) determine the method and frequency of using/handling the chemical, and thus deduce the potential for exposure and the proportion of the worker group exposed at any one time;

(c) explore the likely radiological environment/s pertaining at that time; and

(d) clarify the unresolved cost centre numbers. by interpolation between confirmed jobs.

To reduce the amount of data which had to be collected and processed, it was decided to limit consideration of chemical factors to employment prior to the date of birth of each case child.

43 To set the study in motion, letters were sent to management and union representatives of both BNFL and UKAEA at Sellafield. These set out a number of reassurances:

(a) none of NII personnel involved in this phase of the work was aware of the names of any of the cases or controls;

(b) it was not the aim to criticise, or pass judgement on, working methods present or past, but rather to find out what potential there had been on site for exposure to certain chemicals and other factors;

(c) neither was it the aim to focus on particular individuals; volunteers were sought from the various job groups through line management;

(d) individuals who felt they had any knowledge of use to this study were invited to contact NII.

In addition it was agreed that contacts with ex-employees would be made only through BNFL/AEA management.

44 In some areas of the site where highly specialised or unique work took place, such as in some of the Research and Development laboratories, there was a strong likelihood that very few people had performed that task, even during a long period of time. Thus

during an interview with a representative jobholder, it was not possible to rule out the fact that the interviewee either knew or even was the case or control father. In order to cater for that eventuality, a cautionary statement was read out before undertaking an interview where such a discovery was deemed credible.

45 This cautionary statement was as follows:

"The objective of this part of HSE's Post Gardner Study is the investigation of environmental factors in the workplace (eg potential exposure to chemicals) since operations began on the Sellafield site. We are gathering information by conducting informal interviews with a number of current and previous employees who have personal knowledge of past working practices. The people we are talking to have been selected because of their knowledge of work in particular areas of the plant, regardless of whether they are among the 200 or so individuals covered by the study. The interviews are voluntary and confidential.

The HSE inspectors conducting the interview do not know the identity of the men included in the study. Nor do they know which individuals are "cases" and which are "controls". You have been selected for interview because of your knowledge of past working practices, and for no other reason.

During this interview it is possible that you may recognise someone in the study. You may even be that person yourself. If you do think you recognise someone, please do not reveal their identity to me or anyone else.

We appreciate that for some people this may be a very personal and sensitive issue, and we do not wish to cause offence to any member of staff. We would welcome your assistance in the interview, but if you do not wish to participate please feel free to withdraw at any time."

46 For each case or control father, and for each of his separately identifiable periods on a job, an exposure profile sheet was completed on the basis of information obtained by interview. These were conducted at Sellafield during September and October 1992.

47 The sheets were separately checked to identify:

(a) any time-period gaps in the data;

(b) any overlapping data which was inconsistent and needed resolution and;

(c) any misinterpretation of the job histories supplied to the interviewers.

48 A series of meetings were held between Teams C and D to resolve such problems. This resulted in a more coherent and consistent ranking of all job types and exposure levels. No attempt was made, however, to quantify any of the exposure levels so ranked.

49 Because of the lack of any direct measurement of individual neutron doses in the 1950s, and because of doubts about the completeness and consistency of such measurements across individuals in later periods, it was decided to combine this information with job history information to produce a qualitative classification of an individuals' job spells into one of 3 groups:

(a) Group 1: no exposure to neutrons, or where the information from Team B showed that neutron dose was a very small percentage of the X + gamma dose;

(b) Group 2: neutron exposure above group 1 levels, but below these where there was a potential for high neutron exposure;

(c) Group 3: high potential neutron exposure.

50 All individual job spells in the study were reviewed by a group drawn from Teams C and D, Team B providing some technical support for the group. The following information was considered:

(a) the period covered by the spell;

(b) the existence of recorded neutron monitoring for the individual during the spell;

(c) the total X+gamma and neutron doses recorded during the spell, and their ratio;

(d) the job codes assigned to the spell (see Table 5 in the main report);

(e) the job title which the man held during this period.

51 The potential neutron exposure coding was primarily determined by the job code. Spells with job code 16 (fuel plants) were coded as potentially highly exposed to neutrons, Group 3, with 11 exceptions where the job title suggested that neutron exposure potential was low. Job spells coded 7 (Windscale piles), 8 (Calder) or 18 (AGR-Advanced Gas-cooled Reactor) were coded to Group 2, with some 18 exceptions based on job descriptions. All other spells were coded as unexposed to neutrons Group 1 above, with the following exceptions:

(a) for spells in the period from 1960, where the information received from Team B showed that neutron dose was more than 3% of the X + gamma whole body dose during the period of the spell, and the X + gamma whole body dose was more than 2 mSv;

(b) for pre-1960 spells, where the job record (including annual staff reports where available), implied some neutron exposure potential. Four pre-1960 job spells fell into this category.

52 This categorisation of job spells was converted into 2 variables measuring the extent of each subject's potential neutron exposure; the variable NHI represented the number of days a subject had spent in job spells categorised as high potential neutron exposure. The variable NEUT represented the total number of days spent in job spells with any potential neutron exposure as described above.

53 Six fathers had non-zero monitored tritium exposure before their child's conception. One of these (a non-lymphatic leukaemia case) had been assessed as unexposed to tritium. This case was excluded from analyses of assessed potential exposure to tritium (variables TRI1 and TRI2). Three other subjects (all controls) had positive tritium monitoring data, and had been assessed as unknown tritium exposure potential. Analyses of ever/never tritium exposed (variables TEN1 and TEN2) were based on a combination of the measured and assessed tritium variables, and includes all four of these subjects (1 case, 3 controls)

REFERENCES TO APPENDIX 2

1 Burrows PI and Bevington LM: *HSE investigation of leukaemia and other cancers in the children of male Sellafield workers - uncertainties in the data extraction and translation of external dose records.* Report NII/R/08/93 (internal report)

2 Bevington LM, Burrows PI: . *HSE investigation of leukaemia and other cancers in the children of male Sellafield workers - external dose extraction and translation work* Report NII/R/20/93 (internal report).

3 National Radiological Protection Board. Contract Report: *Assessment of internal dose to subjects in the HSE Follow-up to Gardner Study.* NRPB-M389, March 1993.

4 Heller CG and Clairmont Y (1964): *Kinetics of the germinal epithelium in man.* Recent progress in hormone research. 20, 545-575.

5 Heller C and Clairmont Y (1963): *Spermatogenesis in man: an estimate of its duration.* Science 140, 184-185.

6 Robaire B and Hermo L (1988): *Efferent ducts, epididymis and vas deferens*: structure, functions and their regulation. In: The Physiology of Reproduction (Eds E Knobil, J Neill et al) pp 999-1080. Raven Press, New York.

7 Rowley MJ, Teshima F and Heller C (1970): *Duration of transit of spermatazoa through the human male ductular system.* Fertility and Sterility, 21, 390-395.

APPENDIX 3
Statistical methods, definition of variables and detailed results

Explanatory variables

1 Table A1 lists all the potential explanatory variables available within the study. The following paragraphs set out the underlying definitions and explain how the variables were constructed.

Demographic details

2 SEAS - Seascale resident at birth: this variable was assessed from the mother's (or, before April 1969 sometimes the father's) address as reported on the child's birth certificate. Having a Seascale resident family means that the address recorded on the birth certificate lay within the civil parish of Seascale.

3 JOBC - Job Class: records whether the father's occupation at the assumed conception date was industrial or non-industrial.

4 PCE - (Pre Conception Exposure). In workforce before child's conception: records whether the child's father had started work at Sellafield before the conception date of the child (assumed to be 266 days before the date of birth).

Factors related to child's and father's birthplace

5 The distance of the child's family residence at time of birth from the Sellafield plant was recorded by measuring distances from the centre of the Sellafield site to the birth residence. For this purpose birthplace was not identified to street level but to the next level up the postal address hierarchy. Thus all residence in, for example, Seascale or Cleator Moor, were assigned the same distance from the plant, measured to the centre of the place in question (as judged by eye) on the Ordnance Survey Map (1:50,000 scale).

6 In order to examine the suggestion by Kinlen[5,12], that population mixing can cause or promote the occurrence of childhood leukaemia, we recorded whether each father in the study was born in Cumbria or not (variable FBTH). This data was taken from birth certificates and from personnel records, and was available for all but 15 of the study subjects.

7 This classification of fathers was also used to construct a measure of the level of "immigration" in different groups of study population fathers. For this purpose the population was divided into 11 groups: 5 of these groups were the 5 main concentrations of birth residences (each represented by more than 10 study subjects): Seascale, Egremont, Cleator Moor, Frizington and Whitehaven. The other 6 groups

are made up of subjects with birth residences outside those 5 centres, divided into distance bands with cut points at the distances defined by the 5 main places previously named (3, 7, 11, 13.5 and 15 km respectively). The index of migration levels (variable MIGR) in these 11 areas was computed by taking the ratio of births to non-Cumbrian born fathers to those to Cumbrian-born fathers within each area.

8 The variables listed above do not depend on any choice of a relevant pre-conception period. All other variables in the study are time dependent in this sense, and have been evaluated either on the total pre-conception period, or in the 12 weeks prior to conception.

Measured or assessed radiation dose

9 XG - External Radiation (X- and Gamma): father's external radiation exposure as recorded in the workplace records of film badge monitoring. The dose estimates used in this study were compiled by going back to the original film badge records. See Appendix 2 for further details.

10 Variables HIDA and RMAX: were calculated from the film badge monitoring data to examine the possible effect of dose rate on the outcomes of interest. HIDA records the number of days covered by badges which recorded a dose rate of 0.5 mSv/day or more. This dose rate represents the 97th percentile of the dose rate distribution for the totality of badges worn (pre-conception) by the study population fathers and is over three times the rate corresponding to the current statutory annual dose limit (50 mSv). While HIDA measures extended exposure to high dose rates, RMAX records the single highest dose rate (mSv/day) on any badge worn by each subject.

11 NEUT and NHI - exposure to neutrons. Individual subjects' work histories were split into spells during which their job and work area were unchanged. A categorisation of work areas and jobs was developed (see below), and work spells were coded according to this breakdown. Four work areas were regarded as potentially giving rise to significant neutron dose: the Fuel plants; the Windscale Piles; the Calder reactors; and the Advanced Gas-cooled Reactor (AGR). Of these, the highest neutron doses would be expected in association with Fuel plants.

12 Taking account of this information, and of measured neutron exposure available on some individuals from the early 1960s, job spells were categorised as having none, some, or high potential neutron exposure. The variables NEUT and NHI, record the number of days spent by study subjects, in any job with potential neutron exposure (NEUT), or in a high potential neutron job (NHI). A fuller account of this coding is given in Appendix 2.

13 IT - total internal radiation. All available internal monitoring data for the study subjects were obtained and assessed by the National Radiological Protection Board (NRPB) (blind to case-control status), to calculate the internal dose to the gonads. Separate assessments were made for three pre-conception periods: total, one year and 64 days. Estimates for the 12 weeks prior to conception were made by interpolation (linear except for tritium).

14 IA - internal radiation dose from alpha emitters: the NRPB assessments were made separately for each radionuclide monitored. IA is that part of the total internal radiation dose delivered by alpha emitting radionuclides. Since the majority of internal dose estimated from the monitoring data was due to plutonium, IA and IT are very close for most subjects.

15 ITRI - internal radiation dose from tritium.

Workplace exposures

Coding of work histories

16 A database was created to record abstracted details of subjects' work histories. Five types of information were recorded.

(a) A history of jobs held, with (as available) job titles, cost centres and building numbers;

(b) Records of visits to the Medical Centre for decontamination after contamination incidents;

(c) A record of absences from work - either annual leave or sick leave - for each leave year;

(d) details of involvement in 'incidents' as recorded in the Sellafield incident database; and,

(e) A record of any medical restrictions on work in active areas.

17 This data was abstracted, keyed and then checked back against the original source to clear errors. The original dossiers were also reviewed a second time to ensure that all relevant information items had been abstracted. This data then formed the basis for two further exercises:

(a) A coding of work histories into 33 broad categories (see parageaphs 18 and 19);

(b) An assessment of individuals' exposure potential to a list of 35 exposure factors (paragraphs 20 to 22).

Work area/job

18 A categorisation of the main areas of the Sellafield site, and of the principal multi-area job functions was set up. The categories are listed in the final section of Table A-1. Individual job spells were coded to this categorisation. Wherever possible a unique work area code was assigned, but some work patterns imply presence in several areas, or the performance of certain general functions across most areas of the site. Depending on the kind of job, and the amount of detail available on the individual subject's work history, several work area/job codes might be applied to any job history spell.

19 When considered within the total pre-conception period, individuals were categorised according to whether more than 5% of their time (prior to the child's conception), was in spells coded to the area/job in question (variables PJ1 - PJ33). Over the shorter 12 week pre-conception period the variables JB1 to JB33 record the number of days (within the 12 week period) each subject was coded to the corresponding area/job.

Chemical and other exposure factors

20 Table A-1 also lists the chemicals and other exposure factors which were selected for assessment in the study. Appendix 2 gives the reasons for the choice of chemicals, and explains how these assessments were made. Potential exposure to these 35 chosen substances was rated on a seven-point scale:

1 - Unexposed

Some potential exposure with:

2.1 - Up to 1/3 of such workers exposed;

2.2 - 1/3 to 2/3 of such workers exposed;

2.3 - More than 2/3 of such workers exposed

3 - All such workers exposed

4 - All such workers heavily exposed

9 - Exposure status unknown

21. Each job history spell for each subject was separately scored according to this scheme. A cumulative exposure index was then computed by weighting the number of days with the "natural" weighting scheme: zero, 1/6, 1/2, 5/6, 1, 2 for categories 1 through 4 respectively. If any relevant part of a worker's history was scored 9 for some substance, then his exposure was regarded as unknown. Variables C1 to C35 record the weighted days exposure for each subject. Variables C29 and C30, recording assessments of potential neutron exposure were not used directly, but combined with

the available neutron monitoring data as described in paragraphs 11 and 12 above. For beryllium (C6), tetrabromoethane (C19) and polonium (C35), no subject was given a positive assessment. The number of informative exposure factors based purely on assessed potential for exposure is thus reduced to 30.

Extended assessment of potential tritium exposure

22 In the original assessment of chemical and other exposure factors, job spells were coded to unknown unless the assessor was confident that potential exposure to the substance in question would or would not occur. The nature of the available information on job histories meant that a relatively high proportion of job spells were coded unknown. For tritium, a total of 85 subjects (8 cases) had at least one job spell for which the potential tritium exposure was unknown. Although this data provides the best basis for an assessment of the possible effects of tritium considered on its own, it presents difficulties for the analysis of joint or modified effects of tritium and other factors. After assessed tritium exposure was found to show a significant positive association, a further assessment was therefore made of those spells that had been coded as unknown potential tritium exposure, to identify any such spells for which tritium exposure - although not ruled out by the available information - was much more likely to be absent than present. The number of subjects with unknown tritium exposure potential was reduced to 35 (6 cases). This second assessment was, of course, made blind to case/control status. The variables TRI1 and TRI2 record the original and extended assessment of potential tritium exposure.

Contamination incidents

23 If a worker becomes contaminated with radioactive material, they should attend the Medical Centre for decontamination procedures. Records of these decontaminations are kept, and record the levels of contamination found on different parts of the body, the kind of radioactive material involved, and details of the decontamination process, including information on whether the man in question was discharged completely clear of residual contamination or not.

24 The units in which these contamination levels were recorded were not always made explicit in the records. However, examination of the patterns of usage of the alternative units revealed a clear pattern: up to the end of 1958 39% of entries showed no units, and of those entries with units 94% used cpm (counts per minute); from 1959 only 4% of entries had missing units, and of entries with units 87% used cps (counts per second). This strongly implied a change in record keeping practices introduced in 1959, with cpm the standard unit up to that point and cps thereafter. We have therefore assumed that the units applicable to readings where the count unit is not explicitly stated are cpm up to the end of 1958, cps thereafter.

25 Information on these decontamination episodes for the study subjects was extracted and used to construct the following variables.

NDCN - the number of decontaminations.

NALP - the number of contaminations involving alpha emitters.

NBEG - the number of contaminations not involving alpha emitters.

HEAV - the number of "heavy" contaminations. A "heavy" contamination was defined as one for which the maximum activity count was more than 500 cps. This cut-off is arbitrary, and merely serves to divide the contamination incidents into a heavier and not so heavy group. The cut-off was determined by examining the data for a natural break point. This was done blind to case-control status.

CLEA - the number of incidents where the man was discharged with some residual contamination. Such incidents are rare: only 16 of the 323 recorded decontaminations in the study fell into this category. All but 3 of these occurred in the 1950s. None of them was associated with the Windscale fire.

Contaminating jobs

26 Workers will only visit the Medical Centre for decontamination when they know or suspect they have become contaminated, and although there are numerous safeguards to prevent a contaminated individual from leaving the site, some contaminations may go unnoticed. To assess whether men who have worked in jobs where contamination was most likely were more likely to father a leukaemic child, the frequency of contaminating incidents recorded in different job types was calculated and three categories of job were distinguished (see Table A-2). From this job categorisation two variables were computed:

CON1 - The number of days in a job in the highest contamination potential group;

CON2 - The number of days in the top or middle group of potentially contaminating jobs.

Windscale fire

27 FIRE - records whether an individual was noted in the Sellafield incident database (or elsewhere in available records), as having been directly involved in the Windscale fire or the ensuing clean-up operations. The variable IN57 records simply whether the individual was in the workforce on the date of the fire - 10/10/1957.

Grouping of cancer types

28 A COMARE working group proposed the following classification for childhood cancer cases for use in studies relating to the issue of radiation and childhood cancers.

A - Lymphatic leukaemia and non-Hodgkin's lymphoma
B - Other leukaemias
C - Hodgkin's disease
D - Brain and spinal tumours
E - Other cancers

Professor Gardner's West Cumbria case-control study covered cases in groups A and B combined. The numbers of cases in the present study broken down by the full categorisation above are 12, 4, 3, 4 and 9 respectively. In the results reported here three case groups have been used: group A of the above categorisation (sometimes abbreviated in what follows to LLNH); the combined groups A and B (abbreviated LNHL); and all other cancers (OCAN).

Statistical methods

Pre-conception variables

29 Analytical methods appropriate for study groups selected with different sampling fractions for chosen sub-groups have been described by Weinberg and Wacholder (The design and analysis of case-control studies with biased sampling. 1990, Biometrics 46, 963-75). Essentially, the method involves defining an additional variable which takes a value for each study subject which reflects the (relative) probability of their selection into the study group. This variable is then included a priori into all statistical modelling of the data. An adjustment of this kind is described as an "offset". The analysis of this data also needs to take account of the varying length of follow-up of individuals covered by the study. For example, a child born in 1950 will have had a full 25 years potential follow up, while one born in 1980 will have had around 10. A further complication is that for the period up to 1970 cancer registrations were not recorded on the NHS Central Register (which was the source for case ascertainment). Thus the probability of becoming a case is higher for those subjects whose follow up includes time after 1970 than for those with earlier follow up. These differences can be adjusted for in a similar way to the differences in selection probabilities, by defining a second offset reflecting, for each subject, the probability of their becoming a case (as defined for this study) during their period of follow up. These probabilities were calculated using national cancer death rates for the periods 1950 to 1970 and 1988 to 1990, and national cancer registration rates for the period 1971 to 1987. (When the NHS Central Register was searched to ascertain the cases for this study, cancer registrations for years later than 1987 had not been recorded). Follow-up for subjects whose fathers did not start work at Sellafield until

after their (the child's) date of conception, is only counted from their father's start date.

30 Although the details of the way the study population was selected are somewhat complicated, the basic structure is simple. The study population consists of all cases plus a known proportion of controls from the population of interest subject to two constraints:

(a) For cases the case details had to appear on the NHS Central Register; and,

(b) For cases and controls, there had to be sufficient detail in the surviving and locatable personnel records for fathers to be securely matched to the candidate subject children.

The study can be pictured either as a case-control study, or as a cohort study. The method of analysis used for all pre-conception variables was unconditional logistic regression. The GLIM computer package was used for this.

Accuracy of p-values

31 The p-values and parameter estimate standard errors calculated by the GLIM program depend on distributional assumptions which may not be accurate for very sparse data. In order to assess the extent to which the statistical measures produced on this data might be inaccurate we tested the accuracy of the GLIM assumptions by generating 1,000 replicate datasets for each of the main variables of interest, and compared the distribution of the 1,000 GLIM p-values produced with the distribution these p-values would take if the GLIM assumptions were correct.

32 The detail of these comparisons is given in the Technical Note at the end of this Appendix. The general outcome was that p-values for positive associations calculated on standard assumptions are not materially biased.

Expected case numbers

33 Since the control series for this study is sampled from the population of Sellafield-fathered children (subject to constraint (b), in paragraph 30 above) using a known sampling fraction, the comparison of cases and controls can be expressed in absolute as well as relative terms. That is, the control numbers, together with the known national rates, can be used to estimate an "expected" number of cases. Comparison of the observed number of cases with the number expected gives a direct measure of the absolute risk in the study population. The statistical significance of these comparisons have been calculated assuming that the expected case numbers are distributed proportionately to a Poisson variable with mean equal to the number of

controls, and that the case numbers follow an independent Poisson distribution with mean equal to the expected case numbers.

Analysis of post-conception variables

34 Different analytical methods are required for the analysis of post-conception exposure. This is because the exposures of interest - for example, father's involvement in contamination incidents - is changing through the observation period, so that without adjustment for differences in follow-up time, subjects with longer follow-up will have higher values for their workplace exposure measures than subjects whose follow-up is shorter. To adjust for these differences, each case needs to be compared to controls assessed at the same - or closely similar - age as the case at diagnosis. In this study, the post-conception exposures were examined by conditional logistic regression in 10 age-matched strata using the EGRET computer package.

35 As for the pre-conception analyses, an offset was fitted corresponding to the different selection probabilities across different control series categories. The offset reflecting the accrual of expected cases over time was not applied since in these analyses the age matching makes the equivalent adjustment.

36 The age-matched strata were created by examining the ordered ages of the cases at their first diagnosis and seeking groups within which the oldest and youngest case ages were within 10% of their average age. This led to 10 age strata with mid-points and case numbers as shown in Table A-3.

Stratification of control data

37 Control data was assembled within each stratum, for all the controls who had reached the mid-point diagnosis-age of the cases in the stratum set before the end of the follow-up period. Under this method a single control subject will usually contribute data to several strata, for example, the controls in set 10 will also be controls in sets 1-9. Consequently, the control data in different strata are not independent. This non-independence has no effect on the point estimates of logistic regression coefficients, but does affect the calculation of the standard errors of these estimates. There is no straightforward way of adjusting the standard error estimates for the non-indepence of the control data, but a comparison of the estimates and standard errors for pre-conception variables derived from the unconditional logistic regression (using GLIM), with those derived from the EGRET analyses, suggests that the impact of non-independence in this data is rather small. Table A-4 shows the ratio of GLIM and EGRET estimates and of their standard errors for six pre-conception variables. The average ratio of regression coefficients is close to unity (1.02), consistent with there being no effect on point estimates. The ratios of standard errors show a consistent tendency for the EGRET standard errors to be smaller than those from GLIM, on

average by 11%, with a range from 1% more to 25% less. In other words, the impact of the non-independence on the control data has been to lead to underestimates of the standard errors and thus to overestimates of the significance of any associations. We have not made any adjustment to the results reported below on account of this bias, but this tendency slightly to overestimate the statistical significance of associations has been taken into account in the interpretation of the data.

38 The variables examined in the post-conception analyses are those based on subjects' job histories and records of decontamination. In addition, the main pre-conception variables, which had shown significant effects in the GLIM analyses, were included, so that the estimates for these from the two analytical methods could be compared, and the joint effects of pre- and post-conception variables could be examined.

39 All the post-conception variables were evaluated from the child's conception to, either the date of diagnosis if the child was a case, or, if the child was a control, to the date the child reached the mid-point diagnosis-age of the cases in the matched set.

Results - univariate analyses

40 Tables A-5 to A-7 summarise the statistical strength of association between the three outcome measures LLNH, LNHL, and OCAN, and all potential explanatory variables, taken one by one. (Variables listed in Table A-1 for which no cases - of any diagnosis - had non-zero exposure are not shown). In these tables the strength of association is measured by the reduction in "deviance" achieved when fitting the variable in question to the data. When a fitted variable is treated as a continuous measure, this involves the estimation of one parameter: the increase (or decrease) in risk per unit increase in the listed variable. This is described as a reduction of 1 in the "degrees of freedom" of the data. When an explanatory variable is treated "categorically", as a grouping of the data, fitting this variable involves the estimation of a separate parameter for all but the first of the groups of the categorisation (the first group being taken as a baseline relative to which the increase or decrease of risk in the other groups is measured). Fitting an eight level factor thus entails the estimation of seven parameters, and a reduction of seven in the degrees of freedom.

41 Any variable fitted to data will reduce the deviance (and the degrees of freedom). The explanatory power of variable is judged by the extent to which the reduction of deviance for each parameter exceeds the reduction that would be produced by fitting an unrelated variable. This is measured by the p-value - also shown in Tables A-5 to A-7 - which records the theoretical probability that an unrelated variable would produce a deviance reduction as great or greater than that seen for the variable in question. Where the p-value is 0.05 or lower (the conventional boundary of "statistical significance") the entries are marked by a '+' (for positive associations), or a '-' (for

negative associations). A positive association is one in which a higher risk of being a case is associated with higher values of the explanatory variable. For grouped variables, significant differences among the sub-groups are indicated by a '*' unless there is also a significant trend across the groups, in which case they are marked '+' or '-' depending on the sign of the trend.

42 Continuous variables - such as external radiation dose - can be treated either continuously or in a grouped fashion. Treating these variables as continuous clearly uses the most detailed available information; and when this information is accurate, and the form of the relationship between the variable and the outcome can be accurately specified, this provides the most powerful treatment of the available information. When these conditions are not fulfilled however, treatment as a continuous variable may be misleading. In particular, individuals with extreme values of the variable may have an undue influence on the assessed significance of the variable. For this reason, all continuous variables have also been analysed in two grouped forms:

(a) in three groups: unexposed/exposed below average/exposed above average; (the two exposed groups made up of subjects with values above and below the median of all non-zero values on control subjects for the variable in question); and

(b) a two group version simply comparing the zero value subjects with positive value subjects.

The three main date variables, child's date of birth and father's dates of start and quit, were originally grouped in eight 5-year categories. These were also reduced to a 2-group version by seeking the most significant dichotomy of the original categorisation.

43 For all variables where any version showed a conventionally significant fit, and for other variables of particular interest, the fitted coefficients and their standard errors are shown in Tables A-8 to A-31. These are discussed in turn below, first for the two leukaemia end points, then for other cancers. A complete summary of the most detailed grouped analysis for each pre-conception variable is shown in Tables A-56 to A-58 for case groups LLNH, LNHL and OCAN respectively. Summaries of the post-conception variables are shown in Tables A-59 to A-61.

Leukaemia and non-Hodgkin's lymphoma

44 There is an overall statistically significant excess of leukaemia and NHL. The O/E ratio is 12/4.0 for LLNH ($p = 0.0021$), 16/5.8 for LNHL ($p = 0.00092$).

Patterns in time

45 The pattern of risk by child's date of birth (Table A-8) shows some tendency towards higher risk in the earlier periods, but without any strong trend. The most significant dichotomy of the eight time periods is at 1970, the risk in the earlier period being about double that for the period from 1970. In terms of the estimated absolute risk however, both periods show an excess: for LLNH, O/E = 3.86 before 1970, 1.80 after. This difference is not significant ($p = 0.20$). The pattern is similar for the wider leukaemia/NHL group.

46 There are stronger patterns for risk in relation to father's date of start at Sellafield (Table A-9). Again, the higher risks are in the earlier period. The most significant cut point is at 1965, and the comparison of the periods before and after this date is significant for LLNH ($p = 0.038$). The absolute excess risk is entirely concentrated in the period from 1950 to 1964: O/E = 10/2.25 for LLNH, 13/3.56 for LNHL.

47 A strong pattern is also seen for father's date of leaving Sellafield (Table A-10). Here the risk is seen in subjects who left the work force most recently (from 1975, or who are still employed). This comparison is significant ($p < 0.038$).

48 In relation to diagnosis date the highest rates are seen in the 1960s and 1970s. No LNHL cases were diagnosed before 1960 (Table A-11). Between 1960 and 1979 the O/E ratio was around 4 for LLNH and around 3.5 for LNHL. From 1980 the O/E ratio has been around 2. The variation between time periods is not statistically significant ($p = 0.32$ for LLNH, $p = 0.39$ for LNHL).

Father's age and birthplace

49 Father's age (Table A-12) shows a significant effect, due mainly to the fact that there are no cases among children born to fathers under 25. The risks for the two older fathers' age groups (25-34 and 35+) are similar. Father's own birthplace - a proxy marker of families who had moved into area from elsewhere - has no significant association . The excess of LLNH cases is very evenly shared between children of Cumbrian born and non-Cumbrian born fathers. Three of the four non-lymphatic leukaemia cases were children of non-Cumbrian fathers, and the odds ratio for LNHL in children of fathers born outside Cumbria is raised (1.87) but not significantly so ($p = 0.26$).

Seascale

50 Being a Seascale resident at birth is strongly related to the two leukaemia/NHL end points (Table A-12). The O/E ratio for Seascale births is over 14, significantly different from the rest of the population. This is not surprising, since part of the motivation for this study was a known cluster of cases at Seascale. An excess of

cases outside Seascale has not previously been suggested. The non-Seascale excess does not quite reach statistical significance: for LLNH the O/E ratio is 2.15 (95% CI 0.91 to 4.3, p = 0.078); for the wider case group LNHL the O/E ratio is 1.86 (95% CI 0.88 to 3.5, p = 0.10).

Distance from plant

51 Table A-13 and Figure 3 (in the main report) show the O/E ratio for LNHL cases for the 5 main population centres near the plant and the intermediate distance bands. Individually considered, only Seascale shows a significant excess. There are only 2 cases in the generally more sparsely populated bands between the main centres of population: one case in band 2 (3-7 km) and another in band 6 (greater than 15 km). If the bands and the population centres are ranked by O/E ratio the 5 population centres take the first 4 and the 6th positions. Even allowing for the fact that the expected numbers are generally higher for the population centres, and setting aside the very different figures for Seascale, this is statistically significant (p = 0.03 - assessed by comparing the observed data, excluding Seascale, with 1,000 random assignments of 10 cases to the 10 centres/bands with probabilities proportional to the expected numbers for the centres/bands). Aggregating observed and expected cases over the population centres other than Seascale gives an O/E ratio of 8/3.1 (2.56, 95% CI 1.08 to 5.3); in the intermediate bands combined, the O/E ratio is 2/2.3.

52 The data in Figure 3 shows some suggestion of a gradient by distance from plant, with the high value in Seascale close to the plant, and the most distant band having a ratio almost exactly unity. Figure A-1 accumulates the O/E ratios from the furthest bands inwards. The pattern now shown is of 2 step changes, first when the Whitehaven data is aggregated with band 6, the next when Seascale is reached. The successive values from Whitehaven (at 15 km) down to (but not including) Seascale (3 km) shows no real trend, though if there is a pattern it is one of decrease rather than increase.

Population mixing

53 Figure 4 (main report) shows the relationship of O/E ratio to migration index for the 11 population centres/bands. In Seascale there are $4^{1}/_{2}$ times as many births to non-Cumbrian born fathers as to Cumbrian born fathers. Outside Seascale the average ratio is 1:4 (in the other direction). The population centres seem to fall in a very convincing linear relationship, but the wide confidence intervals mean that, if Seascale is omitted, the correlation between O/E ratio and migration index is not significant. It remains non-significant if the analysis is restricted to the 4 population centres (other than Seascale). With Seascale included there is of course a strong association, effectively identical to that for residence in Seascale (since the migration index distinguishes Seascale from other places so distinctly).

Duration of pre-conception employment

54 The duration of the period from father's start at Sellafield to conception date (or his leaving Sellafield if this was earlier), is quite strongly related to outcome when measured as a continuous variable, but not in either grouped form (Table A-14, variable TIME). Subjects with zero TIME are those whose conception dates pre-dated their father's start at Sellafield. A total of 3 leukaemia/NHL cases fell in this category. None of these fathers were employed in the nuclear industry prior to their work at Sellafield. These 3 cases represent a 2-fold excess. This excess is not statistically significant - nor is it significantly different from the 3-fold excess for the 13 cases conceived after their fathers started work at Sellafield. Among those with some pre-conception TIME, the O/E ratio is about 2 for those conceived within 4 years of their father's start date, and rises to nearly 5 for those conceived more than 4 years from this date. These differences are not significant.

Variables relating to total pre-conception period

Measured radiation dose

55 Father's pre-conception radiation dose (Table A-15, variable XG) shows a rather similar pattern to the previous variable, and is in fact quite highly correlated with it. It is significant fitted as a continuous variable, but not grouped, and the three group version presents a non-significant J-shaped pattern for LNHL, and a non-significant positive trend for LLNH. For comparison with the Gardner report, Table A-15 also shows the data grouped by the exposure categories used in that report.

56 One of the two variables measuring subjects' exposure to high dose rates (HIDA - the total monitored days covered by film badges showing an average dose rate greater than 0.5 mSv/day) shows a just significant positive association in its continuous analysis (Tables A-5 and A-6). This variable is strongly correlated with total radiation dose (XG), and this association disappears after controlling for XG. No other measure of radiation dose shows significant effects.

Chemicals

57 Exposure to used/degraded butex (Table A-16) shows a significant effect in its three group version for LNHL, with three cases in the highest exposure group, though there is no significant or consistent trend. The comparison of the highest exposure group against the lower two is not quite significant ($p = 0.064$).

58 Exposure to chromates and di-chromates (Table A-17) is significant as a continuous variable (and in the three group version for LNHL, but not for LLNH). Examination of the details of the three group model shows that for LNHL there are four cases in the top half of the exposure distribution, giving a significant odds ratio of 5.34. Two of

these cases are non-lymphatic leukaemias and this exposure does not show a significantly raised risk for the more restricted diagnostic group LLNH.

59 Fomaldehyde/formalin exposure shows a strong effect treated as a continuous variable, but this is due entirely to one case with an extreme value on this variable. Hydrofluoric acid is significant as a continuous variable for both leukaemia end points, but this association disappears when the data are grouped. The three group data does not show a consistent trend for either cancer type. Exposure to picric acid is positively and significantly related to the leukaemia end points but only in its continuous analysis. Only one case has non-zero exposure to this substance. The just significant association shown for exposure to zinc and its compounds is a negative one.

60 Exposure to trichloroethylene is significant for LNHL only, in its three grouped version (Table A-18) and shows a significant positive trend (p=0.035). This association is produced by the presence of eight of the 10 cases in the top half of the exposure distribution. The pattern of risk across the three categories does not show a consistent trend but the comparison of the top half group against the two other groups is significant (p = 0.011).

61 Exposure to TTA (Thiophenyl-trifluoro-acetone) shows a significant effect in its three group version for LNHL (Table A-19). This is produced by the three cases in the highest exposure group for which there is a significant 10-fold OR.

62 For tritium (Table A-20) there is a strong positive relationship both for the continuous measure and both grouped measures, and there is a highly significant positive trend (p=0.0018) in risk for the three group analysis.

Actual and potential contamination

63 There is some indication of a positive association with numbers of contamination incidents (Table A-21). Children of fathers with at least one beta/gamma contamination have an odds ratio of 3.2 for LNHL (combining the two positive groups shown in the table) compared to children of fathers with no such contaminations (p = 0.04), and there is a weak positive trend in the three-group analysis of total decontamination visits, though this is not significant (p = 0.08 for LNHL). The significant (p = 0.02) positive trend for LNHL cases with numbers of "not clear" contaminations is based on only 2 cases.

64 The variables related to time spent in contaminating jobs also show no consistently significant effects (Tables A-22 and A-23). The three group version of CON2 (Time in

any contaminating job) is similar for both leukaemia diagnoses, with the strongest effects seen for LNHL (p = 0.026). However the OR estimates do not show a consistent trend: the middle exposure group having a very low OR, and the highest exposed group a moderately raised OR. The fact that the two group version for this variable shows no effect whatever, and that CON1 (Time in most contaminating jobs), also shows no effect, suggests that no strong interpretation can be placed on these patterns.

Job history

65 Only one work area variable showed a significant effect: working in the Calder area is significantly and positively related to both leukaemia end points (Table A-12). All five cases are of lymphatic leukaemia and the odds ratio for this diagnosis is 12.6 (95% CI 3.24 to 49.2).

Twelve weeks pre-conception exposures

66 Many of the variables considered have a little discrimination when assessed over the 12 weeks pre-conception exposure period: the range of possible values for continuous variables is restricted, and most exposure factors become rare. None of the positive associations that appear are based on more than two cases. Measured internal dose from tritium (Table A-24) shows a positive association (p = 0.005) based on one non-lymphatic leukaemia case. The corresponding grouped analyses do not show significant effects. In the two-group analysis the odds ratio for exposure to tritium is 6.76 (95% CI 0.41 to 110). Exposure to hydrofluoric acid shows a positive association (p = 0.051), and the two cases exposed show a significant positive trend over the three exposure groups (p = 0.046). Both these cases are lymphatic leukaemias (Table A-25). The high p value for the three-group analysis of picric acid (p = 0.0001 for LLNH) is generated by a single case in the top half of the exposure distribution with no corresponding controls. When the two positive exposure groups are combined the comparison is non-significant (p = 0.28) (Table A-26). Exposure to TTA also shows a signficant result in its continuous version based on one lymphatic leukaemia and one non-lymphatic leukaemia. The three-group analysis, its trend, and the two-group analysis are all non-significant (Table A-27). Exposures to graphite dust and zinc show nearly significant negative associations for both leukaemia end points, as does exposure to mercury for LNHL.

Post conception exposures

67 The data for leukaemia/NHL cases and post conception exposures are shown in Tables A-59 and A-60. For LLNH cases the number of decontaminations involving alpha emitters shows significant association with risk (p = 0.019) (in the post conception period). This result is based on a single case who had 6 decontamination incidents, all of them involving alpha emitters. Working in the high level waste area (PJ4) gives a

close to significant result for LLNH (p = 0.053), but not for LNHL (p = 0.11). Two LLNH cases worked in this area. There is a nearly significant association for total decontaminations with LLNH cases, and the crude ORs (not age-matched), show a consistent trend to 3.7 for subjects with 1 to 5 decontaminations, and 19.8 for subjects with more than 5 decontaminations (one case and one control). The tendency for over-estimation of significance levels in these analyses (paragraph 37) should be borne in mind here.

Other cancers

68 In contrast to the leukaemia/NHL analyses, the associations seen for other cancers are fewer and generally less marked. Overall, in absolute terms, there is a slight excess of observed over expected cases (16/12.1 p = 0.34). In relation to child's date of birth and father's date of start at Sellafield, there is a hint of the pattern seen for leukaemias, with slightly higher rates for subjects with earlier dates on both variables (Table A-28). However the strongest two-group contrasts for OCAN do not have the same cut-off as for the leukaemias. Also, for OCAN it is the two-group contrast for child's date of birth which is (just) significant while the father's date of start contrast is far from being statistically significant. For leukaemias the situation was reversed. There is no indication of any systematic variation in risk by diagnosis date.

69 Table A-29 shows the data for selected variables of interest. For sex there is a slight, non-significant excess of female cases. Father's age shows no particular relationship. Only one OCAN case had a Seascale resident family. Father's birthplace gives a near significant association (p = 0.053), with a raised OR for children of non-Cumbrian born fathers (3.0; 95% CI 0.94 to 9.33).

70 Table A-30 shows the data for other cancers by place of birth. None of the individual population centres or the intermediate bands stands out. In particular, there is no excess for Seascale: one case, 0.85 expected. No trend in relation to distance from the plant is shown. A comparison of population centres with the intermediate bands shows that for the population centres together there is a just significant excess O/E = 1.92 (95% CI 1.03 to 3.4, p = 0.042). There is a non-significant deficit of cases in the intermediate bands O/E = 0.42 (95% CI 0.05 to 1.6, p = 0.31).

Cumulative pre-conception exposures

71 External radiation shows a significant (p = 0.022) J-shaped relation for other cancers with raised rates for those exposed below the median (33 mSv), and low rates for the highest exposure group (Table A-29). The two OCAN cases whose fathers had Calder jobs represent a slight excess, but this is far from being significant. No OCAN case father was assessed as having exposure to tritium.

72 The two variables measuring father's time in contaminating jobs (CON1 and CON2) are negatively associated with OCAN, significantly (p = 0.015 for continuous analysis - Table A-7) for CON2 (Time in any contaminating job).

73 One job variable - PJ17, work in Windscale Nuclear Laboratories - is significantly (p = 0.024) and positively associated with outcome OCAN. The two cases represent an OR of 13.0 (95% CI 1.84 to 92.1).

Twelve week pre-conception exposures

74 Among the 12-week pre-conception exposures, benzene shows a nearly significant positive association. There are 2 exposed cases. Exposure to graphite dust also shows a significant relationship (Table A-31). Two cases have this exposure and the two-group analysis shows an OR of 10.3 (95% CI 0.82 to 129). The three-group analysis shows an increasing trend (p = 0.02) across the three groups.

Post-conception exposures

75 Both total decontamination incidents (p = 0.025) and the number of contaminations involving beta/gamma emitters (p = 0.003) are positively associated with the occurrence of cancers other than leukaemia and NHL (Table A-32). No father of an "other" cancer case was involved in contamination incidents with alpha emitters. Five fathers of children with "other" cancers had at at least one contamination incident, and three of these had more than five. Ignoring the age matching, the crude odds ratio for subjects with 1-5 and more than 5 contaminations are 0.82 and 17.2 respectively. The association is entirely due to the three cases with more than 5 contamination incidents.

76 The number of "heavy" contaminations also shows a nominally significant association (p = 0.046), though allowing for the slight overestimation of significance levels in the post-conception analyses referred to above (paragraph 37), this would not be a significant association. This association depends on the same 3 cases.

Age at diagnosis

77 Table A-33 shows a breakdown of each case group by age at diagnosis (up to/from age 15). The leukaemia/NHL cases fell very distinctly into two groups by age. The oldest case diagnosed before age 15 was aged $7\frac{1}{2}$. For these cancers, the O/E ratio is very similar for the younger and older cases. For other cancers, the O/E ratio is somewhat raised for the older age group, but not significantly so (p = 0.18).

78 Table A-34 shows a breakdown of the older LNHL cases by selected variables. The patterns are similar to those seen for all cases in respect of Seascale residence, Father's pre-conception radiation dose, date of start, potential tritium exposure and

child's date of birth, though the small number of cases means that none of these associations are significant on the older cases alone. The older cases do not contribute to the association with Calder.

Multiple comparisons

79 In a study of this kind, where many possible explanatory variables are examined, it is to be expected that some of these variables will show positive (or negative) associations simply by chance. Under these conditions the statistical associations which emerge cannot be interpreted as they would be in an experimental or strictly confirmatory study examining a single *a priori* hypothesis. Some assessment has to be made to decide whether the stronger associations observed reflect real associations for which further explanation should be sought, or simply happen to be the strongest associations among the large number of variables examined.

80 The data shown in Figure A-2 compare the p-values arising from fits of the 31 area/job factors to the 3 outcome variables LLNH, LNHL and OCAN with the 31 p-values that would be expected to arise from fitting 31 randomly generated variables with no association to each outcome. The quantities plotted are the logits of the p-values, since this transformation spreads out small p-values and enables differences at the ends of the p-scale to be seen. There are 31 informative job factors since for two job codes - THORP and Changerooms - no subject had any pre-conception job spells.

81 If all the exposure factors examined were unrelated to outcome the 31 plotted points should lie close to the straight line shown on each graph. The p-values in these graphs represent, for each variable, the probability that a truly unrelated variable would generate a more negative association than that observed for the variable in question. Thus variables for which the observed relationship is strongly negative produce p-values close to zero (because it is very unlikely that an unrelated variable would produce a more negative effect), and the corresponding logits are negative. Conversely, variables with strong positive relationships have p-values close to 1, and large positive logits.

82 Only one observation falls well away from the expected line on the positive half of the scale. This is the Calder job factor, which is, by a considerable margin, the most significant positive area/job association both for LLNH and LNHL. The observed point for other cancers (OCAN), all lie quite close to the expected line.

83 Figure A-3 shows similar plots for fits of the 30 assessed exposure factors to case type LLNH. The 4 charts in this figure show the results for 4 alternative measures of these factors: the continuous measure (weighted days exposed); the 3-level factor; the trend across these 3 groups; and the 2-group dichotomy (ever/never exposed). The

most extreme positive points in all these charts relates to assessed tritium exposure, and 2 alternative positions are shown for this depending on whether the original or extended assessment of potential tritium exposure is used (see paragraph 22).

84 The tritium point lies fairly clearly away from the expected line on all 4 measures. Four other exposure factors (formaldehyde, chromates, hydrofluoric acid, picric acid), also lie well away from the line for their continuous measure, but not on any other measure.

85 Considered as the maximum of around 30 similar variables examined, the 1-sided Calder p-value increases from 0.0003 to 0.001. The equivalent adjustment on the tritium associations bring the p-value for the continuous measure up from 10^{-6} to 3×10^{-5}, and for the trend and the 2-group measures from 0.001 to 0.03. Seen thus in the context of the many potential explanatory variables that have been examined, these two factors still appear statistically significant by conventional criteria, though arguably only marginally so for tritium on the more robust group measures of association. Nevertheless, it is clear from Figures A-2 and A-3 that these two factors stand out from all the other job and exposure variable examined.

Multivariate analyses

86 The small numbers of cases available for analysis restricts the extent to which the many possible patterns of association between the outcome variables and the potential explanatory variables can be distinguished statistically. The discussion in the previous section identified Calder and potential for tritium exposure as showing particularly strong associations. One other chemical exposure factor also seems worthy of closer examination: exposure to trichloroethylene, when expressed as a contrast between subjects exposed above and below the median (450 weighted days). Tables A-35 to A-49 show the results of joint analysis of the leukaemia/NHL cases with all possible pairs of the following variables:

SEAS - Seascale residence at birth;
XG4V - Father's pre-conception radiation dose (four groups, scored 0, 20, 70, 175 for groups with zero, 0.1 to 49, 50-99 and 100+ mSv respectively);
TEN2 - Ever/never potentially exposed to tritium (extended assessment);
PJ8 - Working on Calder (more than 5% of time);
LDOS - Father's date of start (up to/from 1965);
C23 - Potential exposure to trichloroethylene (<=/>450 weighted days)

The modified version of the external dose variable was chosen to reduce the effect of the single case father with a pre-conception dose of over 500 mSv, who otherwise determines the analysis. The group scores are the mean control values for each group.

87 Each table shows first the extent to which the explanatory power of each variable overlaps with the other. Where this is the case, the Likelihood Ratio (LR) test for each variable will be lower (and the corresponding p-value higher), when the variable is fitted after controlling for the other variable in the pair. For each pair of variables the significance of their interaction term is also tested. A significant interaction implies that the effect when the factors measured by each variable both apply is significantly different from that predicted by a simple addition of the two effects. The second section of each table shows the parameter estimates and standard errors for the models of interest. The parameter shown is the log of the odds ratio (for XG4V this is the average increment in the log odds for each mSv increase). The third section of each table tabulates the observed and expected cases and their ratio, jointly for the two variables. These tabulations show the numbers of subjects whose status was unknown on either variable. The fitted models are based on those subjects who had non-missing values for both variables of the pair. The data described above is shown separately for case types LLNH and LNHL.

88 Table A-35 shows the joint analysis of Seascale and external radiation. The fit of each variable is unaffected by the presence of the other variable in the model, but there is a significant interaction term ($p = 0.009$). Examination of the parameter estimates and standard errors for the full two variable model (model no. 4) shows that the interaction term is the only significant term in the model. The data for observed and expected cases by Seascale residence and external dose in the final section of Table A-35 shows why this is so. For the non-Seascale subjects there is no apparent effect of external radiation (if external radiation is analysed as a continuous variable, a single non-Seascale case father with an XG value over 500 mSv generates a just significant positive association). In contrast, for Seascale subjects, the four cases all fall in the upper two exposure groups, and are greatly in excess of the expected numbers. The data for the wider case definition LNHL are very similar, all six Seascale cases have XG values over 50 mSv, generating an even stronger interaction ($p = 0.0004$).

89 The joint analyses of the Seascale variable with the Calder, tritium and trichloroethylene variables are shown in Tables A-36 to A-38. These all show independent effects, and no interactions. The cross tabulation of data by Seascale birth and fathers date of start (Table A-39), shows that there are no Seascale cases whose fathers started work in 1965 or later.

90 The joint data for Calder and external radiation are shown in Table A-40. The Calder factor has a strong effect, not greatly influenced by the presence or absence of external radiation in the model. There is a nearly significant interaction ($p = 0.071$ for LLNH, 0.059 for LNHL) reflecting a positive association between XG and leukaemia for non-Calder subjects, in contrast to a negative association for Calder subjects.

91 Table A-41 shows some overlap between the external radiation and tritium effects. For LLNH the p-value for an XG4V effect is 0.17 on its own, 0.51 after adjusting for potential tritium exposure.

92 Table A-42 shows the joint analysis of external radiation and potential trichloroethylene exposure. The stronger associations are seen for case group LNHL. There is some overlap of effect between these variables, with the p-value for XG4V rising from 0.19 on its own to 0.57 after adjusting for potential trichloroethylene exposure. There is also a nearly significant interaction ($p = 0.08$), reflecting a weak negative association between XG and leukaemia for subjects with the longest periods of potential trichloroethylene exposure, compared with a weak positive association for other subjects. A similar pattern is seen for the analyses of the more restricted case group LLNH, for which the main effects of these two variables are less marked, and their interaction stronger ($p = 0.046$).

93 Table A-43 shows the joint analysis for external radiation and father's date of start. There is no evidence of any positive association with external dose for cases whose fathers started in 1965 or later. If an interaction term is fitted, the XG4V coefficient for the later period is negative, though not significantly different from zero. The picture is similar for both case groups, though the associations are stronger for the wider (LNHL) group.

94 Table A-44 shows the joint analysis of Calder and tritium. The effects are independently significant, and there is a strong interaction due to the very high O/E ratio (2/0.01 for LLNH) for subjects who are positive on both factors.

95 Table A-45 shows the joint analysis of Calder and potential trichloroethylene exposure. The enhancement of the significance of each variable in the presence of the other is due to the fact that when both variables are fitted, the baseline cell (not exposed to trichloroethylene and not working on Calder) contains no cases, and the odds ratios in other cells in relation to this are therefore theoretically infinite.

96 The data in Table A-46 shows that the Calder and father's date of start effects are completely independent.

97 The data in Table A-47 shows that there is substantial overlap between the effects of potential exposures to tritium and trichloroethylene. For case group LLNH the tritium effect is the stronger of the two, taken singly ($p = 0.009$, compared with $p = 0.026$ for trichloroethylene). The significance of each variable is removed by the presence of the other in the model - marginally for tritium ($p = 0.053$, controlling for trichloroethylene), clearly for trichloroethylene ($p = 0.17$, controlling for tritium).

A similar picture is seen for case group LNHL, though here trichloroethylene gives a slightly stronger association which remains significant after controlling for tritium. The reason for this strong overlap is clear from the tabulated data. All the positive tritium cases lie in the group with longer periods of potential trichloroethylene exposure.

98 Examination of the joint effects of tritium and father's date of start (Table A-48), shows the effects to be independent. The tabulated data shows that there are no positive tritium cases among the subjects whose fathers started work in 1965 or later. The tritium association is therefore expressed entirely in the subjects whose fathers started before 1965. The small numbers in the later period mean that an equivalent tritium effect in this group can not be ruled out, but if the (non-significant) interaction term is included in this model, the tritium effect for later starters is, of course, negative.

99 The determining feature of the joint analysis of trichloroethylene and father's date of start is that there are no cases with known trichloroethylene exposure status and with fathers who started in 1965 or later (Table A-49). Consequently the father's date of start variable shows a spuriously strong effect in these analyses (spurious, because it is produced by the implied zero risk for subjects with father's start date in 1965 or later).

100 The cross tabulation of data by father's date of start and child's date of birth (Table A-50) shows, as might be expected, a substantial overlap between these factors. All but three of the cases are either "early" on both variables or "late" on both variables. More than 90% of the expected cases fall into these categories also, so there is very little basis for discriminating between the two effects. Taken singly, father's date of start gives the stronger association, and this difference is due to the two cases with dates of birth before 1970 and fathers' dates of start after 1965. Both these cases are lymphatic leukaemias and give an O/E ratio of 14.8 for this cell of the cross-tabulation.

101 Table A-51 shows a cross tabulation of Seascale residence at birth by father's place of birth. For the wider case group there is some suggestion that, within Seascale, there are higher rates for the children of non-Cumbrian born fathers than for Cumbrian born fathers, though the rate for the latter are still substantially raised (based on a single case). For subjects not resident at birth in Seascale, the rates are - very slightly - higher for the children of Cumbrian born fathers. However, these contrasts are very far from statistical significance ($p > 0.5$ for the interaction term in the full model for SEAS and FBTH).

102 Because of the distinct nature of the results for Seascale, all the univariate analyses were repeated on the Seascale-born sub-set of the data alone. None of the variables explained or materially reduced the strong association with cumulative pre-conception dose. Two variables did show independently significant effects after controlling for cumulative dose: the 12-week pre-conception dose, and the number of pre-conception decontamination visits. For both variables the associations are significant only for the wider case group (LNHL).

103 Table A-52 shows the joint analysis of 12-week pre-conception dose and Seascale residence at birth for the whole population. For LLNH, 12-week pre-conception dose does not show a significant association, and although the O/E ratios for Seascale subjects by 12-week dose category show a consistent upward trend, this is not statistically significant ($p = 0.18$). For the wider case group (LNHL) the pattern is generally similar, but with two additional Seascale cases in the top 12-week dose group, the positive trend with 12-week dose for Seascale subjects is now significant ($p = 0.005$). There is no such trend for the non-Seascale subjects, and the difference between Seascale and non-Seascale subjects is clearly significant (interaction $p = 0.0059$). It should be noted that one of the case fathers in the top 12-week dose group has all his 12-week dose imputed (see Appendix 2, paragraph 23). Without this case the 4-group trend for Seascale subjects is not significant ($p = 0.31$), and the interaction term is just significant ($p = 0.046$).

104 Table A-53 shows a similar analysis for Seascale and decontamination visits. For LLNH the number of decontaminations (measured as a continuous variable), is only significant in interaction with Seascale ($p = 0.031$). The grouped data shows a J-shaped pattern for non-Seascale births, and an upward trend for Seascale (though with no cases or controls in the top group - more than two contaminations). The trends for this grouped data are non-significant. For the wider case group (LNHL), the association with number of decontaminations is strengthened for the Seascale subjects. The interaction term is now highly significant ($p = 0.00046$), and the difference between the O/E ratio for Seascale subjects with and without decontamination incidents is significant ($p = 0.0071$).

105 Table A-54 shows the analysis of leukaemia/NHL cases in Seascale subjects alone, jointly by father's cumulative and 12-week pre-conception dose. For LLNH cases only cumulative dose shows a significant association. For the wider case group (LNHL), cumulative dose gives much the strongest association ($p < 0.00001$), but the 12-week dose is also (just) statistically significant ($p = 0.047$) with or without controlling for cumulative dose. Both measures of dose show a positive association. If the data for both variables are dichotomised (cumulative at 50 mSv, 12-weeks at 2.5 mSv) all the cases have cumulative dose above 50 mSv, and within this higher cumulative dose

groups there is a significant contrast ($p = 0.033$) between those with 12-week doses above and below 2.5 mSv. Without the imputed dose case referred to above (paragraph 103), none of these contrasts is significant.

106 A similar joint analysis for cumulative dose and total pre-conception decontaminations for Seascale subjects only is shown in Table A-55. As continuous variables both are independently highly significant ($p < 0.00001$ for cumulative dose; $p = 0.0002$ for number of decontaminations) for LNHL cases. When both variables are dichotomised, the contrast of those with and without recorded decontaminations within the higher cumulative dose subjects is not significant ($p = 0.13$). The pattern of associations is similar for LLNH cases, but with weaker effects for the decontamination variable.

Technical Note: Accuracy of p-values

The accuracy of the standard distributional assumptions underlying the calculation of p-values and standard errors from the GLIM logistic regression analysis was assessed as follows, taking the external radiation variable (XG) as an example. 1,000 replicates of the data were randomly generated. For each of the 1,000 replicates, XG values for the 12 LLNH cases were chosen at random from the 191 study population values (179 controls plus 12 cases), with probability proportional to the expected cases generated by each subject (that is, the subjects were weighted inversely by their selection probabilities, and proportionately to the expected case incidence over their follow-up time). The association between the probability of being a case and XG was then estimated for each replicate using GLIM, and the deviance change, sign of association, and p-value (assuming a chi-square distribution for the deviance change) were recorded. The replicates were then ranked from the most significant negative association, through non-significant associations to the most significant positive association. For each replicate a quantity P_{neg} was calculated as follows:

$$P_{neg} = \begin{cases} 1 - P_{GLIM}/2 & \text{for positive associations} \\ P_{GLIM}/2 & \text{for negative associations} \end{cases}$$

In words, P_{neg} is the probability of that unrelated variable would produce a more negative association than the one being tested. The P_{GLIM} value is halved in these formulae since deviance changes do not distinguish between positive and negative associations, and in this analysis they are treated separately. If the chi-square distribution assumption holds P_{neg} will be uniformly distributed on (0,1), and the expected value for the r-th P_{neg} value will be r/1001. Since we are primarily interested in the ends of this distribution, we use the logit transformation and plot logit P_{neg} against logit r/1001 for the 1000 replicates. Figure A-4(a) shows this plot. For all but the most extreme replicates there is very close agreement between the theoretical and empirical distributions. At the lower end the plot starts to turn downwards from the theoretical line at about logit = -4 (corresponding to negative associations with p = .02 and lower). At logit p = -5 (p about 0.007) the observed points depart very distinctly from the theoretical line, indicating that with the distribution of XG values in this population - and with 12 cases - negative associations producing large deviance shifts are less rare than predicted by the chi-square distribution. At the upper end of the plot the observations also drift away from the theoretical line, though much less markedly. The implication here is that large deviance changes for positive associations are less easily achieved than predicted by the chi-square distribution.

In other words, the p-values derived from GLIM under standard assumptions will slightly understate the significance of positive relationships with p-values less than about 0.01.

Figure A-4(b) shows a similar plot for the 3-group measures generated from the replicates analysed as continuous variables in Figure A-4(a). Since for a grouped analysis the concept of positive and negative association is not automatically meaningful, this plot shows only positive logit values. The values plotted are -logit ($P_{GLIM}/2$) and -logit (r/2002). This plot suggests that the GLIM p-values (2-tailed) in the range 0.04 to 0.001 are too small, but this does not affect the interpretation of the present data as there was nothing approaching a significant relationship for XG in its grouped version. Figure A-4(c) shows the results for tests for trend on the 3-group data. The theoretical and empirical values are in good agreement except for the most extreme negative associations. Figure A-4(d) shows the corresponding data for Ever/never exposed categories for XG. The theoretical values fall in blocks, since the analysis is determined by the number of cases ever exposed and there are only 13 distinct outcomes for this. The plot shows that the theoretical p-values will slightly exaggerate significance in the tails of the distribution.

Figure A-5 shows the results of replicating on the Seascale variable. This shows a similar general pattern to the 2-group XG data - and for the same reason, since the analyses is determined by the number of cases assigned to Seascale. Within the limits imposed by the grouping there is quite close agreement with theory. The study data falls in the second most extreme positive group and the GLIM p-value of 0.08 is in close agreement with the empirical value.

The data for Calder in Figure A-6 is very similar to that for Seascale but here the study data falls in the highest positive group for which the theoretical p-value 0.0007 appears to exaggerate the significance in relation to the empirical p-value of about 0.002.

Figure A-7 shows the replicate data for the variable TRI1. The lower end of this plot shows that for negative associations large deviance changes cannot be generated anything like as frequently as implied by the standard chi-square assumption. The standard assumptions work reasonably well for positive relationships down to p-values of about 0.002, but from here large deviance changes are more frequent that predicted. The GLIM p-value for the study data (10^{-6}) is therefore too small, though the true value is likely to be well below 0.001. Figure A-7(b) suggests that the GLIM p-value may understate the significance of the 3-group data for TRI1, the p-value being about 0.002. The plots for the 3-group linear trend and the Ever/never exposed dichotomy show very similar patterns, both suggesting that the GLIM p-values are about right.

Table A-1: List of potential explanatory variables

Variable code	Variable name	Factor /variate	Level definitions/variate units
DOBQ	Child's date of birth	f	5-year periods (8)
DOSQ	Date of start at Sellafield	f	5-year periods (8)
QUIQ	Sellafield quit date	f	5-year periods (8)
DODX	Date of diagnosis	f	10-year periods (4)
SEX	Sex	f	Male/Female
FAGE	Father's age at child's conception	f	<25/25-34/>35
SEAS	Seascale resident at birth	f	No/Yes
JOBC	Job class	f	Industrial/non-industrial
PCE	Employed at Sellafield before child's conception	f	Yes/No
TIME	Years from start at Sellafield to child's conception (or Sellafield quit, if earlier)	v	years
FBTH	Father's birthplace	f	Cumbria/Elsewhere
DIST	Distance of residence at birth from Sellafild site	v	km
MIGR	Migration index for place/area of birth	v	ratio of control subjects born to non-Cumbrian fathers to those born to Cumbrian fathers
Measured and assessed radiation exposure			
XG	External radiation (x & gamma)	v	mSv
HIDA	Total monitored days on dosemeters recording a dose rate > 0.5 mSv/day	v	days
RMAX	Highest dose rate for any dosemeter worn	v	mSv/day
NEUT	Days in any neutron job	v	days
NHI	Days in high neutron job	v	days
IT	Internal radiation (all nuclides)	v	mSv
IA	Internal radiation (alpha emitters)	v	mSv
ITRI	Internal radiation (tritium)	v	mSv
TEN1	Assessed or measured tritium exposure (based on ITRI and TRI1)	f	never/ever exposed
TEN2	Assessed or measured tritium exposure (based on ITRI and TRI2)	f	never/ever exposed
Assessed exposure to chemicals and other workplace exposures			
C1	Anilene	v	
C2	Anthracene	v	
C3	Arsenic & compounds	v	
C4	Benzene	v	
C5	Benzidine(& compounds)	v	
C6	Beryllium (dust)	v	
C7	Butex (di-n-butyl ether) (used/degraded)	v	
C8	Chromates/di-chromates	v	
C9	Formaldehyde/formalin	v	
C10	Graphite dust	v	
C11	Hydrazine	v	weighted days exposed
C12	Hydrofluoric acid	v	
C13	Kerosene (used/degraded)	v	
C14	Lead & compounds	v	
C15	Mercury	v	
C16	Phosphoric acids	v	
C17	Picric acid	v	
C18	SDG3 #	v	
C19	Tetrabromoethane	v	
C20	Chloroform	v	
C21	Tetrachloroethane	v	
C22	Dichloroethane	v	

continued..

a proprietary decontaminant; main constituents sodium sulphate, citric acid, detergent and EDTA (ethylene diamine tetra-acetic acid).

Table A-1 (cont.)

Variable code	Variable name	Factor /variate	Level definitions/variate units
C23	Trichloroethylene	v	
C24	Carbon tetrachloride	v	
C25	Sulphamic acid	v	
C26	TTA (Thiophenyl trifluoro acetone)	v	
C27	o-Toluidines	v	
C28	Zinc and compounds	v	weighted days exposed
C31	Alpha in air (Pu)	v	
C32	Alpha in air (U)	v	
C33	Beta/gamma (only) in air	v	
TRI1	Tritium (first assessment)	v	
TRI2	Tritium (extended assessment)	v	
C35	Polonium	v	
Actual and potential contamination			
NDCN	Total decontamination visits	v	number
NALP	Number of alpha contaminations	v	number
NBEG	Number of beta/gamma contaminations	v	number
HEAV	Number of "heavy" contaminations	v	number
CLEA	Number of "not clear" contaminations	v	number
CON1	Days in most contaminating jobs	v	days
CON2	Days in any contaminating job	v	days
FIRE	Involved in Windscale fire	f	No/Yes
IN57	In workforce on 10/10/57	f	No/Yes
Work areas and jobs			
1	R&DD (Research & Development) - chemical	vf	
2	R&DD (Research & Development) - mechanical	vf	
3	Decontamination	vf	
4	High level waste	vf	
5	Waste management	vf	
6	Effluent plants	vf	
7	Windscale piles & B29	vf	
8	Calder	vf	
9	Ponds West	vf	
10	Pond 5 - SIXEP	vf	Recorded as factors (codes PJi):
11	Oxide ponds	vf	*>5% of time in job (N/Y)*
12	Reprocessing (old)	vf	for total pre-conception
13	Reprocessing (new)	vf	analyses; as variates (codes JBi):
14	North Group	vf	*days in job*
15	THORP	vf	for analyses of 12 week
16	Fuel plants	vf	pre-conception period
17	Windscale Nuclear Labs	vf	
18	Advanced Gas Reactor	vf	
19	Main workshop	vf	
20	Graphite workshop	vf	
21	Maintenance - sep area	vf	
22	Maintenance - non active	vf	
23	Plumbers	vf	
24	Painters/joiners	vf	
25	Maintenance - electrical/instruments	vf	
26	Changerooms	vf	
27	Health Physics monitors	vf	
28	Stores	vf	
29	Training	vf	
30	Site transport	vf	
31	Police/firemen	vf	
32	Draughtsmen & other office workers	vf	
33	Chemical plumbers	vf	

Table A-2: Area/job groups ranked by all-incidents rate

Area/job	Man days in study	Cum. % man day	Incidents			
			No.	Rate per 10 man-years		
				Central	95% CI	
					Low	High
High incident rates:						
Decontamination	12657	1.0	18	5.18	3.07	8.19
Fuel plants	118939	10.8	130	3.98	3.31	4.74
High level waste	32228	13.4	28	3.16	2.10	4.57
North group	13669	14.5	11	2.93	1.46	5.24
Ponds West	75233	20.7	57	2.76	2.08	3.59
Windscale piles & B29	15767	21.9	10	2.31	1.11	4.25
Reprocessing (old)	27176	24.2	17	2.28	1.33	3.65
TOTAL - high rate areas	**295669**		**271**	**3.34**	**2.95**	**3.75**
Intermediate incident rates:						
R&DD	209895	41.3	80	1.39	1.10	1.73
Reprocessing (new)	55937	45.9	19	1.24	0.74	1.93
Maintenance - sep area	83930	52.7	23	1.00	0.63	1.50
TOTAL - intermediate rate areas	**349762**		**122**	**1.27**	**1.06**	**1.51**
Low incident rates:						
Site Transport	4932	53.1	1	0.74	0.02	4.11
Effluent plants	6451	53.7	1	0.56	0.01	3.15
Waste management	6577	54.2	1	0.55	0.01	3.08
Training	40718	57.5	6	0.54	0.20	1.17
Maintenance - electrical/instruments	28116	59.8	4	0.52	0.14	1.33
Windscale Nuclear Labs	49557	63.9	7	0.51	0.21	1.06
Chemical plumbers	10584	64.8	1	0.34	0.01	1.92
Advanced Gas Reactor	38484	67.9	3	0.28	0.06	0.83
Calder	94653	75.6	4	0.15	0.04	0.39
Main workshop	46199	79.4	1	0.08	0.00	0.44
Unknown/other sites	85487	86.4	1	0.04	0.00	0.24
Draughtsmen & other office workers	85383	93.4	0	0.00	0.00	0.16
Police	28877	95.7	0	0.00	0.00	0.47
Graphite workshop	16806	97.1	0	0.00	0.00	0.80
Maintenance - painters	13476	98.2	0	0.00	0.00	1.00
Pond 5/SIXEP	5130	98.6	0	0.00	0.00	2.62
Stores	4963	99.0	0	0.00	0.00	2.71
Health Physics monitors	3149	99.3	0	0.00	0.00	4.27
Changerooms	2756	99.5	0	0.00	0.00	4.88
THORP	2049	99.7	0	0.00	0.00	6.56
Maintenance - plumbers	1916	99.8	0	0.00	0.00	7.02
Maintenance - non active	1639	100.0	0	0.00	0.00	8.20
Oxide ponds	365	100.0	0	0.00	0.00	36.82
TOTAL - low rate areas	**578267**		**30**	**0.19**	**0.13**	**0.26**
GRAND TOTAL	**1223698**		**423**	**1.26**	**1.14**	**1.38**

Table A-3: Numbers of cases in the 10 age-matched strata for conditional logistic regression of post-conception variables

Stratum	Case group			Mid-point age (years)
	LLNH	LNHL	OCAN	
1	1	1	0	0.88
2	2	2	0	1.63
3	1	1	0	2.09
4	2	3	0	2.56
5	0	0	2	4.30
6	2	2	1	4.97
7	1	2	2	7.88
8	0	0	1	10.30
9	1	2	5	18.50
10	2	3	5	23.50

Table A-4: Comparison of log odds ratio estimates and their standard errors for selected pre-conception variables, as derived from unconditional (GLIM) and conditional (EGRET) logistic regression analyses.

	GLIM		EGRET		GLIM/EGRET ratio	
Variable	**estimate**	**standard error**	**estimate**	**standard error**	**estimate**	**standard error**
XG	0.01041	0.003616	0.009783	0.0029	1.06	1.25
SEAS	1.942	0.6431	2.05	0.615	0.95	1.05
LDOS	1.473	0.7859	1.651	0.792	0.89	0.99
PJ8	2.536	0.6942	2.305	0.591	1.10	1.17
TEN2	1.699	0.6549	1.731	0.591	0.98	1.11
TRI2	0.01001	0.001587	0.008994	0.00148	1.11	1.07
				Average ratio:	1.02	1.11

Table A-5: Summary of the strength of statistical association between outcome variable LLNH (Lymphatic leukaemia & NHL) and potential explanatory variables.

Variable		Continuous analysis (variates only, all deviance changes on 1 df)			Grouped analyses: Three or more groups				Grouped analyses: Two groups (all deviance changes on 1 df)		
		dev	p	sign	dev	df	p	sign	dev	p	sign
A: Variables not dependent on choice of pre-conception exposure window											
DOBQ	Child's date of birth				12.7	7	0.080		1.6	0.20	
DOSQ	Date of start at Sellafield				11.4	7	0.12		4.3	0.038	-
QUIQ	Sellafield quit date				10.1	7	0.18		4.3	0.038	+
DODX	Date of diagnosis				3.5	3	0.32				
SEX	Sex								0.3	0.58	
FAGE	Father's age at child's conception				6.4	2	0.042	+			
FBTH	Father's place of birth								0.0	0.86	
SEAS	Seascale resident at birth								7.0	0.008	+
JOBC	Job class								0.0	0.90	
PCE	In workforce before child's conception								0.3	0.60	
TIME	Years from start at Sellafield to child's conception (or Sellafield quit if earlier)	6.2	0.013	+	2.6	2	0.28		0.3	0.60	
DIST	Distance from Sellafield site to child's residence at birth	3.9	0.050	-					0.5	0.46	
MIGR	Migrant index for place/area of birth	7.3	0.0007	+	2.7	2	0.26		0.4	0.92	
B: Variables evaluated over total pre-conception period											
B1: Measured radiation exposure											
XG	External radiation (x & gamma)	7.5	0.006	+	1.9	2	0.38		1.1	0.29	
HIDA	Total monitored days covered by badges with dose rate > 0.5mSv/day	4.4	0.040	+	0.1	2	0.94		0.0	0.85	
RMAX	Maximum monitored dose rate	0.0	0.97		1.5	2	0.47		1.1	0.28	
NEUT	Days in any neutron job	3.4	0.060		3.1	2	0.21		2.3	0.13	
NHI	Days in high neutron job	0.1	0.82		0.8	2	0.66		0.0	0.90	
IT	Internal radiation (all nuclides)	0.3	0.61		1.1	2	0.56		0.0	0.92	
IA	Internal radiation (alpha emitters)	0.1	0.77		0.2	2	0.91		0.2	0.69	
ITRI	Internal radiation (tritium)	0.3	0.61		0.9	2	0.63		0.9	0.34	
B2: Assessed exposure to chemicals and other workplace exposures											
C2	Anthracene	1.9	0.16		1.9	2	0.38		1.9	0.16	
C3	Arsenic & compounds	2.1	0.15		1.9	2	0.39		0.9	0.36	
C4	Benzene	2.6	0.10		2.9	2	0.24		2.9	0.089	
C7	Butex (used/degraded)	0.1	0.73		2.6	2	0.28		0.5	0.48	
C8	Chromates/di-chromates	6.3	0.012	+	3.5	2	0.18		0.0	0.88	
C9	Formaldehyde/formalin	11.2	0.0008	+	3.9	2	0.14		2.2	0.13	
C10	Graphite dust	0.8	0.37		3.1	2	0.21		0.1	0.71	
C11	Hydrazine	0.0	0.95		0.2	2	0.92		0.1	0.76	
C12	Hydrofluoric acid	7.9	0.005	+	2.9	2	0.23		2.7	0.10	
C13	Kerosene (used/degraded)	0.6	0.45		0.2	2	0.92		0.1	0.70	
C14	Lead & compounds	1.5	0.21		4.4	2	0.11		3.1	0.078	
C15	Mercury	0.7	0.41		2.5	2	0.28		0.1	0.74	
C16	Phosphoric acids	1.9	0.17		2.8	2	0.24		1.8	0.17	
C17	Picric acid	6.8	0.009	+	1.5	2	0.46		0.4	0.55	
C20	Chloroform	0.3	0.58		2.0	2	0.38		0.6	0.44	
C23	Trichloroethylene	1.9	0.17		4.6	2	0.10		0.0	0.97	
C24	Carbon tetrachloride	1.3	0.26		1.7	2	0.42		1.1	0.30	
C26	TTA	0.0	0.88		1.9	2	0.39		0.0	0.92	
C28	Zinc and compounds	4.2	0.040	-	3.1	2	0.21		1.8	0.18	
C31	Alpha in air (Pu)	0.5	0.49		0.7	2	0.71		0.5	0.50	
C32	Alpha in air (U)	1.6	0.20		0.7	2	0.71		0.2	0.69	
C33	Beta/gamma (only) in air	1.9	0.17		1.9	2	0.46		0.0	0.83	
TRI1/TEN1	Tritium (1st assessment)	22.9	2E-06	+	10.3	2	0.0057	+	7.6	0.0059	+
TRI2/TEN2	Tritium (extended assessment)	23.1	2E-06	+	8.1	2	0.0018	+	6.0	0.014	+

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Table A-5 (cont.)		Continuous analysis			Grouped analyses						
					Three or more groups				Two groups		
Variable		dev	p	sign	dev	df	p	sign	dev	p	sign
B3: Actual and potential contamination											
NDCN	Total decontamination visits	0.6	0.42		3.1	2	0.21		1.6	0.21	
NALP	Number of alpha contaminations	4.2	0.040	+	2.6	2	0.27		2.1	0.15	
NBEG	Number of beta/gamma contaminations	0.1	0.75		2.4	1	0.31		2.3	0.13	
HEAV	Number of "heavy" contaminations	0.0	0.86		1.8	2	0.40		0.1	0.75	
CLEA	Number of "not clear" contaminations	0.6	0.44		0.9	2	0.64		0.8	0.38	
CON1	Time in most contaminating jobs	0.3	0.58		0.6	2	0.73		0.3	0.57	
CON2	Time in any contaminating job	3.5	0.061		4.2	2	0.12		0.0	0.88	
FIRE	Involved in Windscale fire								1.2	0.27	
IN57	In workforce on 10/10/57								1.4	0.23	
B4: Work area/job (if more than %5 of period)											
PJ1	R&DD - chemical								0.2	0.65	
PJ2	R&DD - mechanical								2.0	0.15	
PJ4	High level waste								2.2	0.14	
PJ6	Effluent plant								0.5	0.46	
PJ7	Windscale piles & B29								2.0	0.16	
PJ8	Calder								11.6	0.0007	+
PJ9	Ponds West								2.1	0.15	
PJ12	Reprocessing (old)								0.0	0.98	
PJ16	Fuel plants								0.1	0.70	
PJ17	Windscale Nuclear Labs								1.7	0.19	
PJ18	Advanced Gas Reactor								2.7	0.10	
PJ19	Main workshop								1.1	0.31	
PJ20	Graphite workshop								0.9	0.35	
PJ21	Maintenance - sep area								0.0	0.87	
PJ22	Maintenance - non active								0.4	0.53	
PJ25	Changerooms								0.1	0.76	
PJ29	Training								4.1	0.043	-
PJ31	Police								0.3	0.60	
C: Variables evaluated over 12 weeks pre-conception period											
C1: Measured radiation exposure											
XG	External radiation (x & gamma)	0.0	0.96		1.7	2	0.42		1.6	0.20	
HIDA	Total monitored days covered by badge with dose rate > 0.5mSv/day	2.0	0.16		2.0	2	0.38		2.0	0.16	
RMAX	Maximum monitored dose rate	0.7	0.41		2.7	2	0.26		2.2	0.14	
NEUT	Days in any neutron job	2.4	0.12		2.2	1	0.14		2.2	0.14	
NHI	Days in high neutron job	0.1	0.72		0.1	1	0.72		0.1	0.72	
IT	Internal radiation (all nuclides)	0.9	0.34		0.2	2	0.92		0.1	0.71	
IA	Internal radiation (alpha emitters)	0.9	0.33		0.2	2	0.90		0.2	0.66	
ITRI	Internal radiation (tritium)	0.4	0.53		0.4	2	0.82		0.4	0.53	
C2: Assessed exposure to chemicals and other workplace exposures											
C2	Anthracene	1.3	0.25		1.3	2	0.52		1.3	0.25	
C3	Arsenic & compounds	0.8	0.37		0.8	2	0.67		0.8	0.37	
C4	Benzene	2.5	0.11		5.9	2	0.053		0.0	0.85	
C7	Butex (used/degraded)	1.8	0.18		1.8	1	0.18		1.8	0.18	
C8	Chromates/di-chromates	1.1	0.30		0.6	2	0.76		0.0	0.92	
C9	Formaldehyde/formalin	0.3	0.57		0.3	2	0.85		0.3	0.57	
C10	Graphite dust	3.7	0.054	-	3.7	2	0.16		3.7	0.053	
C11	Hydrazine	0.4	0.50		0.8	2	0.66		0.0	0.82	
C12	Hydrofluoric acid	3.8	0.051	+	4.0	2	0.13		3.6	0.058	
C13	Kerosene (used/degraded)	0.7	0.41		1.1	2	0.56		1.1	0.30	
C14	Lead & compounds	2.7	0.10		3.0	2	0.22		1.9	0.16	
C15	Mercury	2.9	0.088		2.9	2	0.23		2.9	0.088	
C16	Phosphoric acids	0.2	0.65		0.4	2	0.83		0.4	0.55	
C17	Picric acid	5.2	0.022	+	17.7	2	0.0002	+	1.1	0.28	
C20	Chloroform	0.5	0.48		1.1	2	0.57		0.0	0.85	
C23	Trichloroethylene	0.6	0.44		1.7	2	0.44		0.2	0.66	
C24	Carbon tetrachloride	0.8	0.37		1.6	2	0.45		1.4	0.24	
C26	TTA	3.7	0.054	+	2.8	2	0.25		0.6	0.43	

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Table A-5 (cont.)		Continuous analysis			Grouped analyses						
					Three or more groups				Two groups		
Variable		dev	p	sign	dev	df	p	sign	dev	p	sign
C28	Zinc and compounds	6.4	0.011	-	6.4	2	0.040	-	6.4	0.011	-
C31	Alpha in air (Pu)	0.1	0.81		0.5	2	0.78		0.1	0.77	
C32	Alpha in air (U)	1.7	0.19		2.8	2	0.25		0.4	0.52	
C33	Beta/gamma (only) in air	2.9	0.090		4.3	2	0.12		0.4	0.50	
TRI1/TEN1	Tritium (1st assessment)	0.4	0.52		2.5	2	0.29		1.0	0.31	
TRI2/TEN2	Tritium (extended assessment)	0.6	0.45		2.7	2	0.25		1.3	0.26	
C3: Actual and potential contamination											
NDCN	Total decontamination visits	0.8	0.37		0.8	2	0.66		0.8	0.36	
NALP	Number of alpha contaminations	0.2	0.63		0.2	1	0.63		0.2	0.63	
NBEG	Number of beta/gamma contaminations	0.6	0.44		0.6	2	0.75		0.6	0.44	
HEAV	Number of "heavy" contaminations	0.3	0.59		0.3	1	0.59		0.3	0.59	
CON1	Time in most contaminating jobs	0.2	0.64		0.3	2	0.88		0.2	0.64	
CON2	Time in any contaminating job	0.0	0.93		0.2	2	0.88		0.0	0.98	
C4: Work area/job (weighted days in 12 week pre-conception period)											
JB1	R&DD - chemical	0.1	0.76		0.2	2	0.90		0.1	0.74	
JB2	R&DD - mechanical	2.4	0.12		2.5	2	0.28		2.0	0.15	
JB4	High level waste #								2.1	0.15	
JB6	Effluent plant #								0.3	0.61	
JB7	Windscale piles & B29 #								0.6	0.43	
JB8	Calder #								1.5	0.22	
JB9	Ponds West	1.5	0.22		1.5	2	0.47		1.5	0.22	
JB12	Reprocessing (old) #								1.4	0.24	
JB16	Fuel plants #								0.0	0.94	
JB17	Windscale Nuclear Labs #								1.7	0.19	
JB18	Advanced Gas Reactor #								1.1	0.30	
JB19	Main workshop #								0.8	0.37	
JB20	Graphite workshop #								0.2	0.63	
JB21	Maintenance - sep area	0.2	0.65		0.3	2	0.88		0.2	0.66	
JB22	Maintenance - non active #								0.2	0.63	
JB25	Changerooms	0.3	0.59		0.6	2	0.75		0.3	0.59	
JB29	Training #								0.1	0.73	
JB31	Police #								0.3	0.60	

All non-zero case and control values equal: the continuous, 3 group and 2 group analyses are identical.

D: Variables evaluated between conception and diagnosis

D1: Actual and potential contamination

NDCN	Total decontamination visits	3.7	0.06	
NALP	Number of alpha contaminations	5.5	0.02	+
NBEG	Number of beta/gamma contaminations	1.7	0.19	
HEAV	Number of "heavy" contaminations	0.9	0.34	
CLEA	Number of "not clear" contaminations	1.8	0.18	
CON1	Time in most contaminating jobs	2.9	0.09	
CON2	Time in any contaminating job	1.6	0.21	

D2: Work area/job

PJ1	R&DD - chemical	0.0	0.97	
PJ2	R&DD - mechanical	0.8	0.37	
PJ4	High level waste	3.7	0.05	+
PJ8	Calder	0.5	0.47	
PJ12	Reprocessing (old)	0.0	0.83	
PJ16	Fuel plants	0.1	0.82	
PJ17	Windscale Nuclear Labs	1.3	0.25	
PJ18	Advanced Gas Reactor	0.2	0.64	
PJ19	Main workshop	0.7	0.39	
PJ20	Graphite workshop	0.7	0.40	
PJ21	Maintenance - sep area	1.1	0.30	
PJ25	Changerooms	0.1	0.77	
PJ32	Draughtsmen & other office workers	0.2	0.68	

Table A-6: Summary of the statistical associations between outcome variable LNHL (Leukaemia & non-Hodgkins lymphoma) and potential explanatory variables.

Variable		Continuous analysis (variates only, all deviance changes on 1 df)			Grouped analyses: Three or more groups				Grouped analyses: Two groups (all deviance changes on 1 df)		
		dev	p	sign	dev	df	p	sign	dev	p	sign
A: Variables not dependent on choice of pre-conception exposure window											
DOBQ	Child's date of birth				3.9	7	0.79		1.2	0.27	
DOSQ	Date of start at Sellafield				10.8	7	0.15		3.5	0.063	
QUIQ	Sellafield quit date				11.3	7	0.13		4.4	0.037	-
DODX	Date of diagnosis				3.0	3	0.39				
SEX	Sex								0.0	0.93	
FAGE	Father's age at child's conception				8.4	2	0.015	+			
FBTH	Father's place of birth								1.3	0.26	
SEAS	Seascale resident mother/father								11.9	0.0005	+
JOBC	Job class								0.6	0.44	
PCE	In workforce before child's conception								0.2	0.69	
TIME	Days from Sellafield start to child's conception (or quit if earlier)	5.1	0.023	+	3.2	2	0.20		0.2	0.69	
DIST	Distance from Sellafield site to child's residence at birth	3.8	0.050	-					1.4	0.23	
MIGR	Migrant index for place/area of birth	12.5	0.0004	+	5	2	0.080		0.6	0.78	
B: Variables evaluated over total pre-conception period											
B1: Measured radiation exposure											
XG	External radiation (x & gamma)	6.6	0.010	+	2.0	2	0.37		0.2	0.63	
HIDA	Total monitored days covered by badges with dose rate > 0.5mSv/day	3.7	0.050	+	0.5	2	0.78		0.1	0.71	
RMAX	Maximum monitored dose rate	0.2	0.65		0.2	2	0.87		0.2	0.63	
NEUT	Days in any neutron job	2.0	0.15		1.6	2	0.46		0.8	0.36	
NHI	Days in high neutron job	0.2	0.65		0.9	2	0.62		0.2	0.67	
IT	Internal radiation (all nuclides)	0.3	0.59		2.5	2	0.29		0.1	0.75	
IA	Internal radiation (alpha emitters)	0.1	0.74		1.1	2	0.59		0.4	0.51	
ITRI	Internal radiation (tritium)	0.7	0.42		1.8	2	0.40		0.3	0.57	
B2: Assessed exposure to chemicals and other workplace exposures											
C2	Anthracene	2.5	0.11		2.5	2	0.28		2.5	0.11	
C3	Arsenic & compounds	1.3	0.26		1.4	2	0.51		0.4	0.55	
C4	Benzene	0.2	0.66		4.4	2	0.11		0.0	0.89	
C7	Butex (used/degraded)	2.5	0.11		6.6	2	0.038	*	0.0	0.85	
C8	Chromates/di-chromates	8.2	0.0043	+	8.2	2	0.016	*	0.6	0.42	
C9	Formaldehyde/formalin	10.6	0.0011	+	3.6	2	0.17		1.8	0.18	
C10	Graphite dust	1.5	0.22		2.9	2	0.23		0.0	0.95	
C11	Hydrazine	0.1	0.74		0.2	2	0.92		0.1	0.77	
C12	Hydrofluoric acid	6.0	0.014	+	1.5	2	0.47		1.3	0.25	
C13	Kerosene (used/degraded)	0.1	0.72		0.3	2	0.85		0.1	0.74	
C14	Lead & compounds	0.0	0.99		4.8	2	0.089		0.6	0.44	
C15	Mercury	0.3	0.59		0.7	2	0.69		0.6	0.45	
C16	Phosphoric acids	1.0	0.32		3.2	2	0.21		0.1	0.71	
C17	Picric acid	5.6	0.018	+	1.3	2	0.53		0.2	0.70	
C20	Chloroform	0.3	0.60		0.2	2	0.90		0.2	0.64	
C23	Trichloroethylene	3.2	0.074		7.2	2	0.027	+	0.1	0.73	
C24	Carbon tetrachloride	0.7	0.39		2.3	2	0.31		1.8	0.18	
C26	TTA	0.5	0.47		8.2	2	0.017	*	1.4	0.24	
C28	Zinc and compounds	6.1	0.013	-	4.8	2	0.092		3.5	0.063	
C31	Alpha in air (Pu)	0.0	0.99		1.9	2	0.38		0.2	0.62	
C32	Alpha in air (U)	0.0	0.91		0.1	2	0.95		0.0	0.87	
C33	Beta/gamma (only) in air	0.3	0.62		0.1	2	0.97		0.0	0.89	
TRI1/TEN1	Tritium (1st assessment)	18.3	2E-05	+	6.3	2	0.042	+	7.1	0.0076	+
TRI2/TEN2	Tritium (extended assessment)	19.1	1E-05	+	5.0	2	0.081		6.1	0.014	+

continued..

Table A-6 (cont.)

Variable		Continuous analysis dev	p	sign	Grouped analyses: Three or more groups dev	df	p	sign	Two groups dev	p	sign
B3: Actual and potential contamination											
NDCN	Total decontamination visits	0.7	0.42		3.2	2	0.20		2.9	0.090	
NALP	Number of alpha contaminations	3.0	0.081		1.8	2	0.41		1.1	0.29	
NBEG	Number of beta/gamma contaminations	0.2	0.67		4.1	2	0.13		4.0	0.040	+
HEAV	Number of "heavy" contaminations	0.1	0.72		1.7	2	0.42		0.0	0.92	
CLEA	Number of "not clear" contaminations	5.4	0.021	+	6.8	2	0.033	+	3.0	0.083	
CON1	Time in most contaminating jobs	1.3	0.26		2.0	2	0.37		1.7	0.20	
CON2	Time in any contaminating job	4.7	0.031	+	7.3	2	0.026	*	0.0	0.85	
FIRE	Involved in Windscale fire								0.8	0.38	
IN57	In workforce on 10/10/57								1.8	0.18	
B4: Work area/job (if more than %5 of period)											
PJ1	R&DD - chemical								2.2	0.14	
PJ2	R&DD - mechanical								1.5	0.22	
PJ4	High level waste								1.5	0.22	
PJ6	Effluent plant								0.8	0.37	
PJ7	Windscale piles & B29								1.0	0.31	
PJ8	Calder								8.6	0.0034	+
PJ9	Ponds West								2.5	0.11	
PJ12	Reprocessing (old)								0.2	0.65	
PJ16	Fuel plants								0.5	0.46	
PJ17	Windscale Nuclear Labs								1.2	0.28	
PJ18	Advanced Gas Reactor								2.1	0.15	
PJ19	Main workshop								1.4	0.23	
PJ20	Graphite workshop								0.4	0.55	
PJ21	Maintenance - sep area								0.1	0.80	
PJ22	Maintenance - non active								0.6	0.45	
PJ25	Changerooms								0.4	0.53	
PJ29	Training								5.1	0.024	-
PJ31	Police								0.3	0.56	
C: Variables evaluated over 12 weeks pre-conception period											
C1: Measured radiation exposure											
XG	External radiation (x & gamma)	0.3	0.58		1.0	2	0.58		1.0	0.32	
HIDA	Total monitored days covered by badges with dose rate > 0.5mSv/day	2.9	0.090		2.9	2	0.23		2.9	0.090	
RMAX	Maximum monitored dose rate	1.1	0.30		0.6	2	0.87		0.5	0.49	
NEUT	Days in any neutron job	1.0	0.31		0.8	1	0.36		0.8	0.36	
NHI	Days in high neutron job	0.0	0.91		0.0	1	0.91		0.0	0.91	
IT	Internal radiation (all nuclides)	1.4	0.24		0.4	2	0.82		0.4	0.53	
IA	Internal radiation (alpha emitters)	0.7	0.42		0.5	2	0.78		0.5	0.49	
ITRI	Internal radiation (tritium)	7.9	0.0050	+	3.5	2	0.17		1.6	0.21	
C2: Assessed exposure to chemicals and other workplace exposures											
C2	Anthracene	1.7	0.20		1.7	2	0.44		1.7	0.20	
C3	Arsenic & compounds	1.1	0.30		1.1	2	0.58		1.1	0.30	
C4	Benzene	2.5	0.11		2.4	2	0.30		1.4	0.23	
C7	Butex (used/degraded)	0.0	0.92		0.6	1	0.43		0.6	0.43	
C8	Chromates/di-chromates	0.9	0.34		0.1	2	0.94		0.0	0.88	
C9	Formaldehyde/formalin	0.4	0.52		0.4	2	0.81		0.4	0.52	
C10	Graphite dust	4.8	0.029	-	4.8	2	0.091		4.8	0.029	-
C11	Hydrazine	1.1	0.30		1.3	2	0.52		0.4	0.52	
C12	Hydrofluoric acid	3.2	0.076		3.0	2	0.22		2.5	0.11	
C13	Kerosene (used/degraded)	0.5	0.50		3.4	2	0.18		2.3	0.13	
C14	Lead & compounds	1.1	0.30		1.3	2	0.53		1.2	0.27	
C15	Mercury	3.7	0.054	-	3.7	2	0.16		3.7	0.054	-
C16	Phosphoric acids	0.5	0.46		0.4	2	0.84		0.2	0.62	
C17	Picric acid	4.3	0.037	+	16.9	2	0.0002	+	0.8	0.36	
C20	Chloroform	0.4	0.51		0.3	2	0.87		0.2	0.69	
C23	Trichloroethylene	0.0	0.86		0.7	2	0.70		0.0	0.96	
C24	Carbon tetrachloride	1.1	0.29		2.2	2	0.34		2.1	0.15	
C26	TTA	4.0	0.045	+	2.6	2	0.27		2.4	0.12	
C28	Zinc and compounds	8.7	0.0032	-	8.7	2	0.013		8.7	0.0032	-
C31	Alpha in air (Pu)	0.1	0.80		0.1	2	0.94		0.1	0.74	

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Table A-6 (cont.)		Continuous analysis			Grouped analyses						
					Three or more groups				Two groups		
Variable		dev	p	sign	dev	df	p	sign	dev	p	sign
C32	Alpha in air (U)	0.8	0.36		0.5	2	0.79		0.3	0.60	
C33	Beta/gamma (only) in air	2.4	0.12		1.6	2	0.46		0.6	0.43	
TRI1/TEN1	Tritium (1st assessment)	0.1	0.75		1.6	2	0.45		2.1	0.15	
TRI2/TEN2	Tritium (extended assessment)	0.2	0.63		1.9	2	0.39		2.6	0.11	
C3: Actual and potential contamination											
NDCN	Total decontamination visits	2.0	0.16		5.9	2	0.052		0.4	0.51	
NALP	Number of alpha contaminations #								0.3	0.56	
NBEG	Number of beta/gamma contaminations	2.7	0.10		5.6	2	0.062		1.0	0.33	
HEAV	Number of "heavy" contaminations #								0.4	0.53	
CLEA	Number of "not clear" contaminations #	(1 case, 0 controls; Fisher exact p=0.082)									
CON1	Time in most contaminating jobs	1.1	0.29		1.1	2	0.57		1.1	0.29	
CON2	Time in any contaminating job	0.1	0.77		0.4	2	0.84		0.1	0.82	
IN57	In workforce on 10/10/57 #	(1 case, 0 controls; Fisher exact p=0.082)									
C4: Work area/job (days in 12 week pre-conception period)											
JB1	R&DD - chemical	1.0	0.31		1.2	2	0.54		0.9	0.33	
JB2	R&DD - mechanical	1.8	0.18		1.9	2	0.38		1.5	0.22	
JB4	High level waste #								1.4	0.23	
JB6	Effluent plant #								0.4	0.54	
JB7	Windscale piles & B29 #								0.9	0.33	
JB8	Calder #								0.8	0.37	
JB9	Ponds West	1.8	0.18		1.8	2	0.41		1.8	0.18	
JB12	Reprocessing (old) #								2.1	0.15	
JB16	Fuel plants #								0.1	0.80	
JB17	Windscale Nuclear Labs #								1.2	0.28	
JB18	Advanced Gas Reactor #								0.8	0.36	
JB19	Main workshop #								1.1	0.29	
JB20	Graphite workshop #								0.3	0.56	
JB21	Maintenance - sep area	0.0	0.97		0.1	2	0.97		0.0	0.98	
JB22	Maintenance - non active #								0.3	0.56	
JB25	Changerooms	0.1	0.76		0.3	2	0.84		0.1	0.75	
JB29	Training #								0.1	0.71	
JB31	Police #								0.3	0.56	
# All non-zero case and control values equal: continuous, 2 group and 3 group analyses are identical.											
D: Variables evaluated between conception and diagnosis											
D1: Actual and potential contamination											
NDCN	Total decontamination visits	2.5	0.12								
NALP	Number of alpha contaminations	3.8	0.052								
NBEG	Number of beta/gamma contaminations	1.1	0.29								
HEAV	Number of "heavy" contaminations	0.5	0.46								
CLEA	Number of "not clear" contaminations	1.3	0.26								
CON1	Time in most contaminating jobs	1.1	0.29								
CON2	Time in any contaminating job	2.3	0.13								
D2: Work area/job											
PJ1	R&DD - chemical								1.6	0.21	
PJ2	R&DD - mechanical								0.3	0.59	
PJ4	High level waste								2.6	0.11	
PJ8	Calder								0.1	0.82	
PJ12	Reprocessing (old)								0.2	0.89	
PJ16	Fuel plants								0.3	0.57	
PJ17	Windscale Nuclear Labs								0.8	0.37	
PJ18	Advanced Gas Reactor								0.1	0.91	
PJ19	Main workshop								0.4	0.55	
PJ20	Graphite workshop								0.3	0.60	
PJ21	Maintenance - sep area								0.3	0.58	
PJ25	Changerooms								0.0	0.99	
PJ27	Health Physics monitors								0.1	0.73	
PJ32	Draughtsmen & other office workers								0.0	0.96	

Table A-7: Summary of the strength of statistical association between outcome variable OCAN (Cancers other than leukaemia & NHL) and potential explanatory variables.

Variable		Continuous analysis (variates only, all deviance changes on 1 df)			Grouped analyses: Three or more groups				Grouped analyses: Two groups (all deviance changes on 1 df)		
		dev	p	sign	dev	df	p	sign	dev	p	sign
A: Variables not dependent on choice of pre-conception exposure window											
DOBQ	Child's date of birth				12.4	7	0.089		3.8	0.051	
DOSQ	Date of start at Sellafield				4.5	7	0.72		1.0	0.32	
QUIQ	Sellafield quit date				10.2	7	0.18		3.3	0.069	
DODX	Date of diagnosis				3.5	3	0.32				
SEX	Sex								1.2	0.28	
FAGE	Father's age at child's conception				2.4	2	0.30				
FBTH	Father's place of birth								3.7	0.050	*
SEAS	Seascale resident mother								0.1	0.78	
JOBC	Job class								0.7	0.41	
PBE	In workforce before child's birth								0.0	1.00	
TIME	Days from start to quit at Sellafield	3.5	0.062		5.2	2	0.076		0.0	0.99	
DIST	Distance from Sellafield site to child's residence at birth	0.4	0.52						1.0	0.30	
MIGR	Migrant index for place/area of birth	0.0	0.88		1.4	2	0.49		0.6	0.45	
B: Variables evaluated over total pre-conception period											
B1: Measured radiation exposure											
XG	External radiation (x & gamma)	3.8	0.052	-	7.7	2	0.022	*	0.2	0.67	
HIDA	Total monitored days covered by badges with dose rate > 0.5mSv/day	3.4	0.060		2.7	2	0.27		1.7	0.19	
RMAX	Maximum monitored dose rate	4.9	0.030	-	2.4	2	0.30		0.2	0.67	
NEUT	Days in any neutron job	0.8	0.36		2.4	2	0.29		1.1	0.30	
NHI	Days in high neutron job	1.6	0.20		2.0	2	0.37		0.4	0.53	
IT	Internal radiation (all nuclides)	0.3	0.57		1.0	2	0.60		0.4	0.53	
IA	Internal radiation (alpha emitters)	0.1	0.76		1.1	2	0.58		0.8	0.38	
ITRI	Internal radiation (tritium)	0.4	0.54		1.2	2	0.54		1.2	0.26	
B2: Assessed exposure to chemicals and other workplace exposures											
C2	Anthracene	0.2	0.69		1.7	2	0.43		0.6	0.42	
C3	Arsenic & compounds	0.4	0.50		0.4	2	0.80		0.4	0.50	
C4	Benzene	0.1	0.81		0.6	2	0.73		0.5	0.46	
C7	Butex (used/degraded)	0.2	0.62		4.3	2	0.12		0.7	0.39	
C8	Chromates/di-chromates	2.0	0.16		2.8	2	0.25		0.4	0.55	
C9	Formaldehyde/formalin	0.3	0.56		0.3	2	0.85		0.3	0.56	
C10	Graphite dust	0.8	0.38		1.3	2	0.53		0.0	0.91	
C11	Hydrazine	1.4	0.24		1.2	2	0.56		0.1	0.78	
C12	Hydrofluoric acid	0.5	0.48		1.2	2	0.56		0.1	0.75	
C13	Kerosene (used/degraded)	0.7	0.42		2.3	2	0.32		0.9	0.34	
C14	Lead & compounds	0.7	0.39		5.7	2	0.057		0.8	0.38	
C15	Mercury	0.1	0.70		1.6	2	0.46		0.0	0.95	
C16	Phosphoric acids	0.8	0.36		0.1	2	0.94		0.1	0.72	
C17	Picric acid	0.8	0.38		0.8	2	0.68		0.8	0.38	
C20	Chloroform	0.8	0.38		2.7	2	0.26		0.0	0.88	
C23	Trichloroethylene	2.8	0.093		3.4	2	0.19		3.3	0.067	
C24	Carbon tetrachloride	2.3	0.13		2.5	2	0.29		0.0	0.85	
C26	TTA	0.6	0.45		1.1	2	0.58		0.1	0.79	
C28	Zinc and compounds	1.5	0.21		2.1	2	0.34		0.9	0.34	
C31	Alpha in air (Pu)	0.3	0.57		1.1	2	0.58		0.3	0.57	
C32	Alpha in air (U)	1.7	0.19		2.2	2	0.33		2.1	0.14	
C33	Beta/gamma (only) in air	3.0	0.090		1.4	2	0.49		1.0	0.33	
TRI1/TEN1	Tritium (1st assessment)	2.9	0.090		3.0	2	0.23		3.8	0.052	
TRI2/TEN2	Tritium (extended assessment)	2.7	0.10		2.8	2	0.25		3.4	0.066	

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Table A-7 (cont.)		Continuous analysis			Grouped analyses						
					Three or more groups				Two groups		
Variable		dev	p	sign	dev	df	p	sign	dev	p	sign
B3: Actual and potential contamination											
NDCN	Total decontamination visits	0.1	0.80		0.5	2	0.80		0.4	0.50	
NALP	Number of alpha contaminations	2.2	0.14		2.2	2	0.33		2.2	0.14	
NBEG	Number of beta/gamma contaminations	0.0	0.99		0.2	2	0.91		0.1	0.70	
HEAV	Number of "heavy" contaminations	0.0	0.85		1.7	2	0.42		0.1	0.78	
CLEA	Number of "not clear" contaminations	0.1	0.72		0.4	2	0.82		0.2	0.64	
CON1	Time in most contaminating jobs	1.9	0.16		6.2	2	0.046	*	1.3	0.25	
CON2	Time in any contaminating job	5.9	0.015	-	8.9	2	0.012	-	2.9	0.090	
FIRE	Involved in Windscale fire								0.7	0.41	
IN57	In workforce on 10/10/57								1.4	0.23	
B4: Work area/job (if more than %5 of period)											
PJ1	R&DD - chemical								0.0	0.90	
PJ2	R&DD - mechanical								1.4	0.24	
PJ4	High level waste								1.3	0.26	
PJ6	Effluent plant								0.9	0.33	
PJ7	Windscale piles & B29								2.4	0.12	
PJ8	Calder								0.4	0.54	
PJ9	Ponds West								0.0	0.85	
PJ12	Reprocessing (old)								0.2	0.70	
PJ16	Fuel plants								0.4	0.54	
PJ17	Windscale Nuclear Labs								5.1	0.024	+
PJ18	Advanced Gas Reactor								1.1	0.30	
PJ19	Main workshop								0.3	0.62	
PJ20	Graphite workshop								0.2	0.62	
PJ21	Maintenance - sep area								0.0	0.92	
PJ22	Maintenance - non active								1.3	0.26	
PJ25	Changerooms								0.3	0.57	
PJ29	Training								0.6	0.43	
PJ31	Police								2.8	0.10	
C: Variables evaluated over 12 weeks pre-conception period											
C1: Measured raiation exposure											
XG	External radiation (x & gamma)	0.9	0.34		3.6	2	0.17		2.1	0.14	
HIDA	Total monitored days covered by badges with dose rate > 0.5mSv/day	3.2	0.070		3.2	2	0.2		3.2	0.070	
RMAX	Maximum monitored dose rate	2.7	0.10		3.6	2	0.17		1.5	0.22	
NEUT	Days in any neutron job	0.0	0.91		0.1	1	0.76		0.1	0.76	
NHI	Days in high neutron job	0.0	0.85		0.1	1	0.82		0.1	0.82	
IT	Internal radiation (all nuclides)	0.1	0.82		0.1	2	0.95		0.1	0.75	
IA	Internal radiation (alpha emitters)	0.1	0.79		1.0	2	0.59		0.7	0.39	
ITRI	Internal radiation (tritium)	0.7	0.41		0.7	2	0.71		0.7	0.41	
C2: Assessed exposure to chemicals and other workplace exposures											
C2	Anthracene	2.3	0.13		2.7	2	0.26		1.2	0.28	
C3	Arsenic & compounds	0.4	0.51		0.4	2	0.80		0.4	0.51	
C4	Benzene	3.8	0.053	+	5.2	2	0.074		4.9	0.027	+
C7	Butex (used/degraded)	0.4	0.53		1.9	1	0.17		1.9	0.17	
C8	Chromates/di-chromates	0.8	0.37		1.0	2	0.61		0.4	0.51	
C9	Formaldehyde/formalin	0.3	0.60		0.3	2	0.87		0.3	0.60	
C10	Graphite dust	5.4	0.020	+	5.7	2	0.059		3.4	0.064	
C11	Hydrazine	0.2	0.66		1.0	2	0.60		0.0	0.87	
C12	Hydrofluoric acid	0.1	0.71		1.8	2	0.40		1.3	0.26	
C13	Kerosene (used/degraded)	0.1	0.75		2.4	2	0.30		0.1	0.73	
C14	Lead & compounds	0.1	0.78		0.9	2	0.64		0.8	0.37	
C15	Mercury	0.6	0.45		1.6	2	0.45		0.2	0.64	
C16	Phosphoric acids	0.0	0.95		0.4	2	0.83		0.3	0.57	
C17	Picric acid	0.4	0.54		0.4	1	0.54		0.4	0.54	
C20	Chloroform	0.1	0.77		2.8	2	0.25		0.6	0.43	
C23	Trichloroethylene	0.6	0.46		3.4	2	0.18		0.9	0.35	
C24	Carbon tetrachloride	2.3	0.13		4.9	2	0.088		0.6	0.44	
C26	TTA	0.0	0.85		2.5	2	0.28		1.4	0.24	
C28	Zinc and compounds	0.9	0.35		1.1	2	0.59		0.3	0.55	

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Table A-7 (cont.)		Continuous analysis			Grouped analyses						
					Three or more groups				Two groups		
Variable		dev	p	sign	dev	df	p	sign	dev	p	sign
C31	Alpha in air (Pu)	0.0	0.92		3.3	2	0.19		0.7	0.41	
C32	Alpha in air (U)	0.2	0.68		3.3	2	0.20		0.2	0.65	
C33	Beta/gamma (only) in air	1.3	0.25		1.0	2	0.62		1.0	0.32	
TRI1/TEN1	Tritium (1st assessment)	1.8	0.18		1.8	2	0.41		2.2	0.14	
TRI2/TEN2	Tritium (extended assessment)	1.6	0.20		1.6	2	0.44		2.6	0.11	
C3: Actual and potential contamination											
NDCN	Total decontamination visits	2.40	0.12		6.5	2	0.040	*	0.6	0.46	
NALP	Number of alpha contaminations	0.3	0.57		0.3	1	0.57		0.3	0.57	
NBEG	Number of beta/gamma contaminations	3.1	0.080		6.1	2	0.050	*	1.1	0.29	
HEAV	Number of "heavy" contaminations	0.4	0.53		0.4	1	0.53		0.4	0.53	
CLEA	Number of "not clear" contaminations	0.0	1.00		0.0	0	1.00		0.0	1.00	
CON1	Time in most contaminating jobs	3.1	0.077		14.5	2	0.0007	*	3.2	0.075	
CON2	Time in any contaminating job	3.3	0.068		8.6	2	0.014	*	3.5	0.062	
C4: Work area/job (weighted days in 12 week pre-conception period)											
JB1	R&DD - chemical	0.3	0.58		0.4	2	0.82		0.4	0.55	
JB2	R&DD - mechanical	1.4	0.24		1.4	2	0.51		1.4	0.24	
JB4	High level waste #								0.7	0.41	
JB6	Effluent plant	2.80	0.090		15.4	2	0.0005	+	2.7	0.10	
JB7	Windscale pile & B29 #								1.0	0.31	
JB8	Calder #								0.0	0.90	
JB9	Ponds West	1.3	0.25		1.3	2	0.52		1.3	0.25	
JB12	Reprocessing (old) #								2.2	0.14	
JB16	Fuel plants	0.0	0.88		17.4	2	0.0002	*	0.0	0.86	
JB17	Windscale Nuclear Labs #								1.1	0.30	
JB18	Advanced Gas Reactor #								0.6	0.44	
JB19	Main workshop #								0.4	0.50	
JB20	Graphite workshop #								3.2	0.076	
JB21	Maintenance - sep area	0.0	0.83		7.2	2	0.028	*	0.0	0.86	
JB22	Maintenance - non active #								0.3	0.56	
JB25	Changerooms	0.1	0.71		0.3	2	0.86		0.1	0.70	
JB29	Training #								5.6	0.020	+
JB31	Police #								2.8	0.10	
	# All non-zero case and control values equal: continuous, 2 group and 3 group analyses are identical.										
D: Variables evaluated between conception and diagnosis											
D1: Actual and potential contamination											
NDCN	Total decontamination visits	5.0	0.025	+							
NBEG	Number of beta/gamma contaminations	9.1	0.003	+							
HEAV	Number of "heavy" contaminations	4.0	0.046	+							
CLEA	Number of "not clear" contaminations	1.0	0.33								
CON1	Time in most contaminating jobs	0.1	0.71								
CON2	Time in any contaminating job	0.7	0.42								
D2: Work area/job											
PJ1	R&DD - chemical								0.1	0.70	
PJ6	Effluent plant								3.1	0.081	
PJ7	Windscale piles & B29								0.2	0.63	
PJ8	Calder								0.0	0.90	
PJ9	Ponds West								0.7	0.40	
PJ12	Reprocessing (old)								0.2	0.67	
PJ13	Reprocessing (new)								0.1	0.77	
PJ16	Fuel plants								2.6	0.11	
PJ17	Windscale Nuclear Labs								0.5	0.49	
PJ19	Main workshop								2.1	0.15	
PJ20	Graphite workshop								0.0	0.87	
PJ21	Maintenance - sep area								0.0	0.95	
PJ25	Changerooms								0.0	0.97	
PJ31	Police								1.8	0.18	

Table A-8: Leukaemia & NHL cases by child's date of birth

		Lymphatic leukaemia & NHL								
		Cases				95% CI		LR test Change in:		
Date of birth	Controls	Obs	Exp	O/E	OR	from	to	deviance	df	p
1950-54	14	2	0.44	4.58						
1955-59	25	0	0.68	0.00	0.00	0.00	1.19			
1960-64	29	4	0.73	5.45	1.13	0.17	7.38			
1965-69	19	3	0.48	6.19	1.42	0.19	10.60			
1970-74	21	1	0.75	1.34	0.25	0.02	3.22	12.7	7	0.08
1975-79	20	0	0.47	0.00	0.00	0.00	1.72			
1980-84	23	2	0.35	5.78	1.11	0.13	9.32			
1985 +	28	0	0.11	0.00	0.00	0.00	7.41			
Most significant 2-group split										
1950-69	87	9	2.33	3.86						
1970+	92	3	1.67	1.80	0.43	0.11	1.66	1.6	1	0.20

		All leukaemias & NHL								
		Cases				95% CI		LR test Change in:		
Date of birth	Controls	Obs	Exp	O/E	OR	from	to	deviance	df	p
1950-54	14	2	0.76	2.63						
1955-59	25	3	1.13	2.65	0.95	0.13	6.87			
1960-64	29	4	1.12	3.56	1.28	0.20	8.40			
1965-69	19	3	0.68	4.41	1.74	0.23	12.89	3.9	7	0.79
1970-74	21	1	0.95	1.05	0.34	0.03	4.41			
1975-79	20	1	0.57	1.74	0.57	0.04	7.29			
1980-84	23	2	0.42	4.74	1.59	0.19	13.32			
1985 +	28	0	0.15	0.00	0.01	0.00	9.36			
Most significant 2-group split										
1950-69	87	12	3.70	3.25						
1970+	92	4	2.10	1.91	0.52	0.16	1.74	1.2	1	0.27

Table A-9: Leukaemia & NHL cases by father's date of start at Sellafield

		Lymphatic leukaemia & NHL								
		Cases				95% CI		LR test Change in:		
Date of start	Controls	Obs	Exp	O/E	OR	from	to	deviance	df	p
1950-54	43	3	1.11	2.70						
1955-59	29	3	0.72	4.15	1.66	0.30	9.11			
1960-64	13	4	0.42	9.60	5.05	0.93	27.54			
1965-69	12	0	0.25	0.00	0.00	0.00	5.52			
1970-74	22	0	0.56	0.00	0.00	0.00	2.44	11.4	7	0.12
1975-79	38	2	0.74	2.71	1.03	0.16	6.76			
1980-84	11	0	0.12	0.00	0.00	0.00	11.06			
1985 +	11	0	0.08	0.00	0.00	0.00	18.19			
Most significant 2-group split										
1950-64	85	10	2.25	4.44						
1965+	94	2	1.75	1.14	0.23	0.05	0.92	4.3	1	0.038

		All leukaemias & NHL								
		Cases				95% CI		LR test Change in:		
Date of start	Controls	Obs	Exp	O/E	OR	from	to	deviance	df	p
1950-54	43	6	1.82	3.30						
1955-59	29	3	1.14	2.62	0.78	0.17	3.53			
1960-64	13	4	0.60	6.66	2.63	0.59	11.82			
1965-69	12	0	0.31	0.00	0.00	0.00	3.61			
1970-74	22	0	0.72	0.00	0.00	0.00	1.55	10.8	7	0.15
1975-79	38	2	0.92	2.18	0.61	0.11	3.38			
1980-84	11	1	0.17	5.98	2.12	0.18	25.11			
1985 +	11	0	0.12	0.00	0.00	0.00	9.65			
Most significant 2-group split										
1950-64	85	13	3.56	3.65						
1965+	94	3	2.23	1.34	0.32	0.09	1.18	3.5	1	0.063

Table A-10: Leukaemia & NHL cases by father's date of leaving Sellafield

		Lymphatic leukaemia & NHL								
		Cases				95% CI		LR test Change in:		
Quit date	Controls	Obs	Exp	O/E	OR	from	to	deviance	df	p
1950-54	6	0	0.13	0.00	0.002	0.00	8.04			
1955-59	5	0	0.16	0.00	0.0006	0.00	6.53			
1960-64	12	0	0.44	0.00	0.0006	0.00	2.38			
1965-69	10	1	0.26	3.86	1.09	0.12	10.14	10.1	7	0.18
1970-74	8	0	0.32	0.00	0.0005	0.00	3.27			
1975-79	13	3	0.32	9.26	3.39	0.71	16.23			
1980-84	20	1	0.38	2.60	0.69	0.08	6.10			
1985 +	105	7	1.98	3.53						
Most significant 2-group split										
1950-74	41	1	1.31	0.76						
1975+	138	11	2.69	4.09	5.97	1.09	112	4.3	1	0.038

		All leukaemias & NHL								
		Cases				95% CI		LR test Change in:		
Quit date	Controls	Obs	Exp	O/E	OR	from	to	deviance	df	p
1950-54	6	1	0.21	4.66	1.32	0.13	13.07			
1955-59	5	0	0.29	0.00	0.0008	0.00	3.45			
1960-64	12	0	0.69	0.00	0.0009	0.00	1.45			
1965-69	10	1	0.39	2.54	0.65	0.07	5.80	11.3	7	0.13
1970-74	8	0	0.43	0.00	0.0009	0.00	2.33			
1975-79	13	3	0.51	5.93	2.03	0.44	9.32			
1980-84	20	1	0.56	1.79	0.43	0.05	3.69			
1985 +	105	10	2.71	3.69						
Most significant 2-group split										
1950-74	41	2	2.02	0.99						
1975+	138	14	3.78	3.71	4.19	1.11	27.1	4.4	1	0.037

Note: Odds ratios calculated relative to the final (1985+) sub-group.

Table A-11: Leukaemia & NHL cases by date of diagnosis

	Lymphatic leukaemia & NHL					
	Cases			95% CI		
Date of diagnosis	Obs	Exp	O/E	from	to	
1950-59	0	0.22	0.00	0.00	17.6	Confidence intervals
1960-69	3	0.73	4.11	0.84	12.4	for O/E ratios.
1970-79	6	1.33	4.51	1.64	10.1	Test for equal
1980+	3	1.71	1.75	0.36	5.21	O/E ratios, p=0.32

	All leukaemia & NHL					
	Cases			95% CI		
Date of diagnosis	Obs	Exp	O/E	from	to	
1950-59	0	0.38	0.00	0.00	10.2	Confidence intervals
1960-69	4	1.26	3.17	0.86	8.43	for O/E ratios.
1970-79	7	1.85	3.78	1.50	8.03	Test for equal
1980+	5	2.30	2.17	0.70	5.17	O/E ratios, p=0.39

Note: Since controls do not have a diagnosis date, there is no corresponding control distribution by this factor. The expected case numbers in each period are calculated from the number and age distribution of all controls alive and under observation in that period.

Table A-12: Leukaemia & NHL cases by selected explanatory factors

Data in table are for Lymphatic leukaemia & NHL, numbers of non-lymphatic leukaemias are shown in parentheses.
Full 3-group data for all leukaemia & NHL shown in Table A-57.

Variable	Controls	Cases		O/E	OR	95% CI		LR test Change in:		
		Obs	Exp			from	to	deviance	df	p
Sex										
Male	93	6 (3)	2.33	2.58						
Female	86	6 (1)	1.68	3.58	1.40	0.43	4.55	0.3	1	0.58
Father's age										
<25	36	0	0.85	0.00	0.00	0.00	0.91			
25-34	109	8 (2)	2.30	3.48	0.70	0.19	2.56	6.4	2	0.042
35+	33	4 (2)	0.84	4.79						
Seascale resident at birth										
No	140	8 (2)	3.73	2.15						
Yes	39	4 (2)	0.28	14.44	6.97	1.98	24.59	7.0	1	0.0080
Father's birth place										
Cumbria	103	8 (1)	2.56	3.13						
Elsewhere	62	4 (3)	1.12	3.56	1.12	0.32	3.95	0.0	1	0.86
Job class										
Industrial	118	9 (2)	3.10	2.91						
Non-industrial	61	3 (2)	0.91	3.31	1.09	0.29	4.16	0.0	1	0.30
Work on Calder during total pre-conception period										
<=5% of time	164	7 (4)	3.68	1.90						
>5% of time	15	5	0.32	15.48	12.63	3.24	49.23	11.6	1	0.00067

Table A-13: Observed and expected leukaemia & NHL cases by residence at birth, distance from plant and migration index of birth place/area.

Birth place/Band	Distance (km) from plant	Migration index	Controls	Cases (LNHL) Observed	Expected	O/E ratio	95% CI from	to
Band 1	<3	1.00	2	0	0.092	0	0	85
Seascale	3	4.49	39	6	0.41	14.8	5.2	31
Band 2	3-7	0.23	13	1	0.60	1.66	0.04	11.4
Egremont	7	0.56	14	2	0.52	3.88	0.45	17
Band 3	7-11	0.33	12	0	0.34	0	0	13
Cleator Moor	11	0.26	18	1	0.81	1.23	0.03	7.9
Band 4	11-13.5	0.15	5	0	0.16	0	0	39
Frizington	13.5	0.43	10	1	0.35	2.83	0.07	21
Band 5	13.5-15	0.00	2	0	0.10	0	0	78
Whitehaven	15	0.28	35	4	1.44	2.78	0.74	7.8
Band 6	>15	0.15	29	1	0.97	1.03	0.03	6.2
Totals								
population centres (all)			116	14	3.53	3.97	2.12	6.9
population centres (excluding Seascale)			77	8	3.12	2.56	1.08	5.3
other			63	2	2.26	0.88	0.11	3.3

Table A-14: Leukaemia & NHL cases by time from father's start date to child's conception date (or quit date if earlier) (variable TIME)

Data in table are for Lymphatic leukaemia & NHL, numbers of non-lymphatic leukaemias are shown in parentheses.
Full 3-group data for all leukaemia & NHL shown in Table A-57.

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	0.408	0.494						
TIME	0.162	0.061	1.176	1.043	1.326	6.2	1	0.013

Grouped analyses	Cases					95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
TIME = 0	24	2 (1)	0.96	2.07					
TIME 0.1 to m	78	3 (1)	1.60	1.87	0.83	0.13	5.49	0.28	0.18
TIME > m	77	7 (2)	1.43	4.88	2.36	0.44	12.73		
2 groups									
TIME = 0	24	2 (1)	0.96	2.07					
Exposed (>0)	155	10 (3)	3.04	3.29	1.53	0.31	7.65	0.60	

Median non-zero TIME value for controls (m) = 4.01 years

Table A-15: Leukaemia & NHL cases by father's cumulative recorded external radiation exposure prior to child's conception (variable XG)

Data in table are for Lymphatic leukaemia & NHL, numbers of non-lymphatic leukaemias are shown in parentheses.
Full 3-group data for all leukaemia & NHL shown in Table A-57.

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	0.526	0.443						
XG	0.010	0.004	1.010	1.003	1.018	7.5	1	0.0063

Grouped analyses	Cases					95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
4 groups									
0	35	2 (2)	1.23	1.62				0.58	0.17
0.1-49 mSv	89	4	1.48	2.71	1.64	0.28	9.66		
50-99 mSv	27	3 (1)	0.69	4.37	2.84	0.43	18.88		
100+ mSv	28	3 (1)	0.61	4.93	3.19	0.48	21.24		
3 groups									
0	35	2 (2)	1.23	1.62					
0.1-33.2 mSv	72	3	1.19	2.52	1.52	0.24	9.83	0.38	0.17
33.3+ mSv	72	7 (2)	1.58	4.43	2.84	0.54	14.84		
2 groups									
0	35	2 (2)	1.23	1.62					
>0	144	10 (2)	2.77	3.61	2.25	0.47	10.72	0.29	

Median non-zero XG value for controls (m) = 33.2 mSv

Table A-16: Leukaemia & NHL cases by duration of father's assessed potential exposure to butex during the total pre-conception period (variable C7)

Data in table is for all leukaemia & NHL, numbers of lymphatic leukaemias (included in total) are shown in parentheses.
Full 3-group data for lymphatic leukaemia & NHL shown in Table A-56.

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	1.220	0.429						
C7	0.001	0.001	1.001	1.000	1.002	2.5	1	0.11

Grouped analyses		Cases				95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	65	6 (5)	1.63	3.68					
C7 0.1 to m	12	0	0.45	0.00	0.00	0.00	2.24	0.037	0.29
C7 > m	11	3 (1)	0.28	10.77	4.00	0.77	20.82		
2 groups									
Unexposed	65	6 (5)	1.63	3.68					
Exposed (>0)	23	3 (1)	0.73	4.14	1.16	0.26	5.26	>0.5	

Median non-zero C7 value for controls (m) = 570.4 weighted days

Table A-17: Leukaemia & NHL cases by duration of father's assessed potential exposure to chromates/di-chromates during the total pre-conception period (variable C8)

Data in table is for all leukaemia & NHL, numbers of lymphatic leukaemias (included in total) are shown in parentheses.
Full 3-group data for lymphatic leukaemia & NHL shown in Table A-56.

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	0.672	0.479						
C8	0.003	0.001	1.003	1.001	1.004	8.2	1	0.0043

Grouped analyses		Cases				95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	59	4	1.63	2.46					
C8 0.1 to m	16	0	0.54	0.00	0.00	0.00	2.78	0.016	0.079
C8>m	16	4 (2)	0.41	9.80	5.34	1.11	25.69		
2 groups									
Unexposed	59	4	1.63	2.46					
Exposed (>0)	32	4	0.95	4.20	1.84	0.42	8.10	0.42	

Median non-zero C8 value for controls (m) = 300.2 weighted days

Table A-18: Leukaemia & NHL cases by duration of father's assessed potential exposure to trichloroethylene during the total pre-conception period (variable C23)

Data in table is for all leukaemia & NHL, numbers of lymphatic leukaemias (included in total) are shown in parentheses.
Full 3-group data for lymphatic leukaemia & NHL shown in Table A-56.

Continuous analysis			OR increment per unit	95% CI		LR test Change in:		
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	0.877	0.552						
C23	0.001	0.000	1.001	1.000	1.002	3.2	1	0.074

Grouped analyses	Cases					95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	13	1 (1)	0.34	2.98					
C23 0.1 to m	37	1 (1)	1.11	0.90	0.28	0.02	4.94	0.027	0.035
C23 > m	37	8 (6)	1.12	7.16	2.97	0.32	27.54		
2 groups									
C23 <= m	50	2 (2)	1.45	1.38					
C23 > m	37	8 (6)	1.12	7.16	6.75	1.37	33.4	0.011	
2 groups									
Unexposed	13	1 (1)	0.34	2.99					
Exposed (>0)	74	9 (7)	2.23	4.03	1.45	0.16	12.86	0.73	

Median non-zero C23 value for controls (m) = 450.5 weighted days

Table A-19: Leukaemia & NHL cases by duration of father's assessed potential exposure to TTA during the total pre-conception period (variable C26)

Data in table is for all leukaemia & NHL, numbers of lymphatic leukaemias (included in total) are shown in parentheses.
Full 3-group data for lymphatic leukaemia & NHL shown in Table A-56.

Continuous analysis			OR increment per unit	95% CI		LR test Change in:		
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	1.605	0.331						
C26	0.001	0.001	1.001	0.999	1.003	0.5	1	0.47

Grouped analyses	Cases					95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	94	9 (8)	2.33	3.86					
C26 0.1 to m	8	0	0.22	0.00	0.00	0.00	4.37	0.017	0.050
C26 > m	7	3 (1)	0.15	20.68	10.29	1.83	57.90		
2 groups									
Unexposed	94	9 (8)	2.33	3.86					
Exposed (>0)	15	3 (1)	0.36	8.25	2.58	0.58	11.52	0.24	

Median non-zero C26 value for controls (m) = 329.3 weighted days

Table A-20: Leukaemia & NHL cases by duration of father's assessed potential exposure to tritium prior to child's conception (based on original tritium assessment variables TRI1 and TEN1).

Data in table are for Lymphatic leukaemia & NHL, numbers of non-lymphatic leukaemias are shown in parentheses. Full 3-group data for all leukaemia & NHL shown in Table A-57.

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	0.915	0.433						
TRI1	0.010	0.0016	1.010	1.007	1.013	22.9	1	<.00001

Grouped analyses		Cases				95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups (variable TRI1)									
Unexposed	87	5 (4)	2.13	2.35					
TRI1 0.1 to m	8	2	0.13	14.97	8.29	1.26	54.7	0.0057	0.0018
TRI1 > m	7	3	0.15	20.29	15.9	2.52	100.6		
2 groups (variable TEN1)									
Unexposed	87	5	2.13	2.35					
Exposed	18	5	0.37	13.54	7.77	1.91	31.5	0.0059	

Median non-zero TRI1 value for controls (m) = 168 weighted days

Table A-21: Leukaemia and NHL cases by measures of father's involvement in contamination incidents prior to child's conception

Variable	Lymphatic leukaemia & NHL							
	Cases				95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
All contamination incidents									
0	139	7	2.98	2.35				0.21	0.096
1 or 2	26	2	0.67	3.00	1.32	0.25	6.94		
>2	14	3	0.36	8.41	4.31	0.95	19.6		
Alpha contaminations									
0	170	10	3.78	2.64				0.27	0.11
1	6	1	0.16	6.38	2.66	0.28	25.5		
>1	3	1	0.07	14.97	9.37	0.63	139		
Beta/gamma contaminations									
0	143	7	3.08	2.27				0.31	0.13
1 or 2	24	3	0.61	4.89	2.40	0.56	10.4		
>2	12	2	0.31	6.45	3.23	0.57	18.1		
"Heavy" contaminations									
0	168	11	3.76	2.93				0.40	0.91
1	6	1	0.11	9.20	3.68	0.36	37.4		
>1	5	0	0.13	0.00	0.01	0.00	9.51		
"Not clear" contaminations									
0	174	11	3.87	2.84				0.64	0.44
1	4	1	0.11	8.05	3.43	0.32	36.3		
>1	1	0	0.01	0.00	0.07	0.00	193		

Variable	All leukaemia & NHL							
	Cases				95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
All contamination incidents									
0	139	9	4.33	2.08				0.20	0.078
1 or 2	26	4	0.98	4.09	2.22	0.61	8.11		
>2	14	3	0.49	6.15	3.48	0.80	15.13		
Alpha contaminations									
0	170	14	5.46	2.56				0.41	0.20
1	6	1	0.24	4.10	1.69	0.18	15.86		
>1	3	1	0.091	11.0	6.66	0.46	93.51		
Beta/gamma contaminations									
0	143	9	4.48	2.01				0.13	0.088
1 or 2	24	5	0.89	5.60	3.47	1.01	11.89		
>2	12	2	0.42	4.81	2.67	0.49	14.43		
"Heavy" contaminations									
0	168	15	5.47	2.73				0.42	0.76
1	6	1	0.14	6.94	2.85	0.28	28.46		
>1	5	0	0.18	0.00	0.011	0.00	7.66		
"Not clear" contaminations									
0	174	14	5.60	2.50				0.033	0.021
1	4	1	0.19	5.39	2.51	0.24	26.01		
>1	1	1	0.012	86.5	264	2.62	26556		

Table A-22: Leukaemia & NHL cases by father's time in "most contaminating" jobs prior to child's conception (variable CON1)

Lymphatic leukaemia & NHL

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	1.299	0.331						
CON1	-0.0003	0.0005	0.9997	0.9987	1.0010	0.3	1	0.58

Grouped analyses		Cases (LLNH)				95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	123	9	2.73	3.29					
CON1 0.1 to m	28	1	0.62	1.61	0.45	0.05	3.78	0.73	0.73
CON1 > m	28	2	0.65	3.09	0.90	0.18	4.52		
2 groups									
Unexposed	123	9	2.73	3.29					
Exposed (>0)	56	3	1.27	2.36	0.68	0.18	2.59	0.57	

All leukaemia & NHL

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	1.321	0.292						
CON1	-0.0005	0.0005	0.9995	0.9984	1.0000	1.3	1	0.26

Grouped analyses		Cases (LNHL)				95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	123	13	3.96	3.28					
CON1 0.1 to m	28	1	0.89	1.12	0.30	0.04	2.40	0.37	0.30
CON1 > m	28	2	0.94	2.13	0.59	0.12	2.82		
2 groups									
Unexposed	123	13	3.96	3.28					
Exposed (>0)	56	3	1.83	1.64	0.44	0.12	1.62	0.20	

Median non-zero CON1 value for controls (m) = 933.5 days

Table A-23: Leukaemia & NHL cases by father's time in any "contaminating" jobs prior to child's conception (variable CON2)

Lymphatic leukaemia & NHL

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	0.851	0.381						
CON2	0.00038	0.00018	1.000	1.000	1.001	3.5	1	0.061

Grouped analyses	Cases (LLNH)					95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	76	6	1.96	3.05					
CON2 0.1 to m	52	1	1.14	0.88	0.26	0.03	2.14	0.12	0.46
CON2 > m	51	5	0.90	5.56	1.85	0.51	6.63		
2 groups									
Unexposed	76	6	1.97	3.05					
Exposed (>0)	103	6	2.04	2.95	0.91	0.28	2.98	0.88	

All leukaemia & NHL

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	0.803	0.334						
CON2	0.00039	0.00016	1.000	1.000	1.001	4.7	1	0.031

Grouped analyses	Cases (LNHL)					95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	76	8	2.86	2.80					
CON2 0.1 to m	52	1	1.64	0.61	0.18	0.02	1.48	0.026	0.33
CON2 > m	51	7	1.29	5.42	2.01	0.65	6.19		
2 groups									
Unexposed	76	8	2.86	2.80					
Exposed (>0)	103	8	2.93	2.73	0.91	0.32	2.60	0.85	

Median non-zero CON2 value for controls (m) = 1199 days

Table A-24: Leukaemia & NHL cases by duration of father's monitored exposure to tritium during the 12 weeks before conception (variable ITRI)

Data in table is for all leukaemia & NHL, numbers of lymphatic leukaemias (included in total) are shown in parentheses.
Full 3-group data for lymphatic leukaemia & NHL shown in Table A-56.

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	1.072	0.281						
ITRI	11.159	3.328	70160	103	4.8E+07	7.8	1	0.0051

Grouped analyses	Cases					95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	177	15 (12)	5.70	2.63					
ITRI 0.1 to m	1	0	0.038	0.00	0.033	0.00	36.98	0.17	0.11
ITRI > m	1	1	0.057	17.41	47.1	0.52	4250		
2 groups									
Unexposed	177	15 (12)	5.70	2.63					
Exposed (>0)	2	1	0.10	10.48	6.76	0.41	110	0.21	

Median non-zero ITRI value for controls (m) = 0.175 mSv.

Table A-25: Leukaemia & NHL cases by duration of father's assessed potential exposure to hydrofluoric acid during the 12 weeks before conception (variable C12)

Data in table are for Lymphatic leukaemia & NHL, numbers of non-lymphatic leukaemias are shown in parentheses.
Full 3-group data for all leukaemia & NHL shown in Table A-57.

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	1.110	0.438						
C12	0.043	0.019	1.044	1.006	1.085	3.8	1	0.051

Grouped analyses	Cases					95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	98	5 (2)	1.94	2.57					
C12 0.1 to m	7	1	0.09	11.10	4.80	0.46	49.7	0.13	0.046
C12 > m	4	1	0.04	26.8	14.21	1.12	180		
2 groups									
Unexposed	98	5 (2)	1.94	2.57					
Exposed (>0)	11	2	0.13	15.70	7.27	0.95	40.4	0.058	

Median non-zero C12 value for controls (m) = 14 weighted days

Table A-26: Leukaemia & NHL cases by duration of father's assessed potential exposure to picric acid during the 12 weeks before conception (variable C17)

Data in table are for Lymphatic leukaemia & NHL, numbers of non-lymphatic leukaemias are shown in parentheses.
Full 3-group data for all leukaemia & NHL shown in Table A-57.

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	1.308	0.382						
C17	0.074	0.029	1.077	1.017	1.140	5.2	1	0.022

Grouped analyses	Cases					95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	111	8 (2)	2.18	3.66					
C17 0.1 to m	4	0	0.08	0.00	0.00	0.00	12.50	0.00015	0.019
C17 > m	0	1	0.00	--					
				(Fisher exact test, C17>m vs. C17<=m, p=0.073)					
2 groups									
Unexposed	111	8 (2)	2.18	3.66					
Exposed (>0)	4	1	0.08	12.42	4.46	0.38	52.3	0.28	

Median non-zero C17 value for controls (m) = 42 weighted days

Table A-27: Leukaemia & NHL cases by duration of father's assessed potential exposure to TTA during the 12 weeks before conception (variable C26)

Data in table is for all leukaemia & NHL, numbers of lymphatic leukaemias (included in total) are shown in parentheses.
Full 3-group data for lymphatic leukaemia & NHL shown in Table A-56.

Continuous analysis			OR increment per unit			LR test Change in:		
				95% CI				
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	1.419	0.350						
C26	0.050	0.023	1.052	1.005	1.101	4.0	1	0.045

Grouped analyses	Cases					95% CI			p for
	Controls	Obs	Exp	O/E	OR	from	to	p	trend
3 groups									
Unexposed	96	9 (8)	2.56	3.50					
C26 0.1 to m	6	1	0.081	12.37	3.62	0.38	34.83	0.27	0.11
C26 > m	2	1 (1)	0.071	14.17	8.68	0.43	173.8		
2 groups									
Unexposed	96	9 (8)	2.56	3.50					
Exposed (>0)	8	2 (1)	0.015	13.21	4.81	0.80	29.0	0.12	

Median non-zero C26 value for controls (m) = 14 weighted days

Table A-28: Cases of cancer other than leukaemia or NHL by child's date of birth and father's dates of employment at Sellafield

Date of birth		Cases				95% CI		LR test Change in:		
	Controls	Obs	Exp	O/E	OR	from	to	deviance	df	p
1950-54	14	4	1.67	2.39						
1955-59	25	1	2.72	0.37	0.10	0.01	1.06			
1960-64	29	8	3.07	2.61	0.97	0.22	4.26			
1965-69	19	1	1.52	0.66	0.18	0.02	1.96			
1970-74	21	1	1.52	0.66	0.18	0.02	1.94	12.4	7	0.088
1975-79	20	1	0.76	1.31	0.36	0.03	3.87			
1980-84	23	0	0.56	0.00	0.00	0.00	2.76			
1985 +	28	0	0.23	0.00	0.00	0.00	6.71			
Most significant 2-group split										
1950-64	68	13	7.46	1.74				3.85	1	0.05
1965+	111	3	4.59	0.65	0.30	0.08	1.00			

Date of start		Cases				95% CI		LR test Change in:		
	Controls	Obs	Exp	O/E	OR	from	to	deviance	df	p
1950-54	43	5	4.08	1.22						
1955-59	29	6	2.89	2.07	2.06	0.54	7.78			
1960-64	13	1	1.32	0.76	0.60	0.06	5.88			
1965-69	12	1	0.45	2.21	1.72	0.18	16.81			
1970-74	22	1	1.36	0.74	0.59	0.06	5.87	4.5	7	0.72
1975-79	38	2	1.29	1.55	1.22	0.21	7.00			
1980-84	11	0	0.31	0.00	0.01	0.00	12.10			
1985 +	11	0	0.35	0.00	0.01	0.00	10.42			
Most significant 2-group split										
1950-59	72	11	6.97	1.58				1.0	1	0.31
1960+	107	5	5.08	0.98	0.56	0.18	1.75			

Date of quit		Cases				95% CI		LR test Change in:		
	Controls	Obs	Exp	O/E	OR#	from	to	deviance	df	p
1950-54	6	0	0.56	0.00	0.00	0	6.87			
1955-59	5	1	0.69	1.45	1.87	0.16	21.6			
1960-64	12	5	1.65	3.03	5.83	1.29	26.4			
1965-69	10	2	0.90	2.22	2.70	0.44	16.7	10.18	7	0.18
1970-74	8	0	0.81	0.00	0.00	0.00	4.75			
1975-79	13	2	1.12	1.78	2.33	0.37	1.47			
1980-84	20	1	1.12	0.90	0.92	0.10	8.59			
1985 +	105	5	5.20	0.96						

Note: Odds ratios based on 1985+ group

Most significant 2-group split										
1950-69	33	8	3.80	2.10				3.33	1	0.068
1970+	146	8	8.25	0.97	0.36	0.12	1.06			

Date of diagnosis	Cases			95% CI		
	Obs	Exp	O/E	from	to	
1950-59	1	0.36	2.78	0.07	16.4	Confidence intervals
1960-69	2	1.24	1.61	0.19	6.01	for O/E ratios.
1970-79	5	4.73	1.06	0.34	2.53	p for equal O/E
1980+	8	5.71	1.40	0.60	2.82	ratios > 0.5

Table A-29: Cases of cancer other than leukaemia & NHL cases by selected explanatory factors

Variable	Controls	Cases Obs	Cases Exp	O/E	OR	95% CI from	95% CI to	LR test Change in: deviance	df	p
Sex										
Male	93	6	5.94	1.01						
Female	86	10	6.11	1.64	1.81	0.61	5.33	1.2	1	0.28
Father's age										
<25	36	1	2.16	0.46						
25-34	109	11	6.61	1.66	4.14	0.50	34.1	2.4	2	0.30
35+	33	4	3.17	1.26	3.09	0.32	30.0			
Seascale resident at birth										
No	140	15	11.21	1.34						
Yes	39	1	0.85	1.18	0.75	0.10	5.85	0.1	1	>0.5
Father's birth place										
Cumbria	103	7	7.59	0.92						
Elsewhere	62	8	3.22	2.49	3.00	0.94	9.33	3.7	1	0.053
Father's external radiation dose (mSv)										
0	35	6	4.36	1.38						
0.1-33.2	72	8	3.06	2.62	1.76	0.53	5.85	7.7	2	0.022
33.3+	72	2	4.64	0.43	0.24	0.04	1.28			
Work on Calder during total pre-conception period										
<=5% of time	164	14	11.10	1.26						
>5% of time	15	2	0.95	2.11	1.71	0.34	8.73	0.4	1	>0.5

Table A-30: Observed and expected cancers other than leukaemia & NHL cases by residence at birth, distance from plant and migration index of birth place/area.

Birth place/Band	Distance (km) from plant	Migration index	Controls	Cases (LNHL) Observed	Expected	O/E ratio	95% CI from	to
Band 1	<3	1.00	2	0	0.16	0.00	0.00	49
Seascale	3	4.49	39	1	0.85	1.18	0.03	7.0
Band 2	3-7	0.23	13	1	1.46	0.69	0.02	4.7
Egremont	7	0.56	14	3	0.98	3.08	0.60	11.3
Band 3	7-11	0.33	12	0	0.70	0.00	0.00	6.3
Cleator Moor	11	0.26	18	1	1.75	0.57	0.01	3.7
Band 4	11-13.5	0.15	5	1	0.29	3.41	0.09	37
Frizington	13.5	0.43	10	2	0.88	2.28	0.27	11.0
Band 5	13.5-15	0.00	2	0	0.20	0.00	0.00	39
Whitehaven	15	0.28	35	7	2.85	2.46	0.95	5.6
Band 6	>15	0.15	29	0	1.95	0.00	0.00	2.0
Totals:	population centres		116	14	7.30	1.92	1.03	3.4
	other		63	2	4.75	0.42	0.05	1.6

Table A-31: Cases of cancer other than leukaemia & NHL by duration of father's assessed potential to graphite dust during the 12 weeks before conception (variable C10)

Continuous analysis			OR increment per unit	95% CI		LR test Change in:		
Coeff.	Estimate	se	Estimate	from	to	deviance	df	p
Mean	-0.741	0.773						
C10	0.062	0.028	1.064	1.007	1.125	5.4	1	0.020

Grouped analyses	Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
3 groups									
Unexposed	63	1	2.88	0.35					
C10 0.1 to m	11	1	0.58	1.71	5.50	0.31	98.9	0.059	0.020
C10 > m	2	1	0.12	8.40	143	1.81	11317		
2 groups									
Unexposed	63	1	2.88	0.35					
Exposed (>0)	13	2	0.70	2.85	10.28	0.82	129	0.064	

Median non-zero C10 value for controls (m) = 14 weighted days

Table A-32: Cases of cancer other than leukaemia & NHL by father's recorded and potential involvement in contamination incidents after child's conception.

Contamination variables				Crude	Increase in OR for unit increase in variable	95% CI		
Variable		Controls	Cases	OR	Estimate	from	to	p
Total decontamination visits	0	126	11					0.025
	1-5	28	2	0.8	1.24	1.05	1.46	
	>5	2	3	17.2				
Number of beta/gamma contaminations	0	131	11					0.003
	>0	25	5	2.4	1.41	1.15	1.74	
Number of "heavy" contaminations	0	149	13					0.046
	>0	7	3	4.9	2.17	1.22	3.87	
Number of "not clear" contaminations	0	153	15					0.327
	>0	3	1	3.4	3.42	0.41	28.81	
Years in most contaminating jobs	0	106	11					0.708
	>0	50	5	1.0	1.02	0.92	1.12	
Years in any contaminating job	0	65	8					0.415
	>0	91	8	0.7	1.03	0.96	1.10	

Table A-33: Observed and expected cases by age at diagnosis and case group

Case group	Age at diagnosis	Cases Obs	Exp	O/E	p (O=E)
LLNH	**0-14**	9	3.02	2.98	0.0087
	15+	3	1.00	3.00	0.16
LNHL	**0-14**	11	4.23	2.60	0.0096
	15+	5	1.57	3.18	0.046
OCAN	**0-14**	5	5.30	0.94	>0.5
	15+	11	6.80	1.62	0.18

Table A-34: Observed and expected LNHL cases diagnosed at ages 15+, by selected explanatory variables

Variable	Cases Obs	Exp	O/E	p (O=E)	p (equal O/Es)
Seascale resident at birth					
No	4	1.47	2.72	0.13	
Yes	1	0.1	10.0	0.19	0.33
Father's pre-conception radiation dose (mSv)					
0	3	0.65	4.62	0.061	
0.1-49	1	0.42	2.38	>0.5	
50-99	0	0.28	-	>0.5	0.50
100+	1	0.21	4.76	0.38	
Father's date of start					
1950-64	4	1.25	3.20	0.08	
1965+	1	0.32	3.13	>0.5	>0.5
Child's date of birth					
1950-69	5	1.43	3.50	0.034	
1970+	0	0.14	-	>0.5	0.33
Working on Calder					
<5%	5	1.46	3.42	0.035	
>=5%	0	0.11	-	>0.5	0.39
Potential tritium exposure					
0	3	1.41	2.13	0.34	
>0	2	0.16	12.5	0.024	0.074

Table A-35: Leukaemia/NHL cases by Seascale residence at birth (SEAS) and father's pre-conception radiation dose (XG4V)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			7.0	1	0.0080
2	XG4V	SEAS		1.8	1	0.18
2	SEAS	XG4V		7.4	1	0.0066
3	XG4V			1.4	1	0.23
4	Interaction	SEAS	XG4V	6.8	1	0.0094

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const.	0.4838	0.4877	4	const.	0.9468	0.461
	SEAS	2.008	0.6548		SEAS	0.1226	1.169
	XG4V	0.006259	0.0045		XG4V	-0.002	0.006568
					Interaction	0.0272	0.01131

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
External radiation (mSv)						
0	2	1.22	1.65	0	0.02	0.00
1-49	4	1.29	3.11	0	0.19	0.00
50-99	1	0.64	1.55	2	0.04	47.3
100+	1	0.58	1.72	2	0.03	71.6

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			11.9	1	0.00055
2	XG4V	SEAS		2.2	1	0.14
2	SEAS	XG4V		12.4	1	0.00043
3	XG4V			1.8	1	0.18
4	Interaction	SEAS	XG4V	12.7	1	0.00037

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const.	0.3672	0.4295	4	const.	0.941	0.4088
	SEAS	2.222	0.564		SEAS	0.0178	1.007
	XG4V	0.006273	0.004		XG4V	-0.005	0.006755
					Interaction	0.0348	0.01099

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
External radiation (mSv)						
0	4	1.85	2.17	0	0.02	0.00
1-49	4	1.79	2.24	0	0.28	0.00
50-99	1	0.94	1.07	3	0.07	44.8
100+	1	0.82	1.22	3	0.04	75.0

Table A-36: Leukaemia/NHL cases by Seascale residence at birth (SEAS) and pre-conception Calder work (PJ8)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			7.0	1	0.0080
2	PJ8	SEAS		12.3	1	0.00044
2	SEAS	PJ8		7.8	1	0.0052
3	PJ8			11.6	1	0.00067
4	Interaction	SEAS	PJ8	1.9	1	0.17

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	0.2671	0.4754
	SEAS	2.192	0.7106
	PJ8	2.663	0.712

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
Calder						
<5% of time	5	3.42	1.46	2	0.26	7.74
>=5% of time	3	0.30	9.85	2	0.02	107

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			11.9	1	0.00055
2	PJ8	SEAS		9.5	1	0.0021
2	SEAS	PJ8		12.9	1	0.00034
3	PJ8			8.6	1	0.0034
4	Interaction	SEAS	PJ8	1.4	1	0.25

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	0.3234	0.4001
	SEAS	2.349	0.5988
	PJ8	2.232	0.6769

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
Calder						
<5% of time	7	4.96	1.41	4	0.38	10.6
>=5% of time	3	0.43	7.02	2	0.03	73.5

Table A-37: Leukaemia/NHL cases by Seascale residence at birth (SEAS) and pre-conception potential tritium exposure (TEN2)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			6.4	1	0.011
2	TEN2	SEAS		4.9	1	0.027
3	TEN2			5.3	1	0.021
2	SEAS	TEN2		6.0	1	0.014
4	Interaction	SEAS	TEN2	0.0	1	1.00

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	0.7006	0.4281
	SEAS	1.709	0.6679
	TEN2	1.514	0.6442

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
Tritium	Obs	Exp	O/E	Obs	Exp	O/E
0	5	2.70	1.85	2	0.20	10.2
>0	3	0.41	7.28	2	0.06	35.6
Unknown	0	0.61	0.00	0	0.03	0.00

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			10.9	1	0.0010
2	TEN2	SEAS		4.6	1	0.031
3	TEN2			9.4	1	0.0021
2	SEAS	TEN2		6.1	1	0.014
4	Interaction	SEAS	TEN2	0.2	1	0.69

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const	0.6587	0.382
	SEAS	1.955	0.5806
	TEN2	1.336	0.5909

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
Tritium	Obs	Exp	O/E	Obs	Exp	O/E
0	7	3.87	1.81	3	0.28	10.6
>0	3	0.59	5.09	3	0.08	36.2
Unknown	0	0.93	0.00	0	0.04	0.00

Table A-38: Leukaemia/NHL cases by Seascale residence at birth (SEAS) and pre-conception potential exposure to trichloroethylene (C23)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			4.3	1	0.038
2	C23	SEAS		3.6	1	0.059
2	SEAS	C23		4.2	1	0.041
3	C23			3.7	1	0.054
4	Interaction	SEAS	C23	0.2	1	0.66

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	0.3436	0.7602
	SEAS	1.78	0.7961
	C23	1.499	0.8356

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
C23						
<=median	1	0.93	1.07	1	0.09	10.6
>median	4	0.71	5.66	2	0.08	25.2
unknown	3	2.08	1.44	1	0.10	9.71

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			10.1	1	0.0015
2	C23	SEAS		6.5	1	0.011
2	SEAS	C23		10.2	1	0.0014
3	C23			6.5	1	0.011
4	Interaction	SEAS	C23	0.0	1	0.88

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	-0.3274	0.8262
	SEAS	2.443	0.7348
	C23	1.93	0.8445

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
C23						
<=median	1	1.31	0.77	1	0.14	6.99
>median	4	1.00	3.99	4	0.12	34.7
unknown	5	3.08	1.62	1	0.15	6.81

Table A-39: Leukaemia/NHL cases by Seascale residence at birth (SEAS) and father's date of start at Sellafield (LDOS)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			7.0	1	0.0080
2	LDOS	SEAS		3.7	1	0.053
2	SEAS	LDOS		6.5	1	0.011
3	LDOS			4.3	1	0.038
4	Interaction	SEAS	LDOS	1.5	1	0.22

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	1.276	0.4032
	SEAS	1.872	0.6578
	LDOS	-1.371	0.7829

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
Father's start						
before 1965	6	2.07	2.89	4	0.18	22.4
after 1965	2	1.65	1.21	0	0.10	0.00

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			11.9	1	0.00055
2	LDOS	SEAS		2.8	1	0.095
2	SEAS	LDOS		11.3	1	0.00080
3	LDOS			3.5	1	0.062
4	Interaction	SEAS	LDOS	2.8	1	0.092

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	1.045	0.368
	SEAS	2.119	0.5714
	LDOS	-1.032	0.6659

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
Father's start						
before 1965	7	3.28	2.13	6	0.28	21.4
after 1965	3	2.11	1.42	0	0.12	0.00

Table A-40: Leukaemia/NHL cases by father's pre-conception radiation dose (XG4V) and Calder work (PJ8)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	XG4V			1.4	1	0.23
2	PJ8	XG4V		10.1	1	0.0015
2	XG4V	PJ8		0.0	1	1.00
3	PJ8			11.6	1	0.00067
4	Interaction	PJ8	XG4V	3.3	1	0.071

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const.	0.7279	0.4479	4	const	0.3630	0.5366
	XG4V	-0.00022	0.0053		XG4V	0.0068	0.005751
	PJ8	2.55	0.7716		PJ8	4.0110	1.112
					Interaction	-0.018	0.01019

Cross-tabulation of grouped data

	Calder					
	<5% of time			>=5% of time		
	Obs	Exp	O/E	Obs	Exp	O/E
External radiation (mSv)						
0	2	1.23	1.62	0	0.00	0.00
1-49	2	1.36	1.47	2	0.11	18.0
50-99	1	0.64	1.55	2	0.04	47.6
100+	2	0.44	4.57	1	0.17	5.87

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	XG4V			1.8	1	0.18
2	PJ8	XG4V		6.9	1	0.0085
2	XG4V	PJ8		0.1	1	0.72
3	PJ8			8.6	1	0.0034
4	Interaction	PJ8	XG4V	3.6	1	0.059

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const.	0.7718	0.376	4	const	0.4977	0.4255
	XG4V	0.001626	0.0044		XG4V	0.0067	0.004731
	PJ8	1.968	0.7088		PJ8	3.4970	1.061
					Interaction	-0.018	0.009645

Cross-tabulation of grouped data

	Calder					
	<5% of time			>=5% of time		
	Obs	Exp	O/E	Obs	Exp	O/E
External radiation (mSv)						
0	4	1.87	2.14	0	0.00	0.00
1-49	2	1.90	1.05	2	0.16	12.6
50-99	2	0.94	2.13	2	0.06	31.8
100+	3	0.63	4.78	1	0.23	4.30

Table A-41: Leukaemia/NHL cases by father's pre-conception radiation dose (XG4V) and potential tritium exposure (TEN2)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for	LR test deviance	df	p
1	XG4V		1.9	1	0.17
2	TEN2	XG4V	4.6	1	0.032
2	XG4V	TEN2	0.4	1	0.51
3	TEN2		6.0	1	0.014
4	Interaction	XG4V TEN2	1.7	1	0.19

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	0.847	0.456
	XG4V	0.0033	0.0049
	TEN2	1.547	0.694

Cross-tabulation of grouped data

	Tritium								
	0			>0			Unknown		
External radiation (mSv)	Obs	Exp	O/E	Obs	Exp	O/E	Obs	Exp	O/E
0	2	1.23	1.62	0	0.00	0.00	0	0.00	0.00
1-49	2	1.01	1.98	2	0.18	11.0	0	0.28	0.00
50-99	1	0.32	3.12	2	0.11	17.7	0	0.25	0.00
100+	2	0.33	6.01	1	0.17	5.78	0	0.10	0.00

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for	LR test deviance	df	p
1	XG4V		2.4	1	0.12
2	TEN2	XG4V	4.4	1	0.037
2	XG4V	TEN2	0.7	1	0.41
3	TEN2		6.1	1	0.014
4	Interaction	XG4V TEN2	0.4	1	0.52

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	0.877	0.390
	XG4V	0.0037	0.0043
	TEN2	1.377	0.632

Cross-tabulation of grouped data

	Tritium								
	0			>0			Unknown		
External radiation (mSv)	Obs	Exp	O/E	Obs	Exp	O/E	Obs	Exp	O/E
0	4	1.87	2.14	0	0.00	0.00	0	0.00	0.00
1-49	2	1.38	1.45	2	0.25	7.95	0	0.43	0.00
50-99	2	0.45	4.41	2	0.16	12.8	0	0.39	0.00
100+	2	0.44	4.50	2	0.26	7.56	0	0.15	0.00

Table A-42: Leukaemia/NHL cases by father's pre-conception radiation dose (XG4V) and potential trichloroethylene exposure (C23)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for	LR test deviance	df	p
1	XG4V		0.5	1	0.47
2	C23	XG4V	3.2	1	0.073
2	XG4V	C23	0.0	1	0.88
3	C23		3.7	1	0.054
4	Interaction	XG4V C23	4.0	1	0.046

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const.	0.682	0.790	4	const.	-0.7033	1.41
	XG4V	0.0010	0.0063		XG4V	0.0186	0.0107
	C23	1.502	0.893		C23	3.5470	1.581
					Interaction	-0.026	0.01361

Cross-tabulation of grouped data

	Trichlororethylene								
	<=median			>median			Unknown		
External radiation (mSv)	Obs	Exp	O/E	Obs	Exp	O/E	Obs	Exp	O/E
0	0	0.10	0.00	0	0.00	0.00	2	1.13	1.77
1-49	0	0.65	0.00	3	0.25	11.9	1	0.58	1.74
50-99	1	0.15	6.88	2	0.31	6.53	0	0.24	0.00
100+	1	0.14	7.39	1	0.23	4.38	1	0.24	4.09

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for	LR test deviance	df	p
1	XG4V		1.8	1	0.19
2	C23	XG4V	5.1	1	0.024
2	XG4V	C23	0.3	1	0.57
3	C23		6.5	1	0.011
4	Interaction	XG4V C23	3.0	1	0.083

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const.	0.226	0.765	4	const.	-1.0630	1.41
	XG4V	0.0033	0.0057		XG4V	0.0190	0.01072
	C23	1.782	0.844		C23	3.5690	1.561
					Interaction	-0.022	0.01265

Cross-tabulation of grouped data

	Trichlororethylene								
	<=median			>median			Unknown		
External radiation (mSv)	Obs	Exp	O/E	Obs	Exp	O/E	Obs	Exp	O/E
0	0	0.17	0.00	0	0.00	0.00	4	1.70	2.35
1-49	0	0.89	0.00	3	0.35	8.52	1	0.82	1.22
50-99	1	0.21	4.85	3	0.44	6.88	0	0.36	0.00
100+	1	0.18	5.50	2	0.33	6.08	1	0.35	2.86

Table A-43: Leukaemia/NHL cases by father's pre-conception radiation dose (XG4V) and date of start at Sellafield (LDOS)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	XG4V			1.4	1	0.23
2	LDOS	XG4V		3.5	1	0.062
2	XG4V	LDOS		0.6	1	0.44
3	LDOS			4.3	1	0.038
4	Interaction	XG4V	LDOS	1.1	1	0.29

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	1.416	0.4761
	XG4V	0.003647	0.0046
	LDOS	-1.362	0.7982

Cross-tabulation of grouped data

	Father's date of start					
	before 1965			since 1965		
	Obs	Exp	O/E	Obs	Exp	O/E
External radiation (mSv)						
0	1	0.54	1.84	1	0.69	1.46
1-49	3	0.75	4.03	1	0.73	1.37
50-99	3	0.49	6.11	0	0.20	0.00
100+	3	0.47	6.35	0	0.14	0.00

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	XG4V			1.8	1	0.18
2	LDOS	XG4V		2.7	1	0.10
2	XG4V	LDOS		1.0	1	0.33
3	LDOS			3.5	1	0.062
4	Interaction	XG4V	LDOS	2.6	1	0.11

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	1.253	0.4233
	XG4V	0.0041	0.0041
	LDOS	-1.031	0.6788

Cross-tabulation of grouped data

	Father's date of start					
	before 1965			since 1965		
	Obs	Exp	O/E	Obs	Exp	O/E
External radiation (mSv)						
0	2	0.96	2.09	2	0.91	2.20
1-49	3	1.15	2.61	1	0.91	1.10
50-99	4	0.76	5.27	0	0.24	0.00
100+	4	0.69	5.77	0	0.17	0.00

Table A-44: Leukaemia/NHL cases by father's pre-conception Calder work (PJ8) and potential tritium exosure (TEN2)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	PJ8			9.9	1	0.0017
2	TEN2	PJ8		9.5	1	0.0021
3	TEN2			13.3	1	0.00026
2	PJ8	TEN2		6.0	1	0.014
4	Interaction	PJ8	TEN2	7.5	1	0.0063

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const	0.1151	0.5857	4	const	0.5035	0.5168
	PJ8	2.949	0.7965		PJ8	2.065	0.8462
	TEN2	2.385	0.7688		TEN2	1.567	0.8175
					interaction	5.297	1.759

Cross-tabulation of grouped data

	Calder					
	<5% of time			>=5% of time		
Tritium	Obs	Exp	O/E	Obs	Exp	O/E
0	4	2.59	1.55	3	0.31	9.64
>0	3	0.46	6.57	2	0.01	170
Unknown	0	0.64	0.00	0	0.00	0.00

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	PJ8			6.9	1	0.0087
2	TEN2	PJ8		8.4	1	0.0037
3	TEN2			9.2	1	0.0024
2	PJ8	TEN2		6.1	1	0.014
4	Interaction	PJ8	TEN2	8.4	1	0.0039

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const	0.5202	0.431	4	const	0.7551	0.4005
	PJ8	2.239	0.7008		PJ8	1.471	0.7805
	TEN2	1.932	0.643		TEN2	1.31	0.6942
					Interaction	5.521	1.71

Cross-tabulation of grouped data

	Calder					
	<5% of time			>=5% of time		
Tritium	Obs	Exp	O/E	Obs	Exp	O/E
0	7	3.71	1.89	3	0.44	6.84
>0	4	0.66	6.10	2	0.02	123
Unknown	0	0.97	0.00	0	0.00	0.00

Table A-45: Leukaemia/NHL cases by father's pre-conception Calder work (PJ8) and potential trichloroethylene exposure (C23)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	PJ8			7.3	1	0.0070
2	C23	PJ8		7.7	1	0.0057
2	PJ8	C23		11.2	1	0.00081
3	C23			3.7	1	0.054
4	Interaction	PJ8	C23	0.9	1	0.34

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	-0.8817	1.114
	PJ8	3.273	1.008
	C23	2.633	1.087

Cross-tabulation of grouped data

	Calder					
	<5% of time			>=5% of time		
	Obs	Exp	O/E	Obs	Exp	O/E
C23						
<=median	0	0.83	0.00	2	0.20	9.89
>median	4	0.74	5.40	2	0.05	43.4
unknowm	3	2.11	1.42	1	0.07	13.4

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	PJ8			5.1	1	0.023
2	C23	PJ8		10.6	1	0.0012
2	PJ8	C23		9.2	1	0.0024
3	C23			6.5	1	0.011
4	Interaction	PJ8	C23	1.4	1	0.24

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	-0.9161	1.042
	PJ8	2.856	0.9642
	C23	2.825	1.036

Cross-tabulation of grouped data

	Calder					
	<5% of time			>=5% of time		
	Obs	Exp	O/E	Obs	Exp	O/E
C23						
<=median	0	1.16	0.00	2	0.29	6.94
>median	6	1.05	5.73	2	0.07	28.6
unknowm	5	3.13	1.60	1	0.10	10.4

Table A-46: Leukaemia/NHL cases by father's pre-conception Calder work (PJ8) and date of start at Sellafield (LDOS)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	PJ8			11.6	1	0.00067
2	LDOS	PJ8		3.7	1	0.054
2	PJ8	LDOS		11.0	1	0.00093
3	LDOS			4.3	1	0.038
4	Interaction	PJ8	LDOS	0.1	1	0.74

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	1.155	0.4221
	PJ8	2.522	0.7157
	LDOS	-1.44	0.8106

Cross-tabulation of grouped data

	Calder					
	<5% of time			>=5% of time		
Father's start	Obs	Exp	O/E	Obs	Exp	O/E
before 1965	6	2.04	2.95	4	0.22	18.5
after 1965	1	1.64	0.61	1	0.11	9.39

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	PJ8			8.6	1	0.0034
2	LDOS	PJ8		3.0	1	0.081
2	PJ8	LDOS		8.1	1	0.0043
3	LDOS			3.5	1	0.062
4	Interaction	PJ8	LDOS	0.0	1	0.84

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const.	1.177	0.3545
	PJ8	2.059	0.6769
	LDOS	-1.109	0.6834

Cross-tabulation of grouped data

	Calder					
	<5% of time			>=5% of time		
Father's start	Obs	Exp	O/E	Obs	Exp	O/E
before 1965	9	3.24	2.78	4	0.32	12.3
after 1965	2	2.10	0.95	1	0.13	7.67

Table A-47: Leukaemia/NHL cases by father's pre-conception potential exposure to tritium (TEN2) and to trichloroethylene (C23)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	C23			5.0	1	0.026
2	TEN2	C23		3.7	1	0.053
2	C23	TEN2		1.9	1	0.17
3	TEN2			6.8	1	0.0090
4	Interaction	C23	TEN2	2.2	1	0.14

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
1	const.	0.833	0.710	2	const.	0.5162	0.7828
	C23	1.788	0.851		C23	1.235	0.9353
					TEN2	1.668	0.8741
3	const.	1.018	0.590				
	TEN2	2.095	0.807				

Cross-tabulation of grouped data

	Tritium								
	0			>0			Unknown		
C23	Obs	Exp	O/E	Obs	Exp	O/E	Obs	Exp	O/E
<=median	2	0.85	2.36	0	0.09	0.00	0	0.10	0.00
>median	1	1.72	0.58	5	0.26	19.3	0	0.20	0.00
unknown	4	0.33	12.3	0	0.12	0.00	0	0.34	0.00

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	C23			8.6	1	0.0033
2	TEN2	C23		3.5	1	0.060
2	C23	TEN2		4.5	1	0.034
3	TEN2			7.7	1	0.0055
4	Interaction	C23	TEN2	1.8	1	0.17

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
1	const.	0.490	0.710	2	const.	0.2179	0.7456
	C23	2.210	0.829		C23	1.764	0.8728
					TEN2	1.507	0.7981
3	const.	1.003	0.522				
	TEN2	2.045	0.742				

Cross-tabulation of grouped data

	Tritium								
	0			>0			Unknown		
C23	Obs	Exp	O/E	Obs	Exp	O/E	Obs	Exp	O/E
<=median	2	1.19	1.68	0	0.12	0.00	0	0.14	0.00
>median	2	0.44	4.55	6	0.37	16.3	0	0.31	0.00
unknown	6	2.52	2.38	0	0.18	0.00	0	0.52	0.00

Table A-48: Leukaemia/NHL cases by father's date of start at Sellafield (LDOS) and pre-conception potential exposure to tritium (TEN2)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	LDOS			6.5	1	0.011
2	TEN2	LDOS		4.8	1	0.028
2	LDOS	TEN2		5.3	1	0.021
3	TEN2			6.0	1	0.014
4	Interaction	LDOS	TEN2	1.9	1	0.17

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const	1.578	0.4388
	LDOS	-1.661	0.8009
	TEN2	1.549	0.6745

Cross-tabulation of grouped data

	Father's date of start					
	before 1965			since 1965		
Tritium	Obs	Exp	O/E	Obs	Exp	O/E
0	5	1.38	3.63	2	1.52	1.31
>0	5	0.30	16.7	0	0.17	0.00
unknown	0	0.58	0.00	0	0.06	0.00

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	LDOS			5.9	1	0.015
2	TEN2	LDOS		4.9	1	0.027
2	LDOS	TEN2		4.7	1	0.030
3	TEN2			6.1	1	0.014
4	Interaction	LDOS	TEN2	2.6	1	0.11

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const	1.515	0.385
	LDOS	-1.364	0.683
	TEN2	1.431	0.6191

Cross-tabulation of grouped data

	Father's date of start					
	before 1965			since 1965		
Tritium	Obs	Exp	O/E	Obs	Exp	O/E
0	7	2.20	3.18	3	1.95	1.54
>0	6	0.47	12.9	0	0.21	0.00
unknown	0	0.89	0.00	0	0.08	0.00

Table A-49: Leukaemia/NHL cases by father's date of start at Sellafield (LDOS) and pre-conception potential exposure to trichloroethylene (C23)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	C23			3.7	1	0.054
2	LDOS	C23		8.6	1	0.0033
2	C23	LDOS		3.1	1	0.079
3	LDOS			9.3	1	0.0023
4	Interaction	C23	LDOS	0.0	1	1.00

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const	1.393	0.7466
	LDOS	-8.484	16.3
	C23	1.476	0.897

Cross-tabulation of grouped data

	Father's date of start					
	before 1965			since 1965		
C23	Obs	Exp	O/E	Obs	Exp	O/E
<=median	2	0.55	3.61	0	0.47	0.00
>median	6	0.51	11.7	0	0.27	0.00
unknown	2	1.18	1.69	2	1.00	1.99

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	C23			6.5	1	0.011
2	LDOS	C23		9.6	1	0.0019
2	C23	LDOS		6.0	1	0.014
3	LDOS			10.2	1	0.0014
4	Interaction	C23	LDOS	0.0	1	1.00

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const	0.9496	0.7447
	LDOS	-7.588	9.75
	C23	1.954	0.8772

Cross-tabulation of grouped data

	Father's date of start					
	before 1965			since 1965		
C23	Obs	Exp	O/E	Obs	Exp	O/E
<=median	2	0.86	2.33	0	0.59	0.00
>median	8	0.78	10.2	0	0.34	0.00
unknown	3	1.92	1.56	3	1.30	2.30

Table A-50: Leukaemia/NHL cases by father's date of start at Sellafield (LDOS) and child's date of birth (LDOB)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	LDOS			4.3	1	0.038
2	LDOB	LDOS		0.6	1	0.46
3	LDOB			3.2	1	0.072
2	LDOS	LDOB		1.6	1	0.20
4	Interaction	LDOS	LDOB	4.3	1	0.039

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
1	const	1.656	0.3429	3	const	1.504	0.3589
	LDOS	-1.473	0.7859		LDOB	-0.849	0.6926
2	const	1.591	0.3599	4	const	1.47	0.3787
	LDOS	-2.175	1.21		LDOS	1.882	1.043
	LDOB	0.838	1.088		LDOB	0.3863	1.207
					Interaction	-4.142	1.846

Cross-tabulation of grouped data

	Father's date of start					
	before 1965			since 1965		
	Obs	Exp	O/E	Obs	Exp	O/E
Date of birth						
before 1970	8	2.12	3.78	1	0.21	4.68
since 1970	2	0.14	14.8	1	1.54	0.65

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	LDOS			3.5	1	0.062
2	LDOB	LDOS		0.6	1	0.43
3	LDOB			2.9	1	0.089
2	LDOS	LDOB		1.2	1	0.27
4	Interaction	LDOS	LDOB	2.8	1	0.092

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
1	const	1.517	0.3086	3	const	1.383	0.3184
	LDOS	-1.15	0.6694		LDOB	-0.645	0.6108
2	const	1.462	0.3202	4	const	1.376	0.3318
	LDOS	-1.846	1.097		LDOS	0.0889	1.181
	LDOB	0.8301	1.02		LDOB	1.737	1.025
					Interaction	-3.113	1.686

Cross-tabulation of grouped data

	Father's date of start					
	before 1965			since 1965		
	Obs	Exp	O/E	Obs	Exp	O/E
Date of birth						
before 1970	11	3.39	3.24	1	0.31	3.27
since 1970	2	0.17	11.7	2	1.92	1.04

Table A-51: Leukaemia/NHL cases by Seascale residence at birth (SEAS) and father's birthplace (FBTH)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			7.7	1	0.0054
2	FBTH	SEAS		1.0	1	0.33
3	FBTH			8.7	1	0.0033
2	SEAS	FBTH		0.0	1	0.85
4	Interaction	SEAS	FBTH	0.2	1	0.63

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const	1.096	0.3935
	SEAS	2.445	0.7719
	FBTH	-0.7208	0.7592

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
Father's birthplace						
Cumbria	7	2.78	2.52	1	0.10	10.5
Elsewhere	1	0.94	1.06	3	0.18	16.5

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Analysis of deviance

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			13.0	1	0.00030
2	FBTH	SEAS		0.1	1	0.74
3	FBTH			11.9	1	0.00057
2	SEAS	FBTH		1.3	1	0.26
4	Interaction	SEAS	FBTH	0.3	1	0.59

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const	0.8849	0.3671
	SEAS	2.404	0.66
	FBTH	-0.2105	0.6336

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
Father's birthplace						
Cumbria	8	4.05	1.98	1	0.14	7.08
Elsewhere	2	1.34	1.49	5	0.26	19.0

Table A-52: Leukaemia/NHL cases by Seascale residence at birth (SEAS) and father's radiation dose in the 12 weeks before conception

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			7.036	1	0.0080
2	XT	SEAS		1.55	1	0.21
2	SEAS	XT		7.4	1	0.0065
3	XT			1.186	1	0.28
4	Interaction	SEAS	XT	0.9	1	0.34

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const.	0.5347	0.4746	4	const.	0.6802	0.4749
	SEAS	2.013	0.6552		SEAS	1.453	0.9127
	XT	0.1123	0.0865		XT	0.0665	0.1019
					Interaction	0.1899	0.1981

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
External radiation (mSv)	Obs	Exp	O/E	Obs	Exp	O/E
0	3	1.68	1.78	0	0.040	0.0
0.1-2.4	2	0.99	2.03	2	0.17	11.4
2.5-4.9	1	0.42	2.36	1	0.042	24.0
5 +	2	0.63	3.15	1	0.020	48.9
p for trend			>0.5			0.18

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			11.9335	1	0.00055
2	XT	SEAS		3.46	1	0.063
2	SEAS	XT		12.54	1	0.00040
3	XT			2.8535	1	0.091
4	Interaction	SEAS	XT	7.582	1	0.0059

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const.	0.2995	0.4298	4	const.	0.6933	0.4064
	SEAS	2.246	0.5678		SEAS	0.6285	0.9169
	XT	0.1466	0.0754		XT	0.0162	0.09865
					Interaction	0.5139	0.1999

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
External radiation (mSv)	Obs	Exp	O/E	Obs	Exp	O/E
0	5	2.51	1.99	0	0.054	0.0
0.1-2.4	2	1.35	1.48	2	0.26	7.8
2.5-4.9	1	0.63	1.59	1	0.062	16.0
5 +	2	0.89	2.24	3	0.033	89.7
p for trend			>0.5			0.005

Table A-53: Leukaemia/NHL cases by Seascale residence at birth (SEAS) and father's total recorded pre-conception contaminations (NDCN)

A: Case group LLNH (lymphatic leukaemia & non-Hodgkin's lymphoma)

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			7.0	1	0.0080
2	NDCN	SEAS		1.3	1	0.26
2	SEAS	NDCN		7.6	1	0.0057
3	NDCN			0.7	1	0.42
4	Interaction	SEAS	NDCN	4.7	1	0.031

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const.	0.6908	0.4101	4	const.	0.7493	0.4039
	SEAS	2.068	0.6649		SEAS	1.264	0.8766
	NDCN	0.1438	0.1161		NDCN	0.1015	0.1273
					Interaction	1.541	0.72

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
Number of decontaminations						
0	5	2.75	1.82	2	0.23	8.67
1-2	0	0.62	0.00	2	0.046	43.21
>2	3	0.36	8.40	0	0.00	--
p for trend			0.13			0.14

B: Case group LNHL (all leukaemia & non-Hodgkin's lymphoma)

Model No.	Variable added	Controlling for		LR test deviance	df	p
1	SEAS			11.9335	1	0.00055
2	NDCN	SEAS		1.5	1	0.22
2	SEAS	NDCN		12.77	1	0.00035
3	NDCN			0.6635	1	0.42
4	Interaction	SEAS	NDCN	12.272	1	0.00046

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
2	const.	0.573	0.3649	4	const.	0.6644	0.3577
	SEAS	2.279	0.5727		SEAS	1.079	0.8133
	NDCN	0.1481	0.1103		NDCN	0.0736	0.1295
					Interaction	2.396	0.7439

Cross-tabulation of grouped data

	Seascale resident at birth					
	No			Yes		
	Obs	Exp	O/E	Obs	Exp	O/E
Number of decontaminations						
0	7	3.99	1.75	2	0.34	5.96
1-2	0	0.91	0.00	4	0.069	57.70
>2	3	0.49	6.15	0	0.00	--
p for trend			0.26			0.0071

Table A-54: Joint analysis of leukaemia & NHL cases by cumulative (XG) and 12-week (XT) pre-conception radiation dose, for Seascale subjects only

A: Lymphatic leukaemia & NHL (LLNH)

Analysis of deviance

Model No.	Variable added	Controlling for	LR test deviance	df	p
1	XG		23.78	1	1E-06
2	XT	XG	0.01	1	>0.5
2	XG	XT	23.59	1	1E-06
3	XT		0.197	1	>0.5

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
1	const	-2.201	2.241	2	const	-2.2	2.25
	XG	0.06402	0.017		XG	0.0647	0.0193
					XT	-0.03	0.4237
3	const	2.634	0.6579				
	XT	0.0774	0.165				

Cross-tabulation of grouped data

12 week pre-conception dose	Cumulative pre-conception dose					
	<50 mSv			50+ mSv		
	Obs	Exp	O/E	Obs	Exp	O/E
<2.5 mSv	0	0.161	0	2	0.054	37.3
2.5+ mSv	0	0.045	0	2	0.017	120.3
All 12-week doses	0	0.207	0	4	0.070	57.0
p for trend:			>0.5			0.26

B: All leukaemia & NHL (LNHL)

Analysis of deviance

Model No.	Variable added	Controlling for	LR test deviance	df	p
1	XG		31.14	1	2E-08
2	XT	XG	3.95	1	0.047
2	XG	XT	31.13	1	2E-08
3	XT		3.965	1	0.046

Details of selected models:

Model No.	Variable	Estimate (log odds)	se	Model No.	Variable	Estimate (log odds)	se
1	const	-1.154	1.478	2	const	-2.869	2.143
	XG	0.05946	0.0131		XG	0.0617	0.0151
					XT	0.3868	0.196
3	const	2.195	0.6328				
	XT	0.2682	0.1372				

Cross-tabulation of grouped data

12 week pre-conception dose	Cumulative pre-conception dose					
	<50 mSv			50+ mSv		
	Obs	Exp	O/E	Obs	Exp	O/E
<2.5 mSv	0	0.230	0	2	0.080	25.1
2.5+ mSv	0	0.069	0	4	0.027	146.3
All 12-week doses	0	0.298	0	6	0.107	56.1
p for trend:			>0.5			0.033

Table A-55: Joint analysis of all leukaemia & NHL cases by cumulative pre-conception radiation dose (XG) and number of pre-conception decontaminations (NDCN) for Seascale subjects only

A: Lymphatic leukaemia & NHL (LLNH)

Analysis of deviance

Model No.	Variable added	Controlling for	LR test deviance	df	p
1	XG		23.78	1	1E-06
2	NDCN	XG	6.54	1	0.011
2	XG	NDCN	24.94	1	6E-07
3	NDCN		5.38	1	0.02

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const	-8.273	6.131
	XG	0.1011	0.0443
	NDCN	3.257	1.802

Cross-tabulation of grouped data

Number of decontaminations	Cumulative pre-conception dose					
	<50 mSv			50+ mSv		
	Obs	Exp	O/E	Obs	Exp	O/E
0	0	0.186	0.0	2	0.045	44.3
>0	0	0.021	0.0	2	0.025	79.9
Total	0	0.207	0.0	4	0.070	57.0
p for trend:			>0.5			>0.5

B: All leukaemia & NHL (LNHL)

Analysis of deviance

Model No.	Variable added	Controlling for	LR test deviance	df	p
1	XG		31.14	1	2E-08
2	NDCN	XG	16.31	1	5E-05
2	XG	NDCN	33.95	1	2E-08
3	NDCN		13.49	1	0.0002

Details of selected models:

Model No.	Variable	Estimate (log odds)	se
2	const	-13.24	5.784
	XG	0.1356	0.041
	NDCN	4.908	1.493

Cross-tabulation of grouped data

Number of decontaminations	Cumulative pre-conception dose					
	<50 mSv			50+ mSv		
	Obs	Exp	O/E	Obs	Exp	O/E
0	0	0.268	0.0	2	0.068	29.5
>0	0	0.030	0.0	4	0.039	102.3
Total	0	0.298	0.0	6	0.107	56.1
p for trend:			>0.5			0.13

Table A-56: Observed and expected cases, and odds ratio's for lymphatic leukaemia and non-Hodgkin's lymphoma (LLNH)

A: Variables not dependent on choice of pre-conception exposure window

			Cases				95% CI			p for
		Controls	Obs	Exp	O/E	OR	from	to	p	trend
DOBQ	1950-69	87	9	2.33	3.86				0.20	
	1970+	92	3	1.67	1.80	0.43	0.11	1.66		
DOSQ	1950-64	85	10	2.25	4.44				0.038	
	1965+	94	2	1.75	1.14	0.23	0.05	0.92		
QUIQ	1950-74	41	1	1.31	0.76				0.038	
	1975+	138	11	2.70	4.09	5.97	1.09	112		
DODX	1950-59	-	0	0.22	0.00	-	0.00	17.6	95% confidence	
	1960-69	-	3	0.73	4.11	-	0.84	12.4	limits for O/E.	
	1970-79	-	6	1.33	4.51	-	1.64	10.1	Test for equal	
	1980+	-	3	1.71	1.75	-	0.36	5.21	O/E ratios, p=0.32	
SEX	Male	93	6	2.33	2.58				0.58	
	Female	86	6	1.68	3.58	1.40	0.43	4.55		
FAGE	<25	36	0	0.85	0.00	0.0007	0	0.91	0.042	
	25-34	109	8	2.30	3.48	0.70	0.19	2.56		
	35+	33	4	0.84	4.79					
FBTH	Cumbria	103	8	2.56	3.13				0.86	
	Elsewhere	62	4	1.12	3.56	1.12	0.32	3.95		
SEAS	Born elsewhere	140	8	3.73	2.15				0.0080	
	Seascale born	39	4	0.28	14.44	6.97	1.98	24.6		
JOBC	Industrial	118	9	3.10	2.91				0.90	
	Non-industrial	61	3	0.91	3.31	1.09	0.29	4.16		
PCE	Yes	155	10	3.04	3.29				0.60	
	No	24	2	0.96	2.07	0.65	0.13	3.28		
TIME	0	24	2	0.97	2.07				0.28	0.18
	0.1 to 4 years	78	3	1.60	1.87	0.83	0.13	5.49		
	> 4 years	77	7	1.43	4.88	2.36	0.44	12.7		
DIST	<= 11.5 km	98	7	1.90	3.69				0.46	
	> 11.5 km	81	5	2.11	2.37	0.64	0.19	2.12		
MIGR	<= 0.28	102	6	2.79	2.15				0.92	
	> 0.28	77	6	1.21	4.95	1.02	0.95	1.08		

B: Variables evaluated over total pre-conception period

B1: Measured radiation exposure

			Cases				95% CI			p for
		Controls	Obs	Exp	O/E	OR	from	to	p	trend
XG	Unexposed	35	2	1.23	1.62				0.38	0.17
	Exposed - low half	72	3	1.19	2.52	1.52	0.24	9.83		
	Exposed - top half	72	7	1.58	4.43	2.84	0.54	14.8		
HIDA	Unexposed	114	7	2.47	2.84				0.94	0.98
	Exposed - low half	37	3	0.82	3.65	1.27	0.31	5.25		
	Exposed - top half	28	2	0.71	2.81	0.95	0.19	4.84		
RMAX	Unexposed	35	2	1.23	1.62				0.47	0.59
	Exposed - low half	72	5	1.09	4.59	2.82	0.52	15.3		
	Exposed - top half	71	5	1.68	2.98	1.87	0.35	10.1		

continued..

Table A-56 (cont.)		Controls	Cases Obs	Exp	O/E	95% CI OR	from	to	p	p for trend
NEUT	Unexposed	133	7	3.10	2.26				0.21	0.080
	Exposed - low half	23	2	0.54	3.73	1.74	0.33	9.29		
	Exposed - top half	23	3	0.37	8.21	4.09	0.94	17.8		
NHI	Unexposed	162	11	3.63	3.03				0.66	0.71
	Exposed - low half	9	1	0.26	3.89	1.38	0.15	12.9		
	Exposed - top half	8	0	0.12	0.00	0.01	0.00	10.5		
IT	Unexposed	105	7	2.41	2.91				0.56	0.64
	Exposed - low half	37	1	0.66	1.51	0.48	0.06	4.06		
	Exposed - top half	37	4	0.93	4.30	1.51	0.41	5.61		
IA	Unexposed	113	7	2.57	2.73				0.91	0.66
	Exposed - low half	33	2	0.63	3.17	1.16	0.22	6.11		
	Exposed - top half	33	3	0.80	3.74	1.38	0.33	5.80		
ITRI	Unexposed	174	12	3.86	3.11				0.63	0.34
	Exposed - low half	3	0	0.07	0.00	0.01	0.00	18.3		
	Exposed - top half	2	0	0.08	0.00	0.00	0.00	15.5		
B2: Assessed exposure to chemicals and other workplace exposures										
C2	Unexposed	77	8	1.45	5.50				0.38	0.16
	Exposed - low half	4	0	0.08	0.00	0.00	0.00	8.59		
	Exposed - top half	4	0	0.09	0.00	0.00	0.00	7.12		
C3	Unexposed	99	8	1.88	4.25				0.39	0.25
	Exposed - low half	3	0	0.03	0.00	0.04	0.00	34.7		
	Exposed - top half	3	1	0.06	18.16	6.71	0.48	94.0		
C4	Unexposed	43	4	0.74	5.43				0.24	0.089
	Exposed - low half	10	0	0.19	0.00	0.00	0.00	3.58		
	Exposed - top half	9	0	0.11	0.00	0.00	0.00	6.42		
C7	Unexposed	65	5	1.18	4.23				0.28	0.82
	Exposed - low half	12	0	0.30	0.00	0.00	0.00	2.96		
	Exposed - top half	11	1	0.17	5.76	1.38	0.14	13.8		
C8	Unexposed	59	4	1.17	3.43				0.18	0.63
	Exposed - low half	16	0	0.37	0.00	0.00	0.00	2.94		
	Exposed - top half	16	2	0.29	6.90	2.19	0.35	13.8		
C9	Unexposed	119	9	2.40	3.75				0.14	0.070
	Exposed - low half	2	0	0.02	0.00	0.04	0.00	54.2		
	Exposed - top half	2	1	0.02	54.28	26.12	1.50	455		
C10	Unexposed	53	4	0.94	4.26				0.21	0.80
	Exposed - low half	7	2	0.18	10.84	3.36	0.46	24.6		
	Exposed - top half	7	0	0.17	0.00	0.00	0.00	5.20		
C11	Unexposed	68	5	1.09	4.59				0.92	0.70
	Exposed - low half	7	1	0.22	4.50	1.09	0.10	11.7		
	Exposed - top half	6	1	0.14	7.06	1.68	0.16	17.8		
C12	Unexposed	87	5	1.63	3.07				0.23	0.18
	Exposed - low half	8	2	0.19	10.67	4.49	0.79	38.3		
	Exposed - top half	8	1	0.12	8.05	2.90	0.28	29.7		
C13	Unexposed	58	5	1.00	5.00				0.92	0.68
	Exposed - low half	14	1	0.24	4.09	0.80	0.08	7.62		
	Exposed - top half	14	1	0.30	3.34	0.65	0.07	6.14		
C14	Unexposed	30	4	0.50	8.03				0.11	0.17
	Exposed - low half	19	0	0.31	0.00	0.00	0.00	1.50		
	Exposed - top half	18	1	0.35	2.84	0.32	0.03	3.20		

continued..

Table A-56 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
C15	Unexposed	67	5	1.06	4.70				0.28	0.45
	Exposed - low half	9	0	0.13	0.00	0.00	0.00	5.87		
	Exposed - top half	9	2	0.19	10.63	2.70	0.42	17.3		
C16	Unexposed	34	3	0.58	5.18				0.24	0.11
	Exposed - low half	19	1	0.48	2.09	0.37	0.03	4.05		
	Exposed - top half	19	0	0.29	0.00	0.00	0.00	2.42		
C17	Unexposed	115	8	2.22	3.60				0.46	0.39
	Exposed - low half	3	0	0.06	0.00	0.01	0.00	18.6		
	Exposed - top half	3	1	0.09	10.94	4.42	0.33	58.5		
C20	Unexposed	64	6	1.37	4.37				0.38	0.66
	Exposed - low half	13	0	0.22	0.00	0.00	0.00	3.77		
	Exposed - top half	12	1	0.25	4.07	0.90	0.10	8.56		
C23	Unexposed	13	1	0.21	4.71				0.10	0.15
	Exposed - low half	37	1	0.82	1.22	0.24	0.01	4.29		
	Exposed - top half	37	6	0.79	7.63	1.83	0.19	17.5		
C24	Unexposed	31	1	0.52	1.94				0.42	0.19
	Exposed - low half	25	2	0.60	3.31	1.84	0.15	22.1		
	Exposed - top half	25	4	0.63	6.37	3.89	0.40	38.1		
C26	Unexposed	94	8	1.70	4.71				0.39	0.76
	Exposed - low half	8	0	0.14	0.00	0.00	0.00	5.80		
	Exposed - top half	7	1	0.10	10.32	2.47	0.24	25.4		
C28	Unexposed	51	5	0.91	5.48				0.21	0.11
	Exposed - low half	15	1	0.32	3.11	0.52	0.05	5.01		
	Exposed - top half	14	0	0.30	0.00	0.00	0.00	2.25		
C31	Unexposed	45	5	1.44	3.47				0.71	0.66
	Exposed - low half	31	1	0.59	1.69	0.42	0.05	3.89		
	Exposed - top half	31	2	0.70	2.87	0.76	0.13	4.35		
C32	Unexposed	49	5	1.51	3.32				0.71	0.51
	Exposed - low half	27	2	0.52	3.88	1.10	0.19	6.29		
	Exposed - top half	27	1	0.60	1.67	0.44	0.05	4.09		
C33	Unexposed	45	4	1.49	2.69				0.46	0.72
	Exposed - low half	38	4	0.83	4.84	1.80	0.40	7.99		
	Exposed - top half	35	1	0.68	1.48	0.49	0.05	4.65		
TRI1	Unexposed	87	5	2.13	2.35				0.0057	0.0018
	Exposed - low half	8	2	0.13	14.97	8.29	1.26	54.7		
	Exposed - top half	7	3	0.15	20.29	15.92	2.52	100		
TRI2	Unexposed	128	7	2.90	2.42				0.018	0.0052
	Exposed - low half	11	2	0.20	10.22	5.11	0.87	30.1		
	Exposed - top half	11	3	0.18	16.23	9.81	1.94	49.7		
TEN2	Unexposed	128	7	2.90	2.42				0.014	
	Exposed	25	5	0.47	10.67	5.47	1.52	19.7		

B3: Actual and potential contamination

		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
NDCN	Unexposed	139	7	2.98	2.35				0.21	0.096
	Exposed - low half	26	2	0.67	3.00	1.32	0.25	6.94		
	Exposed - top half	14	3	0.36	8.41	4.31	0.95	19.6		
NALP	Unexposed	170	10	3.78	2.64				0.27	0.11
	Exposed - low half	6	1	0.16	6.38	2.66	0.28	25.5		
	Exposed - top half	3	1	0.07	14.97	9.37	0.63	139		

continued..

Table A-56 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
NBEG	Unexposed	143	7	3.08	2.27				0.31	0.13
	Exposed - low half	24	3	0.61	4.89	2.40	0.56	10.4		
	Exposed - top half	12	2	0.31	6.45	3.23	0.57	18.1		
HEAV	Unexposed	168	11	3.76	2.93				0.40	0.91
	Exposed - low half	6	1	0.11	9.20	3.68	0.36	37.3		
	Exposed - top half	5	0	0.13	0.00	0.01	0.00	9.51		
CLEA	Unexposed	174	11	3.87	2.84				0.64	0.44
	Exposed - low half	4	1	0.12	8.05	3.43	0.32	36.3		
	Exposed - top half	1	0	0.01	0.00	0.07	0.00	193		
CON1	Unexposed	123	9	2.73	3.29				0.73	0.73
	Exposed - low half	28	1	0.62	1.61	0.45	0.05	3.78		
	Exposed - top half	28	2	0.65	3.09	0.90	0.18	4.52		
CON2	Unexposed	76	6	1.96	3.05				0.12	0.46
	Exposed - low half	52	1	1.14	0.88	0.26	0.03	2.14		
	Exposed - top half	51	5	0.90	5.56	1.85	0.51	6.63		
FIRE	Not involved	176	11	3.90	2.82				0.27	
	Involved	3	1	0.10	9.73	4.71	0.39	56.9		
IN57	Not in workforce	154	9	3.50	2.57				0.23	
	In workforce	25	3	0.50	5.98	2.50	0.61	10.3		

B4: Work area/job (if more than 5% of period)

		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
PJ1	<5% of period	152	10	3.52	2.85				0.65	
	>=5% of period	27	2	0.48	4.15	1.47	0.30	7.23		
PJ2	<5% of period	165	10	3.78	2.65				0.15	
	>=5% of period	14	2	0.22	9.06	3.95	0.73	21.3		
PJ4	<5% of period	175	11	3.94	2.79				0.14	
	>=5% of period	4	1	0.06	16.17	9.93	0.64	154		
PJ6	<5% of period	173	12	3.92	3.06				0.46	
	>=5% of period	6	0	0.08	0.00	0.02	0.00	14.4		
PJ7	<5% of period	172	10	3.76	2.66				0.16	
	>=5% of period	7	2	0.24	8.43	4.04	0.69	23.7		
PJ8	<5% of period	164	7	3.68	1.90				0.00067	
	>=5% of period	15	5	0.32	15.48	12.63	3.24	49.2		
PJ9	<5% of period	161	12	3.69	3.24				0.15	
	>=5% of period	18	0	0.31	0.00	0.00	0.00	3.70		
PJ12	<5% of period	168	11	3.67	3.00				0.98	
	>=5% of period	11	1	0.34	2.97	0.97	0.11	8.34		
PJ16	<5% of period	158	11	3.54	3.10				0.70	
	>=5% of period	21	1	0.46	2.17	0.67	0.09	5.31		
PJ17	<5% of period	174	11	3.93	2.79				0.19	
	>=5% of period	5	1	0.07	13.70	6.29	0.58	67.9		
PJ18	<5% of period	170	10	3.81	2.62				0.10	
	>=5% of period	9	2	0.19	10.64	5.21	0.89	30.5		
PJ19	<5% of period	170	12	3.84	3.13				0.31	
	>=5% of period	9	0	0.16	0.00	0.01	0.00	7.29		

continued..

Table A-56 (cont.)

C: Variables evaluated over 12 week pre-conception period

C1: Measured radiation exposure		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
PJ20	<5% of period	174	11	3.88	2.84				0.35	
	>=5% of period	5	1	0.12	8.24	3.51	0.33	36.8		
PJ21	<5% of period	150	10	3.42	2.93				0.87	
	>=5% of period	29	2	0.58	3.42	1.15	0.24	5.58		
PJ22	<5% of period	176	12	3.94	3.05				0.53	
	>=5% of period	3	0	0.06	0.00	0.01	0.00	19.9		
PJ25	<5% of period	160	11	3.57	3.08				0.76	
	>=5% of period	19	1	0.43	2.34	0.72	0.09	5.79		
PJ29	<5% of period	150	12	3.42	3.51				0.043	
	>=5% of period	29	0	0.58	0.00	0.00	0.00	1.81		
PJ31	<5% of period	173	12	3.96	3.03				0.60	
	>=5% of period	6	0	0.04	0.00	0.03	0.00	28.0		
XG	Unexposed	60	3	1.73					0.42	0.34
	Exposed - low half	60	4	0.90	4.46	2.64	0.55	12.7		
	Exposed - top half	59	5	1.38	3.64	2.18	0.48	9.78		
HIDA	Unexposed	168	12	3.71	3.24				0.38	0.16
	Exposed - low half	10	0	0.27	0.00	0.00	0.00	4.21		
	Exposed - top half	1	0	0.02	0.00	0.00	0.00	48.8		
RMAX	Unexposed	60	3	1.76	1.70				0.26	0.34
	Exposed - low half	60	4	0.90	4.45	2.68	0.58	12.4		
	Exposed - top half	59	5	1.34	3.72	2.28	0.52	9.94		
NEUT	Unexposed	145	8	3.33	2.40				0.14	
	Exposed	34	4	0.67	5.96	2.79	0.76	10.3		
NHI	Unexposed	167	11	3.76	2.93				0.72	
	Exposed	12	1	0.24	4.14	1.53	0.17	14.0		
IT	Unexposed	113	7	2.55	2.75				0.92	0.68
	Exposed - low half	34	2	0.64	3.11	1.13	0.22	5.92		
	Exposed - top half	32	3	0.81	3.70	1.36	0.32	5.71		
IA	Unexposed	114	7	2.59	2.71				0.90	0.65
	Exposed - low half	33	2	0.61	3.30	1.23	0.23	6.44		
	Exposed - top half	32	3	0.81	3.70	1.38	0.33	5.80		
ITRI	Unexposed	177	12	3.94	3.05				0.82	0.54
	Exposed - low half	1	0	0.02	0.00	0.02	0.00	51.7		
	Exposed - top half	1	0	0.04	0.00	0.01	0.00	32.4		

C2: Assessed exposure to chemicals and other workplace exposures

		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
C2	Unexposed	84	8	1.59	5.02				0.52	0.25
	Exposed - low half	3	0	0.06	0.00	0.00	0.00	11.4		
	Exposed - top half	2	0	0.06	0.00	0.00	0.00	11.7		
C3	Unexposed	100	9	1.95	4.62				0.67	0.37
	Exposed - low half	3	0	0.03	0.00	0.01	0.00	31.8		
	Exposed - top half	3	0	0.06	0.00	0.01	0.00	14.5		

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Table A-56 (cont.)		Cases				95% CI				p for
		Controls	Obs	Exp	O/E	OR	from	to	p	trend
C4	Unexposed	53	5	0.99	5.06				0.053	0.29
	Exposed - low half	13	0	0.24	0.00	0.00	0.00	3.06		
	Exposed - top half	6	2	0.09	21.83	6.31	0.84	47.4		
C7	Unexposed	85	7	1.58	4.45				0.18	9.00
	Exposed	11	0	0.20	0.00	0.00	0.00	4.09		
C8	Unexposed	69	5	1.34	3.73				0.76	0.84
	Exposed - low half	19	1	0.42	2.36	0.60	0.07	5.42		
	Exposed - top half	10	1	0.15	6.76	1.85	0.19	18.3		
C9	Unexposed	112	9	2.23	4.04				0.85	0.57
	Exposed - low half	3	0	0.03	0.00	0.01	0.00	36.4		
	Exposed - top half	1	0	0.01	0.00	0.01	0.00	79.2		
C10	Unexposed	63	7	1.07	6.55				0.16	0.053
	Exposed - low half	11	0	0.26	0.00	0.00	0.00	2.18		
	Exposed - top half	2	0	0.04	0.00	0.00	0.00	15.0		
C11	Unexposed	81	6	1.40	4.27				0.66	0.64
	Exposed - low half	8	1	0.20	5.03	1.19	0.12	11.6		
	Exposed - top half	4	0	0.09	0.00	0.01	0.00	9.52		
C12	Unexposed	98	5	1.94	2.57				0.13	0.046
	Exposed - low half	7	1	0.09	11.10	4.80	0.46	49.7		
	Exposed - top half	4	1	0.04	26.83	14.21	1.12	180		
C13	Unexposed	75	5	1.41	3.54				0.56	0.38
	Exposed - low half	8	1	0.09	10.98	3.44	0.33	36.4		
	Exposed - top half	7	1	0.14	7.21	2.25	0.21	23.8		
C14	Unexposed	43	5	0.79	6.35				0.22	0.11
	Exposed - low half	22	1	0.33	3.06	0.42	0.04	3.96		
	Exposed - top half	9	0	0.22	0.00	0.00	0.00	2.64		
C15	Unexposed	80	8	1.44	5.58				0.23	0.088
	Exposed - low half	9	0	0.13	0.00	0.00	0.00	5.07		
	Exposed - top half	5	0	0.13	0.00	0.00	0.00	5.02		
C16	Unexposed	46	4	0.85	4.68				0.83	0.62
	Exposed - low half	22	1	0.37	2.68	0.52	0.06	4.91		
	Exposed - top half	12	1	0.32	3.12	0.66	0.06	6.85		
C17	Unexposed	111	8	2.18	3.66				0.00015	0.019
	Exposed - low half	4	0	0.08	0.00	0.00	0.00	12.5		
	Exposed - top half	0	1	0.00	0.00	(Top vs Low & Unexp, Exact p = 0.073)				
C20	Unexposed	73	6	1.53	3.93				0.57	0.63
	Exposed - low half	10	1	0.18	5.66	1.45	0.15	14.0		
	Exposed - top half	7	0	0.12	0.00	0.00	0.00	7.76		
C23	Unexposed	19	2	0.30	6.76				0.44	0.29
	Exposed - low half	52	6	0.95	6.31	0.90	0.15	5.21		
	Exposed - top half	20	1	0.49	2.03	0.26	0.02	3.26		
C24	Unexposed	36	2	0.66	3.04				0.45	0.46
	Exposed - low half	31	5	0.64	7.85	2.97	0.52	16.9		
	Exposed - top half	14	2	0.36	5.51	1.95	0.24	15.7		
C26	Unexposed	96	8	1.87	4.29				0.25	0.23
	Exposed - low half	6	0	0.05	0.00	0.01	0.00	17.7		
	Exposed - top half	2	1	0.04	23.42	12.17	0.60	249		
C28	Unexposed	57	6	1.04	5.77				0.040	0.011
	Exposed - low half	21	0	0.45	0.00	0.00	0.00	1.43		
	Exposed - top half	10	0	0.22	0.00	0.00	0.00	2.87		

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Table A-56 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
C31	Unexposed	55	6	1.72	3.48				0.78	0.60
	Exposed - low half	29	2	0.48	4.21	1.13	0.21	6.10		
	Exposed - top half	26	1	0.51	1.95	0.51	0.06	4.21		
C32	Unexposed	61	7	1.81	3.87				0.25	0.28
	Exposed - low half	28	2	0.43	4.62	1.10	0.21	5.86		
	Exposed - top half	18	0	0.34	0.00	0.00	0.00	2.83		
C33	Unexposed	56	6	1.69	3.56				0.12	0.20
	Exposed - low half	32	3	0.66	4.54	1.21	0.27	5.40		
	Exposed - top half	31	0	0.56	0.00	0.00	0.00	1.85		
TRI1	Unexposed	100	8	2.40	3.35				0.29	0.36
	Exposed - low half	12	2	0.16	12.23	4.40	0.74	26.3		
	Exposed - top half	1	0	0.04	0.00	0.03	0.00	29.5		
TRI2	Unexposed	132	9	3.05	2.96				0.25	0.30
	Exposed - low half	13	2	0.17	11.73	4.79	0.83	27.5		
	Exposed - top half	1	0	0.04	0.00	0.01	0.00	33.4		
TEN2	Unexposed	131	9	3.02	2.98				0.26	
	Exposed	16	2	0.26	7.79	2.87	0.53	15.5		

C3: Actual and potential contamination		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
NDCN	Unexposed	174	12	3.88	3.10				0.66	0.37
	Exposed - low half	4	0	0.11	0.00	0.01	0.00	11.1		
	Exposed - top half	1	0	0.02	0.00	0.01	0.00	60.9		
NALP	Unexposed	178	12	3.97	3.03				0.63	
	Exposed	1	0	0.04	0.00	0.01	0.00	34.0		
NBEG	Unexposed	175	12	3.91	3.07				0.75	0.44
	Exposed - low half	3	0	0.07	0.00	0.01	0.00	16.9		
	Exposed - top half	1	0	0.02	0.00	0.01	0.00	61.5		
HEAV	Unexposed	177	12	3.96	3.03				0.59	
	Exposed	2	0	0.05	0.00	0.02	0.00	27.0		
CON1	Unexposed	142	10	3.13	3.19				0.88	0.63
	Exposed - low half	36	2	0.86	2.33	0.70	0.14	3.40		
	Exposed - top half	1	0	0.01	0.00	0.05	0.00	150		
CON2	Unexposed	96	7	2.39	2.93				0.88	0.96
	Exposed - low half	80	5	1.58	3.17	1.04	0.31	3.51		
	Exposed - top half	3	0	0.04	0.00	0.04	0.00	33.3		
IN57	Not in workforce	179	12	4.00	3.00					
	In workforce	0	0	0.00	0.00					

C4: Work area/job (weighted days in 12 week pre-conception period)		Controls	Obs	Exp	O/E	OR	from	to	p	trend
JB1	Unexposed	154	11	3.57	3.08				0.90	0.71
	Exposed - low half	24	1	0.41	2.45	0.75	0.09	6.26		
	Exposed - top half	1	0	0.02	0.00	0.02	0.00	52.1		
JB2	Unexposed	166	10	3.78	2.65				0.28	0.24
	Exposed - low half	12	2	0.20	10.11	4.56	0.82	25.3		
	Exposed - top half	1	0	0.02	0.00	0.02	0.00	60.6		
JB4	Unexposed	176	11	3.94	2.79				0.15	
	Exposed	3	1	0.06	15.53	8.85	0.63	125		

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Table A-56 (cont.)

		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
JB6	Unexposed	176	12	3.96	3.03				0.61	
	Exposed	3	0	0.04	0.00	0.02	0.00	30.4		
JB7	Unexposed	176	12	3.90	3.07				0.43	
	Exposed	3	0	0.10	0.00	0.01	0.00	12.0		
JB8	Unexposed	168	10	3.74	2.68				0.22	
	Exposed	11	2	0.27	7.50	3.21	0.59	17.4		
JB9	Unexposed	167	12	3.78	3.18				0.47	0.22
	Exposed - low half	11	0	0.22	0.00	0.00	0.00	5.28		
	Exposed - top half	1	0	0.01	0.00	0.01	0.00	116		
JB12	Unexposed	172	12	3.79	3.17				0.24	
	Exposed	7	0	0.21	0.00	0.00	0.00	5.55		
JB16	Unexposed	164	11	3.69	2.98				0.94	
	Exposed	15	1	0.31	3.19	1.09	0.13	9.37		
JB17	Unexposed	174	11	3.93	2.80				0.19	
	Exposed	5	1	0.07	13.70	6.29	0.58	67.9		
JB18	Unexposed	174	11	3.89	2.83				0.30	
	Exposed	5	1	0.11	9.21	4.15	0.38	45.7		
JB19	Unexposed	172	12	3.88	3.09				0.37	
	Exposed	7	0	0.12	0.00	0.01	0.00	9.94		
JB20	Unexposed	177	12	3.96	3.03				0.63	
	Exposed	2	0	0.04	0.00	0.04	0.00	30.5		
JB21	Unexposed	154	10	3.51	2.85				0.88	0.69
	Exposed - low half	24	2	0.48	4.17	1.47	0.29	7.39		
	Exposed - top half	1	0	0.01	0.00	0.06	0.00	130		
JB22	Unexposed	178	12	3.96	3.03				0.63	
	Exposed	1	0	0.04	0.00	0.01	0.00	30.5		
JB25	Unexposed	169	11	3.81	2.89				0.75	0.70
	Exposed - low half	9	1	0.17	5.99	2.23	0.24	20.8		
	Exposed - top half	1	0	0.02	0.00	0.02	0.00	64.0		
JB29	Unexposed	178	12	3.98	3.01				0.73	
	Exposed	1	0	0.02	0.00	0.02	0.00	61.2		
JB31	Unexposed	173	12	3.96	3.03				0.60	
	Exposed	6	0	0.04	0.00	0.03	0.00	30.4		

Table A-57: Observed and expected cases, and odds ratio's for all leukaemia and non-Hodgkin's lymphoma (LNHL)

		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
A: Variables not dependent on choice of pre-conception exposure window										
DOBQ	1950-69	87	12	3.70	3.25				0.27	
	1970+	92	4	2.10	1.91	0.52	0.16	1.74		
DOSQ	1950-64	85	13	3.56	3.65				0.063	
	1965+	94	3	2.23	1.34	0.32	0.09	1.18		
QUIQ	1950-1974	41	2	2.02	0.99				0.037	
	1975+	138	14	3.78	3.71	4.19	1.11	27.1		
DODX	1950-59	-	0	0.38	0.00	-	0.00	10.20	Confidence intervals	
	1960-69	-	4	1.26	3.17	-	0.86	8.43	for O/E ratios.	
	1970-79	-	7	1.85	3.78	-	1.50	8.03	p for equal O/E	
	1980+	-	5	2.30	2.17	-	0.70	5.17	ratios = 0.39	
SEX	Male	93	9	3.23	2.79				0.93	
	Female	86	7	2.56	2.73	0.96	0.33	2.75		
FAGE	<25	36	0	1.16	0.00	0.0030	0.00	0.72	0.015	
	25-34	109	10	3.24	3.09	0.62	0.20	1.94		
	35+	33	6	1.36	4.42					
FBTH	Cumbria	103	9	3.65	2.47				0.26	
	Elsewhere	62	7	1.60	4.37	1.87	0.64	5.48		
SEAS	Born elsewhere	140	10	5.39	1.86				0.0005	
	Seascale born	39	6	0.41	14.8	8.67	2.90	25.91		
JOBC	Industrial	118	11	4.51	2.44				0.44	
	Non-industrial	61	5	1.28	3.91	1.57	0.51	4.86		
PCE	Yes	155	13	4.36	2.98				0.69	
	No	24	3	1.43	2.09	0.76	0.19	3.03		
TIME	0	24	3	1.43	2.09				0.20	0.17
	0.1 to 4 years	78	4	2.36	1.71	0.71	0.14	3.54		
	> 4 years	77	9	2.02	4.45	2.08	0.49	8.79		
DIST	<= 11.5 km	98	10	2.77	3.61				0.23	
	>11.5 km	81	6	3.02	1.99	0.52	0.18	1.54		
MIGR	<=0.28	102	7	4.08	1.72				0.780	
	>0.28	77	9	1.71	5.26	1.04	0.97	1.12		
B: Variables evaluated over total pre-conception period										
B1: Measured radiation exposure										
XG	Unexposed	35	4	1.87	2.14				0.37	0.27
	Exposed - low half	72	3	1.65	1.19	0.76	0.15	3.71		
	Exposed - top half	72	9	2.27	3.96	1.82	0.50	6.62		
HIDA	Unexposed	114	9	3.57	2.52				0.78	0.56
	Exposed - low half	37	3	1.18	2.54	0.96	0.24	3.82		
	Exposed - top half	28	4	1.04	3.84	1.56	0.43	5.61		
RMAX	Unexposed	36	4	1.87	2.14				0.87	0.77
	Exposed - low half	72	5	1.51	3.32	1.46	0.35	6.01		
	Exposed - top half	71	7	2.42	2.89	1.27	0.34	4.82		

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Table A-57 (cont.)			Cases			95% CI			p for
		Controls	Obs	Exp	O/E	OR	from	to	p	trend
NEUT	Unexposed	133	11	4.54	2.42				0.46	0.25
	Exposed - low half	23	2	0.74	2.71	1.11	0.22	5.52		
	Exposed - top half	23	3	0.51	5.89	2.60	0.64	10.57		
NHI	Unexposed	162	15	5.28	2.84				0.62	0.52
	Exposed - low half	9	1	0.36	2.76	0.99	0.11	9.03		
	Exposed - top half	8	0	0.15	0.00	0.012	0.00	8.52		
IT	Unexposed	105	9	3.52	2.56				0.29	0.40
	Exposed - low half	37	1	0.89	1.12	0.34	0.05	3.21		
	Exposed - top half	37	6	1.38	4.34	1.79	0.58	5.60		
IA	Unexposed	113	9	3.73	2.41				0.59	0.37
	Exposed - low half	33	2	0.86	2.32	0.93	0.19	4.58		
	Exposed - top half	33	5	1.20	4.18	1.84	0.56	6.07		
ITRI	Unexposed	174	15	5.59	2.68				0.40	0.38
	Exposed - low half	3	0	0.088	0.00	0.016	0.00	15.63		
	Exposed - top half	2	1	0.11	8.78	5.45	0.34	88.60		
B2: Assessed exposure to chemicals and other workplace exposures										
C2	Unexposed	77	11	2.12	5.19				0.28	0.11
	Exposed - low half	4	0	0.10	0.00	0.004	0.00	7.25		
	Exposed - top half	4	0	0.13	0.00	0.003	0.00	5.40		
C3	Unexposed	99	11	2.64	4.17				0.51	0.41
	Exposed - low half	3	0	0.039	0.00	0.022	0.00	22.94		
	Exposed - top half	3	1	0.087	11.5	4.13	0.30	56.71		
C4	Unexposed	43	4	1.00	3.99				0.11	0.39
	Exposed - low half	10	0	0.28	0.00	0.002	0.00	3.28		
	Exposed - top half	9	2	0.16	12.6	3.65	0.54	24.89		
C7	Unexposed	65	6	1.63	3.68				0.038	0.29
	Exposed - low half	12	0	0.45	0.00	0.001	0.00	2.25		
	Exposed - top half	11	3	0.28	10.8	4.00	0.77	20.82		
C8	Unexposed	59	4	1.63	2.46				0.016	0.079
	Exposed - low half	16	0	0.54	0.00	0.002	0.00	2.76		
	Exposed - top half	16	4	0.41	9.80	5.34	1.11	25.69		
C9	Unexposed	119	11	3.41	3.23				0.17	0.095
	Exposed - low half	2	0	0.028	0.00	0.028	0.00	41.40		
	Exposed - top half	2	1	0.027	37.5	20.1	1.18	342.3		
C10	Unexposed	53	6	1.35	4.44				0.23	0.54
	Exposed - low half	7	2	0.25	7.90	2.21	0.33	14.96		
	Exposed - top half	7	0	0.22	0.00	0.002	0.00	3.75		
C11	Unexposed	68	8	1.55	5.17				0.92	0.87
	Exposed - low half	7	1	0.32	3.18	0.62	0.06	6.21		
	Exposed - top half	6	1	0.19	5.14	1.01	0.10	10.07		
C12	Unexposed	87	8	2.33	3.44				0.47	0.37
	Exposed - low half	8	2	0.26	7.83	3.26	0.51	20.90		
	Exposed - top half	8	1	0.17	6.02	1.82	0.19	17.35		
C13	Unexposed	58	7	1.43	4.91				0.85	0.89
	Exposed - low half	14	1	0.34	2.91	0.55	0.06	4.98		
	Exposed - top half	14	2	0.41	4.83	1.00	0.18	5.72		
C14	Unexposed	30	4	0.72	5.58				0.089	0.99
	Exposed - low half	19	0	0.45	0.00	0.0006	0.00	1.48		
	Exposed - top half	18	3	0.51	5.94	1.15	0.21	6.21		

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Table A-57 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
C15	Unexposed	67	6	1.49	4.03				0.69	0.40
	Exposed - low half	9	1	0.19	5.15	1.30	0.13	13.04		
	Exposed - top half	9	2	0.25	7.95	2.30	0.37	14.26		
C16	Unexposed	34	3	0.81	3.72				0.21	0.32
	Exposed - low half	19	3	0.69	4.36	1.27	0.22	7.41		
	Exposed - top half	19	0	0.39	0.00	0.0089	0.00	2.55		
C17	Unexposed	115	11	3.16	3.48				0.53	0.52
	Exposed - low half	3	0	0.689	0.00	0.016	0.00	15.38		
	Exposed - top half	3	1	0.12	8.13	3.21	0.25	40.88		
C20	Unexposed	64	8	1.93	4.14				0.90	0.66
	Exposed - low half	13	1	0.33	3.05	0.68	0.07	6.23		
	Exposed - top half	12	1	0.33	3.06	0.68	0.75	6.18		
C23	Unexposed	13	1	0.34	2.98				0.027	0.035
	Exposed - low half	37	1	1.11	0.90	0.28	0.02	4.94		
	Exposed - top half	37	8	1.12	7.16	2.97	0.32	27.54		
C24	Unexposed	31	1	0.68	1.47				0.31	0.13
	Exposed - low half	25	3	0.87	3.45	2.68	0.25	28.23		
	Exposed - top half	25	5	0.91	5.48	4.70	0.50	44.31		
C26	Unexposed	94	9	2.33	3.86				0.017	0.050
	Exposed - low half	8	0	0.22	0.00	0.005	0.00	4.37		
	Exposed - top half	7	3	0.15	20.7	10.3	1.83	57.90		
C28	Unexposed	51	7	1.28	5.45				0.092	0.037
	Exposed - low half	15	1	0.46	2.19	0.35	0.04	3.16		
	Exposed - top half	14	0	0.41	0.00	0.001	0.00	1.64		
C31	Unexposed	45	7	2.13	3.28				0.38	0.96
	Exposed - low half	31	1	0.83	1.21	0.30	0.04	2.38		
	Exposed - top half	31	4	0.98	4.08	1.18	0.30	4.64		
C32	Unexposed	49	7	2.23	3.14				0.95	0.97
	Exposed - low half	27	2	0.72	2.80	0.78	0.14	4.18		
	Exposed - top half	27	3	0.87	3.46	1.01	0.23	4.44		
C33	Unexposed	45	6	2.20	2.73				0.97	0.97
	Exposed - low half	38	4	1.16	3.45	1.17	0.29	4.66		
	Exposed - top half	35	3	0.99	3.03	1.00	0.22	4.44		
TRI1	Unexposed	87	9	3.10	2.91				0.042	0.013
	Exposed - low half	8	2	0.20	10.1	4.11	0.68	24.85		
	Exposed - top half	7	3	0.22	13.8	8.12	1.39	47.38		
TRI2	Unexposed	128	11	4.15	2.65				0.081	0.026
	Exposed - low half	11	2	0.27	7.40	3.17	0.57	17.63		
	Exposed - top half	11	3	0.28	10.8	5.61	1.18	26.66		
TEN2	Unexposed	128	10	4.15	2.41				0.014	
	Exposed	25	6	0.67	8.93	4.71	1.46	15.13		
B3: Actual and potential contamination										
NDCN	Unexposed	139	9	4.33	2.08				0.20	0.078
	Exposed - low half	26	4	0.98	4.09	2.22	0.61	8.11		
	Exposed - top half	14	3	0.49	6.15	3.48	0.80	15.13		
NALP	Unexposed	170	14	5.46	2.56				0.41	0.20
	Exposed - low half	6	1	0.24	4.10	1.69	0.18	15.86		
	Exposed - top half	3	1	0.091	11.0	6.66	0.46	95.51		
NBEG	Unexposed	143	9	4.48	2.01				0.13	0.088
	Exposed - low half	24	5	0.89	5.60	3.47	1.01	11.89		
	Exposed - top half	12	2	0.42	4.81	2.67	0.49	14.43		

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Table A-57 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
HEAV	Unexposed	168	15	5.47	2.73				0.42	0.76
	Exposed - low half	6	1	0.14	6.94	2.85	0.28	28.46		
	Exposed - top half	5	0	0.18	0.00	0.011	0.00	7.66		
CLEA	Unexposed	174	14	5.60	2.50				0.033	0.021
	Exposed - low half	4	1	0.19	5.39	2.51	0.24	26.01		
	Exposed - top half	1	1	0.012	86.5	264	2.62	26556		
CON1	Unexposed	123	13	3.96	3.28				0.37	0.30
	Exposed - low half	28	1	0.89	1.12	0.30	0.04	2.40		
	Exposed - top half	28	2	0.94	2.13	0.59	0.12	2.82		
CON2	Unexposed	76	8	2.86	2.80				0.026	0.33
	Exposed - low half	52	1	1.64	0.61	0.18	0.02	1.48		
	Exposed - top half	51	7	1.29	5.42	2.01	0.65	6.19		
FIRE	Not involved	176	15	5.65	2.66				0.38	
	Involved	3	1	0.15	6.81	3.33	0.28	39.35		
IN57	Not in workforce	154	12	5.04	2.38				0.18	
	In workforce	25	4	0.75	5.35	2.46	0.71	8.61		
B4: Work area/job (if more than 5% of period)										
PJ1	<5% of period	152	12	5.11	2.35				0.14	
	>=5% of period	27	4	0.68	5.87	2.75	0.79	9.59		
PJ2	<5% of period	165	14	5.51	2.54				0.22	
	>=5% of period	14	2	0.28	7.12	3.09	0.59	16.20		
PJ4	<5% of period	175	15	5.69	2.63				0.22	
	>=5% of period	4	1	0.10	10.2	6.31	0.42	95.55		
PJ6	<5% of period	173	16	5.66	2.83				0.37	
	>=5% of period	6	0	0.13	0.00	0.011	0.00	9.98		
PJ7	<5% of period	172	14	5.43	2.58				0.31	
	>=5% of period	7	2	0.36	5.50	2.58	0.46	14.62		
PJ8	<5% of period	164	11	5.34	2.06				0.0034	
	>=5% of period	15	5	0.45	11.0	7.92	2.20	28.52		
PJ9	<5% of period	161	16	5.40	2.96				0.11	
	>=5% of period	18	0	0.39	0.00	0.003	0.00	3.21		
PJ12	<5% of period	168	15	5.26	2.85				0.65	
	>=5% of period	11	1	0.53	1.90	0.62	0.07	5.25		
PJ16	<5% of period	158	15	5.14	2.92				0.46	
	>=5% of period	21	1	0.65	1.54	0.48	0.06	3.76		
PJ17	<5% of period	174	15	5.69	2.64				0.28	
	>=5% of period	5	1	0.11	9.49	4.38	0.42	46.03		
PJ18	<5% of period	170	14	5.56	2.52				0.15	
	>=5% of period	9	2	0.24	8.50	4.14	0.73	23.42		
PJ19	<5% of period	170	16	5.56	2.88				0.23	
	>=5% of period	9	0	0.24	0.00	0.004	0.00	5.45		
PJ20	<5% of period	174	15	5.59	2.68				0.55	
	>=5% of period	5	1	0.20	5.02	2.15	0.21	22.08		
PJ21	<5% of period	150	14	4.97	2.82				0.80	
	>=5% of period	29	2	0.82	2.44	0.82	0.17	3.85		
PJ22	<5% of period	176	16	5.70	2.81				0.45	
	>=5% of period	3	0	0.10	0.00	0.009	0.00	13.71		

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Table A-57 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
PJ25	<5% of period	160	15	5.20	2.88				0.53	
	>=5% of period	19	1	0.59	1.70	0.54	0.07	4.23		
PJ29	<5% of period	150	16	5.02	3.19				0.024	
	>=5% of period	29	0	0.77	0.00	0.001	0.00	1.50		
PJ31	<5% of period	173	16	5.74	2.79				0.56	
	>=5% of period	6	0	0.055	0.00	0.027	0.00	24.25		
C: Variables evaluated over 12 week pre-conception period										
C1: Measured radiation exposure										
XG	Unexposed	60	5	2.58	1.94				0.58	0.31
	Exposed -low half	60	4	1.25	3.21	1.61	0.40	6.44		
	Exposed - top half	59	7	1.97	3.55	1.89	0.55	6.48		
HIDA	Unexposed	168	16	5.33	3.00				0.23	0.088
	Exposed -low half	10	0	0.42	0.00	0.004	0.00	2.90		
	Exposed - top half	1	0	0.042	0.00	0.003	0.00	29.21		
RMAX	Unexposed	60	6	2.63	2.28				0.87	0.63
	Exposed -low half	60	4	1.25	3.20	1.33	0.35	6.43		
	Exposed - top half	59	6	1.91	3.14	1.35	0.40	4.58		
NEUT	Unexposed	145	12	4.86	2.47				0.36	
	Exposed	34	4	0.94	4.27	1.84	0.53	6.31		
NHI	Unexposed	167	15	5.46	2.75				0.91	
	Exposed	12	1	0.33	3.04	1.14	0.13	10.22		
IT	Unexposed	113	9	3.71	2.43				0.82	0.57
	Exposed -low half	34	3	0.87	3.44	1.44	0.36	5.85		
	Exposed - top half	32	4	1.21	3.31	1.39	0.39	4.94		
IA	Unexposed	114	9	3.75	2.40				0.78	0.55
	Exposed -low half	33	3	0.83	3.62	1.56	0.39	6.34		
	Exposed - top half	32	4	1.21	3.31	1.41	0.38	5.01		
ITRI	Unexposed	177	15	5.70	2.63				0.17	0.11
	Exposed -low half	1	0	0.038	0.00	0.033	0.00	36.98		
	Exposed - top half	1	1	0.057	17.4	47.1	0.52	4250		
C2: Assessed exposure to chemicals and other workplace exposures										
C2	Unexposed	84	10	2.28	4.39				0.44	0.20
	Exposed -low half	3	0	0.085	0.00	0.004	0.00	9.50		
	Exposed - top half	2	0	0.093	0.00	0.002	0.00	9.05		
C3	Unexposed	100	11	2.74	4.01				0.58	0.30
	Exposed -low half	3	0	0.039	0.00	0.008	0.00	23.83		
	Exposed - top half	3	0	0.087	0.00	0.004	0.00	10.54		
C4	Unexposed	53	5	1.32	3.77				0.30	0.13
	Exposed -low half	13	2	0.35	5.67	1.62	0.26	10.08		
	Exposed - top half	6	2	0.15	13.8	5.35	0.72	39.93		
C7	Unexposed	85	7	2.15	3.25				0.43	
	Exposed	11	2	5.94	5.94	2.10	0.36	12.36		
C8	Unexposed	69	6	1.86	3.22				0.94	0.79
	Exposed -low half	19	2	0.62	3.21	0.99	0.18	5.52		
	Exposed - top half	10	1	0.20	4.90	1.50	0.16	14.44		

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Table A-57 (cont.)		Controls	Cases Obs	Exp	O/E	95% CI OR	from	to	p	p for trend
C9	Unexposed	112	11	3.15	3.48				0.81	0.52
	Exposed -low half	3	0	0.039	0.00	0.010	0.00	27.46		
	Exposed - top half	1	0	0.016	0.00	0.008	0.00	67.36		
C10	Unexposed	63	9	1.50	5.99				0.091	0.029
	Exposed -low half	11	0	0.35	0.00	0.0009	0.00	1.77		
	Exposed - top half	2	0	0.059	0.00	0.002	0.00	10.43		
C11	Unexposed	81	8	1.94	4.13				0.52	0.38
	Exposed -low half	8	1	0.29	3.48	0.81	0.09	7.63		
	Exposed - top half	4	0	0.15	0.00	0.003	0.00	5.88		
C12	Unexposed	98	7	2.73	2.57				0.22	0.083
	Exposed -low half	7	1	0.13	7.63	3.17	0.32	31.06		
	Exposed - top half	4	1	0.050	19.8	9.82	0.84	115		
C13	Unexposed	75	6	1.97	3.04				0.18	0.31
	Exposed -low half	8	2	0.12	16.5	7.12	1.08	46.98		
	Exposed - top half	7	1	0.22	4.64	1.67	0.16	17.44		
C14	Unexposed	43	6	1.11	5.42				0.53	0.36
	Exposed -low half	22	1	0.46	2.16	0.33	0.04	2.87		
	Exposed - top half	9	1	0.32	3.09	0.51	0.05	5.11		
C15	Unexposed	80	10	1.99	5.02				0.16	0.053
	Exposed -low half	9	0	0.18	0.00	0.003	0.00	4.08		
	Exposed - top half	5	0	0.19	0.00	0.0009	0.00	3.95		
C16	Unexposed	46	5	1.18	4.24				0.84	0.56
	Exposed -low half	22	2	0.56	3.60	0.80	0.14	4.62		
	Exposed - top half	12	1	0.43	2.31	0.52	0.05	5.16		
C17	Unexposed	111	10	3.10	3.23				0.0002	0.031
	Exposed -low half	4	0	0.11	0.00	0.005	0.00	10.25		
	Exposed - top half	0	1	0.00	0.00	(Top vs Low & Unexp, Exact p=0.087)				
C20	Unexposed	73	7	2.13	3.28				0.87	0.62
	Exposed -low half	10	1	0.26	3.82	1.14	0.12	10.73		
	Exposed - top half	7	1	0.17	5.77	1.92	0.19	19.91		
C23	Unexposed	19	2	0.44	4.53				0.70	0.57
	Exposed -low half	52	7	1.31	5.36	1.17	0.21	6.63		
	Exposed - top half	20	2	0.72	2.79	0.58	0.07	4.89		
C24	Unexposed	36	2	0.85	2.37				0.34	0.29
	Exposed -low half	31	6	0.92	6.49	3.32	0.60	18.23		
	Exposed - top half	14	3	0.56	5.33	2.69	0.39	18.63		
C26	Unexposed	96	9	2.56	3.51				0.27	0.11
	Exposed -low half	6	1	0.081	12.4	3.62	0.38	34.77		
	Exposed - top half	2	1	0.071	14.2	8.68	0.43	174		
C28	Unexposed	57	8	1.47	5.43				0.013	0.003
	Exposed -low half	21	0	0.64	0.00	0.0049	0.00	1.07		
	Exposed - top half	10	0	0.31	0.00	0.0004	0.00	2.20		
C31	Unexposed	55	8	2.52	3.18				0.94	0.74
	Exposed -low half	29	2	0.66	3.05	0.84	0.16	4.36		
	Exposed - top half	26	2	0.74	2.72	0.77	0.15	4.08		
C32	Unexposed	61	9	2.64	3.41				0.79	0.52
	Exposed -low half	28	2	0.59	3.39	0.86	0.17	4.41		
	Exposed - top half	18	1	0.50	1.99	0.50	0.06	4.17		
C33	Unexposed	56	8	2.47	3.25				0.46	0.27
	Exposed -low half	32	3	0.92	3.25	0.89	0.21	3.76		
	Exposed - top half	31	1	0.83	1.21	0.30	0.04	2.59		

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Table A-57 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
TRI1	Unexposed	100	11	3.44	3.20				0.45	0.59
	Exposed -low half	12	2	0.25	8.04	2.81	0.49	16.10		
	Exposed - top half	1	0	0.057	0.00	0.017	0.00	19.97		
TRI2	Unexposed	132	12	4.35	2.76				0.39	0.48
	Exposed -low half	13	2	0.26	7.77	3.27	0.58	17.80		
	Exposed - top half	1	0	0.057	0.00	0.021	0.00	23.28		
TEN2	Unexposed	131	11	4.32	2.55				0.11	
	Exposed	16	3	0.38	7.83	3.68	0.84	16.03		
C3: Actual and potential contamination										
NDCN	Unexposed	174	15	5.61	2.68				0.052	0.16
	Exposed -low half	4	0	0.16	0.00	0.013	0.00	8.63		
	Exposed - top half	1	1	0.024	41.3	169	0.79	35994		
NALP	Unexposed	178	16	5.74	2.79				0.56	
	Exposed	1	0	0.059	0.00	0.020	0.00	22.47		
NBEG	Unexposed	175	15	5.67	2.65				0.062	0.10
	Exposed -low half	3	0	0.10	0.00	0.016	0.00	13.80		
	Exposed - top half	1	1	0.024	41.3	171	0.80	36423		
HEAV	Unexposed	177	16	5.73	2.80				0.53	
	Exposed	2	0	0.067	0.00	0.016	0.00	19.58		
CLEA	Unexposed	179	15	5.79	2.59				0.00009	
	Exposed	0	1	0.00	0.00	(Exposed vs Unexp, Exact p=0.082)				
CON1	Unexposed	142	14	4.53	3.09				0.57	0.29
	Exposed -low half	36	2	1.26	1.59	0.47	0.10	2.15		
	Exposed - top half	1	0	0.010	0.00	0.10	0.00	120		
CON2	Unexposed	96	9	3.49	2.58				0.84	0.89
	Exposed -low half	80	7	2.26	3.10	1.16	0.40	3.36		
	Exposed - top half	3	0	0.046	0.00	0.033	0.00	31.01		
IN57	Not in workforce	179	15	5.79	2.59				0.0005	
	In workforce	0	1	0.00	0.00	(In workforce vs Not, Exact p=0.082)				
C4: Work area/job (days in 12 week pre-conception period)										
JB1	Unexposed	154	13	5.19	2.51				0.54	0.40
	Exposed -low half	24	3	0.58	5.14	2.16	0.55	8.54		
	Exposed - top half	1	0	0.027	0.00	0.048	0.00	53.83		
JB2	Unexposed	166	14	5.51	2.54				0.38	0.32
	Exposed -low half	12	2	0.25	7.89	3.54	0.66	18.97		
	Exposed - top half	1	0	0.027	0.00	0.048	0.00	53.18		
JB4	Unexposed	176	15	5.69	2.64				0.23	
	Exposed	3	1	0.10	9.95	5.86	0.41	83.11		
JB6	Unexposed	176	16	5.73	2.79				0.54	
	Exposed	3	0	0.065	0.00	0.031	0.00	20.27		
JB7	Unexposed	176	16	5.63	2.84				0.33	
	Exposed	3	0	0.16	0.00	0.008	0.00	8.22		
JB8	Unexposed	168	14	5.42	2.59				0.37	
	Exposed	11	2	0.38	5.31	2.24	0.43	11.72		
JB9	Unexposed	167	16	5.51	2.91				0.41	0.18
	Exposed -low half	11	0	0.27	0.00	0.006	0.00	4.64		
	Exposed - top half	1	0	0.010	0.00	0.015	0.00	127		

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Table A-57 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
JB12	Unexposed	172	16	5.46	2.93				0.15	
	Exposed	7	0	0.33	0.00	0.003	0.00	3.77		
JB16	Unexposed	164	15	5.34	2.81				0.80	
	Exposed	15	1	0.45	2.23	0.77	0.09	6.48		
JB17	Unexposed	174	15	5.69	2.64				0.28	
	Exposed	5	1	0.11	9.49	4.38	0.42	46.03		
JB18	Unexposed	174	15	5.66	2.65				0.36	
	Exposed	5	1	0.14	7.34	3.35	0.31	36.09		
JB19	Unexposed	172	16	5.61	2.85				0.29	
	Exposed	7	0	0.19	0.00	0.102	0.00	6.96		
JB20	Unexposed	177	16	5.73	2.79				0.56	
	Exposed	2	0	0.059	0.00	0.029	0.00	22.40		
JB21	Unexposed	154	14	5.10	2.74				0.97	1.00
	Exposed -low half	24	2	0.68	2.93	1.04	0.22	5.00		
	Exposed - top half	1	0	0.010	0.00	0.12	0.00	135		
JB22	Unexposed	178	16	5.73	2.79				0.56	
	Exposed	1	0	0.058	0.00	0.020	0.00	22.87		
JB25	Unexposed	169	15	5.54	2.71				0.84	0.85
	Exposed -low half	9	1	0.23	4.36	1.66	0.18	15.03		
	Exposed - top half	1	0	0.027	0.00	0.044	0.00	49.84		
JB29	Unexposed	178	16	5.77	2.77				0.71	
	Exposed	1	0	0.023	0.00	0.052	0.00	58.36		
JB31	Unexposed	173	16	5.74	2.79				0.56	
	Exposed	6	0	0.055	0.00	0.027	0.00	24.25		

Table A-58: Observed and expected cases, and odds ratio's for cancers other than leukaemia and non-Hodgkin's lymphoma (OCAN)

A: Variables not dependent on choice of pre-conception exposure window		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
DOBQ	1950-1964	68	13	7.46	1.74				0.050	
	1965+	111	3	4.59	0.65	0.30	0.08	1.00		
DOSQ	1950-1959	72	11	6.97	1.58				0.31	
	1960+	107	5	5.08	0.98	0.56	0.18	1.75		
QUIQ	1950-1969	33	8	3.80	2.10				0.068	
	1970+	146	8	8.25	0.97	0.36	0.12	1.06		
DODX	1950-59	-	1	0.36	2.78	-	0.07	16.4	Confidence intervals	
	1960-69	-	2	1.24	1.61	-	0.19	6.01	for O/E ratios.	
	1970-79	-	5	4.73	1.06	-	0.34	2.53	p for equal O/E	
	1980+	-	8	5.71	1.40	-	0.60	2.82	ratios >0.5	
SEX	Male	93	6	5.94	1.01				0.28	
	Female	86	10	6.11	1.64	1.81	0.61	5.33		
FAGE	<25	36	1	2.16	0.46				0.30	
	25-34	109	11	6.61	1.66	4.14	0.50	34.1		
	35+	33	4	3.17	1.26	3.09	0.32	30.0		
FBTH	Cumbria	103	7	7.59	0.92				0.053	
	Elsewhere	62	8	3.22	2.49	3.00	0.94	9.33		
SEAS	Born elsewhere	140	15	11.21	1.34				0.78	
	Seascale born	39	1	0.85	1.18	0.75	0.10	5.85		
JOBC	Industrial	118	11	9.49	1.16				0.41	
	Non-industrial	61	5	2.57	1.95	1.63	0.53	5.08		
PCE	Yes	155	12	8.65	1.39				0.99	
	No	24	4	3.40	1.18	1.01	0.28	3.62		
TIME	0	24	4	3.40	1.18				0.076	0.20
	0.1 to 4 years	78	10	4.71	2.12	1.65	0.44	6.21		
	> 4 years	77	2	3.95	0.51	0.33	0.06	2.00		
DIST	<= 11.5 km	98	6	5.89	1.02				0.31	
	> 11.5 km	81	10	6.16	1.62	1.76	0.60	5.19		
MIGR	<= 0.28	102	10	8.49	1.18				0.89	
	> 0.28	77	6	3.56	1.69	0.98	0.91	1.06		
B: Variables evaluated over total pre-conception period										
B1: Measured radiation exposure										
XG	Unexposed	35	6	4.36	1.38				0.022	0.094
	Exposed - low half	72	8	3.06	2.62	1.76	0.53	5.85		
	Exposed - top half	72	2	4.64	0.43	0.24	0.04	1.28		
HIDA	Unexposed	114	12	7.48	1.61				0.27	0.12
	Exposed - low half	37	3	2.39	1.26	0.69	0.18	2.66		
	Exposed - top half	28	1	2.19	0.46	0.23	0.03	1.71		
RMAX	Unexposed	35	6	4.36	1.37				0.26	0.26
	Exposed - low half	72	6	2.79	2.15	1.37	0.39	4.83		
	Exposed - top half	72	4	4.91	0.81	0.47	0.12	1.84		
NEUT	Unexposed	133	11	9.67	1.14				0.29	0.62
	Exposed - low half	23	4	1.39	2.87	2.86	0.79	10.4		
	Exposed - top half	23	1	1.02	0.98	0.80	0.10	6.04		

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Table A-58 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
NHI	Unexposed	162	14	11.09	1.26				0.37	0.85
	Exposed - low half	9	2	0.69	2.89	2.82	0.49	16.3		
	Exposed - top half	8	0	0.27	0.00	0.015	0.00	10.68		
IT	Unexposed	105	11	7.63	1.44				0.60	0.73
	Exposed - low half	37	1	1.55	0.64	0.38	0.05	3.06		
	Exposed - top half	37	4	2.87	1.39	0.89	0.26	3.08		
IA	Unexposed	113	12	8.05	1.49				0.58	0.51
	Exposed - low half	33	1	1.51	0.66	0.38	0.05	3.09		
	Exposed - top half	33	3	2.49	1.20	0.73	0.19	2.83		
ITRI	Unexposed	174	16	11.64	1.38				0.54	0.27
	Exposed - low half	3	0	0.18	0.00	0.006	0.00	28.95		
	Exposed - top half	2	0	0.24	0.00	0.0026	0.00	20.89		
B2: Assessed exposure to chemicals and other workplace exposures										
C2	Unexposed	77	4	4.30	0.93				0.43	0.30
	Exposed - low half	4	0	0.15	0.00	0.015	0.00	23.57		
	Exposed - top half	4	1	0.27	3.71	5.38	0.41	70.2		
C3	Unexposed	99	4	5.08	0.79				0.80	0.50
	Exposed - low half	3	0	0.10	0.00	0.007	0.00	46.73		
	Exposed - top half	3	0	0.18	0.00	0.0042	0.00	25.74		
C4	Unexposed	43	2	1.92	1.04				0.73	0.43
	Exposed - low half	10	1	0.57	1.75	1.79	0.14	23.1		
	Exposed - top half	9	1	0.37	2.73	2.77	0.22	35.4		
C7	Unexposed	65	3	3.08	0.97				0.12	0.94
	Exposed - low half	12	3	0.95	3.14	4.18	0.70	24.9		
	Exposed - top half	11	0	0.65	0.00	0.0014	0.00	5.56		
C8	Unexposed	59	5	3.12	1.60				0.25	0.29
	Exposed - low half	16	2	1.11	1.80	1.15	0.19	6.83		
	Exposed - top half	16	0	0.84	0.00	0.0009	0.00	2.74		
C9	Unexposed	119	8	6.68	1.20				0.85	0.56
	Exposed - low half	2	0	0.067	0.00	0.012	0.00	46.03		
	Exposed - top half	2	0	0.064	0.00	0.012	0.00	48.25		
C10	Unexposed	53	3	2.73	1.10				0.53	0.80
	Exposed - low half	7	1	0.44	2.28	2.30	0.19	27.2		
	Exposed - top half	7	0	0.35	0.00	0.0017	0.00	9.50		
C11	Unexposed	68	4	3.06	1.31				0.56	0.56
	Exposed - low half	7	1	0.64	1.57	1.32	0.12	14.5		
	Exposed - top half	6	0	0.41	0.00	0.0021	0.00	6.86		
C12	Unexposed	87	4	4.60	0.87				0.56	0.97
	Exposed - low half	8	1	0.49	2.02	2.68	0.24	29.7		
	Exposed - top half	8	0	0.30	0.00	0.006	0.00	13.89		
C13	Unexposed	58	5	2.85	1.76				0.32	0.55
	Exposed - low half	14	0	0.67	0.00	0.0010	0.00	3.14		
	Exposed - top half	14	1	0.73	1.37	0.75	0.08	7.27		
C14	Unexposed	30	1	1.49	0.67				0.058	0.84
	Exposed - low half	19	3	0.86	3.51	6.73	0.61	74.0		
	Exposed - top half	18	0	0.95	0.00	0.0009	0.00	5.82		
C15	Unexposed	67	3	2.82	1.06				0.46	0.72
	Exposed - low half	9	1	0.42	2.36	2.47	0.21	28.7		
	Exposed - top half	9	0	0.45	0.00	0.0013	0.00	7.64		

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Table A-58 (cont.)		Cases				95% CI				p for
		Controls	Obs	Exp	O/E	OR	from	to	p	trend
C16	Unexposed	34	3	1.62	1.86				0.94	0.74
	Exposed - low half	19	2	1.42	1.39	0.73	0.11	5.05		
	Exposed - top half	19	1	0.69	1.45	0.72	0.07	7.61		
C17	Unexposed	115	7	6.15	1.14				0.68	0.38
	Exposed - low half	3	0	0.10	0.00	0.0045	0.00	32.27		
	Exposed - top half	3	0	0.23	0.00	0.0021	0.00	14.26		
C20	Unexposed	64	5	3.71	1.35				0.26	0.68
	Exposed - low half	13	2	0.71	2.82	2.41	0.38	15.1		
	Exposed - top half	12	0	0.59	0.00	0.0029	0.00	4.66		
C23	Unexposed	13	3	0.83	3.60				0.19	0.11
	Exposed - low half	37	2	2.07	0.97	0.19	0.03	1.41		
	Exposed - top half	37	2	2.19	0.91	0.18	0.03	1.32		
C24	Unexposed	31	2	1.21	1.66				0.29	0.33
	Exposed - low half	25	4	1.76	2.27	1.56	0.25	9.67		
	Exposed - top half	25	1	1.90	0.53	0.30	0.03	3.39		
C26	Unexposed	94	4	4.34	0.92				0.58	0.94
	Exposed - low half	8	1	0.51	1.97	2.37	0.22	25.4		
	Exposed - top half	7	0	0.30	0.00	0.005	0.00	13.17		
C28	Unexposed	51	4	2.60	1.54				0.34	0.22
	Exposed - low half	15	1	0.90	1.12	0.70	0.07	7.01		
	Exposed - top half	14	0	0.74	0.00	0.0009	0.00	3.23		
C31	Unexposed	45	7	4.91	1.43				0.58	0.85
	Exposed - low half	31	1	1.52	0.66	0.36	0.05	2.95		
	Exposed - top half	31	3	1.89	1.59	0.99	0.22	4.37		
C32	Unexposed	49	8	5.10	1.57				0.34	0.15
	Exposed - low half	27	1	1.29	0.78	0.38	0.04	3.37		
	Exposed - top half	27	1	1.77	0.57	0.28	0.03	2.42		
C33	Unexposed	45	6	4.96	1.21				0.51	0.25
	Exposed - low half	38	2	2.09	0.96	0.67	0.12	3.66		
	Exposed - top half	35	1	2.14	0.47	0.32	0.04	2.79		
TRI1	Unexposed	87	10	6.69	1.50				0.23	0.085
	Exposed - low half	8	0	0.44	0.00	0.0020	0.00	5.57		
	Exposed - top half	7	0	0.46	0.00	0.0023	0.00	5.33		
TRI2	Unexposed	128	10	8.54	1.17				0.25	0.10
	Exposed - low half	11	0	0.50	0.00	0.0015	0.00	6.32		
	Exposed - top half	11	0	0.64	0.00	0.0017	0.00	4.91		
TEN2	Unexposed	128	10	8.54	1.17				0.066	
	Exposed	25	0	1.41	0.00	0.0014	0.00	2.23		
B3: Actual and potential contamination										
NDCN	Unexposed	139	13	9.09	1.43				0.80	0.55
	Exposed - low half	26	2	2.07	0.97	0.62	0.13	2.98		
	Exposed - top half	14	1	0.90	1.11	0.70	0.08	5.72		
NALP	Unexposed	170	16	11.32	1.41				0.33	0.14
	Exposed - low half	6	0	0.55	0.00	0.0035	0.00	4.76		
	Exposed - top half	3	0	0.18	0.00	0.007	0.00	14.30		
NBEG	Unexposed	143	13	9.44	1.38				0.91	0.79
	Exposed - low half	24	2	1.91	1.05	0.71	0.15	3.42		
	Exposed - top half	12	1	0.71	1.42	0.95	0.11	8.05		

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Table A-58 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
HEAV	Unexposed	168	15	11.51	1.30				0.42	0.89
	Exposed - low half	6	1	0.25	3.97	3.42	0.34	34.9		
	Exposed - top half	5	0	0.29	0.00	0.014	0.00	9.83		
CLEA	Unexposed	174	15	11.58	1.30				0.82	0.72
	Exposed - low half	4	1	0.44	2.29	1.98	0.19	20.4		
	Exposed - top half	1	0	0.034	0.00	0.073	0.00	83.69		
CON1	Unexposed	123	13	8.48	1.53				0.046	0.078
	Exposed - low half	28	3	1.69	1.78	1.12	0.28	4.47		
	Exposed - top half	28	0	1.89	0.00	0.0007	0.00	1.27		
CON2	Unexposed	76	11	6.21	1.77				0.012	0.017
	Exposed - low half	52	5	3.32	1.51	0.73	0.23	2.34		
	Exposed - top half	51	0	2.52	0.00	0.0009	0.00	0.83		
FIRE	Not involved	176	15	11.73	1.28				0.41	
	Involved	3	1	0.33	3.07	3.02	0.26	35.3		
IN57	Not in workforce	154	15	10.28	1.46				0.23	
	In workforce	25	1	1.78	0.56	0.33	0.04	2.47		
B4: Work area/job (if more than 5% of period)										
PJ1	<5% of period	152	14	10.76	1.30				0.90	
	>=5% of period	27	2	1.30	1.55	1.11	0.23	5.31		
PJ2	<5% of period	165	16	11.61	1.38				0.24	
	>=5% of period	14	0	0.44	0.00	0.006	0.00	6.07		
PJ4	<5% of period	175	15	11.82	1.27				0.26	
	>=5% of period	4	1	0.23	4.29	5.39	0.35	83.0		
PJ6	<5% of period	173	15	11.79	1.27				0.33	
	>=5% of period	6	1	0.27	3.73	3.82	0.32	44.9		
PJ7	<5% of period	172	16	11.25	1.42				0.12	
	>=5% of period	7	0	0.80	0.00	0.0026	0.00	3.23		
PJ8	<5% of period	164	14	11.10	1.26				0.54	
	>=5% of period	15	2	0.95	2.11	1.71	0.34	8.73		
PJ9	<5% of period	161	15	11.49	1.31				0.85	
	>=5% of period	18	1	0.56	1.78	1.23	0.15	9.95		
PJ12	<5% of period	168	14	10.90	1.29				0.70	
	>=5% of period	11	2	1.16	1.73	1.40	0.27	7.20		
PJ16	<5% of period	158	15	10.84	1.38				0.54	
	>=5% of period	21	1	1.21	0.82	0.54	0.07	4.17		
PJ17	<5% of period	174	14	11.83	1.18				0.024	
	>=5% of period	5	2	0.23	8.77	13.0	1.84	92.1		
PJ18	<5% of period	170	16	11.70	1.37				0.30	
	>=5% of period	9	0	0.35	0.00	0.006	0.00	7.73		
PJ19	<5% of period	170	15	11.61	1.29				0.62	
	>=5% of period	9	1	0.45	2.24	1.85	0.19	17.9		
PJ20	<5% of period	174	15	11.59	1.30				0.62	
	>=5% of period	5	1	0.47	2.14	1.84	0.18	18.7		
PJ21	<5% of period	150	14	10.53	1.33				0.92	
	>=5% of period	29	2	1.53	1.31	0.93	0.19	4.42		

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Table A-58 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
PJ22	<5% of period	176	15	11.82	1.27				0.26	
	>=5% of period	3	1	0.23	4.28	5.51	0.34	88.5		
PJ25	<5% of period	160	15	10.89	1.38				0.57	
	>=5% of period	19	1	1.17	0.86	0.56	0.07	4.45		
PJ29	<5% of period	150	15	10.72	1.40				0.43	
	>=5% of period	29	1	1.33	0.75	0.47	0.07	3.36		
PJ31	<5% of period	173	15	11.98	1.25				0.10	
	>=5% of period	6	1	0.078	12.9	11.9	1.13	126		
C: Variables evaluated over 12 week pre-conception period										
C1: Measured radiation exposure										
XG	Unexposed	60	10	5.85	1.71				0.17	0.35
	Exposed -low half	60	1	2.36	0.42	0.19	0.02	1.44		
	Exposed - top half	59	5	3.85	1.30	0.63	0.19	2.04		
HIDA	Unexposed	168	16	11.00	1.45				0.20	0.073
	Exposed -low half	10	0	0.94	0.00	0.0036	0.00	2.71		
	Exposed - top half	1	0	0.11	0.00	0.0026	0.00	22.58		
RMAX	Unexposed	60	10	5.96	1.68				0.16	0.42
	Exposed -low half	60	1	2.45	0.41	0.18	0.02	1.43		
	Exposed - top half	59	5	3.65	1.37	0.68	0.21	2.22		
NEUT	Unexposed	145	13	10.20	1.27				0.76	
	Exposed	34	3	1.85	1.62	1.25	0.32	4.79		
NHI	Unexposed	167	15	11.46	1.31				0.82	
	Exposed	12	1	0.59	1.68	1.31	0.15	11.9		
IT	Unexposed	113	11	8.03	1.37				0.95	0.74
	Exposed -low half	34	2	1.53	1.31	0.88	0.18	4.25		
	Exposed - top half	32	3	2.50	1.20	0.81	0.21	3.16		
IA	Unexposed	114	12	8.08	1.48				0.59	0.52
	Exposed -low half	33	1	1.48	0.68	0.39	0.05	3.18		
	Exposed - top half	32	3	2.50	1.20	0.73	0.19	2.84		
ITRI	Unexposed	177	16	11.82	1.35				0.71	0.41
	Exposed -low half	1	0	0.11	0.00	0.008	0.00	24.26		
	Exposed - top half	1	0	0.12	0.00	0.007	0.00	22.97		
C2: Asssessed exposure to chemicals and other workplace exposures										
C2	Unexposed	84	3	4.43	0.68				0.26	0.16
	Exposed -low half	3	0	0.18	0.00	0.005	0.00	30.60		
	Exposed - top half	2	1	0.22	4.64	12.8	0.64	253		
C3	Unexposed	100	4	5.23	0.77				0.80	0.51
	Exposed -low half	3	0	0.10	0.00	0.007	0.00	48.07		
	Exposed - top half	3	0	0.18	0.00	0.0043	0.00	26.48		
C4	Unexposed	53	0	2.35	0.00				0.074	0.039
	Exposed -low half	13	1	0.74	1.36 (Exposed vs Unexp, Exact p= 0.078)					
	Exposed - top half	6	1	0.33	3.01					
C7	Unexposed	85	3	3.93	0.76				0.17	
	Exposed	11	2	0.76	2.63	4.23	0.59	30.1		
C8	Unexposed	69	4	3.47	1.15				0.61	0.41
	Exposed -low half	19	1	1.29	0.77	0.65	0.07	6.34		
	Exposed - top half	10	0	0.39	0.00	0.0042	0.00	8.12		

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Table A-58 (cont.)		Cases				95% CI			p for
		Controls	Obs	Exp	O/E	OR	from	to	p	trend
C9	Unexposed	112	6	6.07	0.99				0.87	0.60
	Exposed -low half	3	0	0.10	0.00	0.014	0.00	37.26		
	Exposed - top half	1	0	0.031	0.00	0.016	0.00	122.5		
C10	Unexposed	63	1	2.88	0.35				0.059	0.020
	Exposed -low half	11	1	0.58	1.71	5.50	0.31	98.9		
	Exposed - top half	2	1	0.12	8.40	143	1.81	11317		
C11	Unexposed	81	3	3.54	0.85				0.60	0.87
	Exposed -low half	8	1	0.62	1.62	2.08	0.18	23.4		
	Exposed - top half	4	0	0.38	0.00	0.0024	0.00	11.58		
C12	Unexposed	98	3	5.15	0.58				0.40	0.43
	Exposed -low half	7	1	0.30	3.31	6.52	0.57	75.1		
	Exposed - top half	4	0	0.085	0.00	0.017	0.00	74.34		
C13	Unexposed	75	4	3.77	1.06				0.30	0.87
	Exposed -low half	8	1	0.21	4.78	4.86	0.45	52.0		
	Exposed - top half	7	0	0.43	0.00	0.0035	0.00	8.15		
C14	Unexposed	43	1	2.12	0.47				0.64	0.35
	Exposed -low half	22	1	0.89	1.13	2.49	0.15	42.2		
	Exposed - top half	9	1	0.62	1.61	3.82	0.21	68.6		
C15	Unexposed	80	3	3.74	0.80				0.45	0.43
	Exposed -low half	9	0	0.33	0.00	0.0042	0.00	13.86		
	Exposed - top half	5	1	0.39	2.53	3.88	0.31	48.9		
C16	Unexposed	46	2	2.22	0.90				0.83	0.69
	Exposed -low half	22	2	1.24	1.62	1.89	0.24	14.9		
	Exposed - top half	12	1	0.83	1.21	1.42	0.11	18.2		
C17	Unexposed	111	5	5.97	0.84				0.54	
	Exposed	4	0	0.22	0.00	0.0042	0.00	19.88		
C20	Unexposed	73	4	3.91	1.02				0.25	0.82
	Exposed -low half	10	2	0.61	3.28	3.99	0.59	26.9		
	Exposed - top half	7	0	0.38	0.00	0.0038	0.00	9.48		
C23	Unexposed	19	2	0.89	2.25				0.18	0.86
	Exposed -low half	52	1	2.41	0.42	0.15	0.01	1.83		
	Exposed - top half	20	3	1.51	1.99	0.90	0.12	6.69		
C24	Unexposed	36	1	1.31	0.76				0.088	0.061
	Exposed -low half	31	1	1.93	0.52	0.67	0.04	11.4		
	Exposed - top half	14	4	1.25	3.21	5.93	0.58	61.1		
C26	Unexposed	96	3	4.69	0.64				0.28	0.48
	Exposed -low half	6	1	0.19	5.27	9.29	0.81	107		
	Exposed - top half	2	0	0.15	0.00	0.012	0.00	39.21		
C28	Unexposed	57	3	2.92	1.03				0.59	0.42
	Exposed -low half	21	1	1.28	0.78	0.74	0.07	7.81		
	Exposed - top half	10	0	0.54	0.00	0.0013	0.00	6.67		
C31	Unexposed	55	7	5.57	1.26				0.19	0.75
	Exposed -low half	29	0	1.22	0.00	0.0013	0.00	2.41		
	Exposed - top half	26	2	1.39	1.44	1.04	0.19	5.72		
C32	Unexposed	61	7	5.80	1.21				0.20	0.92
	Exposed -low half	28	0	1.06	0.00	0.0015	0.00	2.88		
	Exposed - top half	18	2	1.02	1.96	1.58	0.28	8.89		
C33	Unexposed	56	6	5.41	1.11				0.62	0.36
	Exposed -low half	32	1	1.69	0.59	0.45	0.05	4.03		
	Exposed - top half	31	1	1.73	0.58	0.44	0.05	3.97		

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Table A-58 (cont.)		Controls	Cases Obs	Exp	O/E	95% CI OR	from	to	p	p for trend
TRI1	Unexposed	100	9	7.25	1.24				0.41	0.18
	Exposed -low half	12	0	0.55	0.00	0.0020	0.00	5.41		
	Exposed - top half	1	0	0.12	0.00	0.0004	0.00	25.03		
TRI2	Unexposed	132	10	8.88	1.13				0.44	0.20
	Exposed -low half	13	0	0.56	0.00	0.0023	0.00	5.83		
	Exposed - top half	1	0	0.12	0.00	0.0004	0.00	27.61		
TEN2	Unexposed	131	10	8.85	1.13				0.16	
	Exposed	16	0	0.83	0.00	0.0019	0.00	3.94		
C3: Actual and potential contamination										
NDCN	Unexposed	174	15	11.71	1.28				0.040	0.13
	Exposed -low half	4	0	0.31	0.00	0.014	0.00	9.34		
	Exposed - top half	1	1	0.034	29.1	187	1.53	22866		
NALP	Unexposed	178	16	11.94	1.34				0.57	
	Exposed	1	0	0.11	0.00	0.021	0.00	24.03		
NBEG	Unexposed	175	15	11.83	1.27				0.046	0.076
	Exposed -low half	3	0	0.19	0.00	0.017	0.00	15.01		
	Exposed - top half	1	1	0.034	29.1	189	1.55	23231		
HEAV	Unexposed	177	16	11.92	1.34				0.53	
	Exposed	2	0	0.14	0.00	0.017	0.00	20.21		
CON1	Unexposed	142	15	9.55	1.57				0.0007	0.32
	Exposed -low half	36	0	2.49	0.00	0.0007	0.00	0.94		
	Exposed - top half	1	1	0.017	57.9	205	3.04	13824		
CON2	Unexposed	96	13	7.58	1.72				0.014	0.20
	Exposed -low half	80	2	4.41	0.45	0.21	0.05	0.96		
	Exposed - top half	3	1	0.063	16.0	11.0	0.90	134		
C4: Work area/job (weighted days in 12 week pre-conception period										
JB1	Unexposed	154	15	10.91	1.38				0.82	0.54
	Exposed -low half	24	1	1.11	0.90	0.57	0.07	4.45		
	Exposed - top half	1	0	0.032	0.00	0.072	0.00	84.1		
JB2	Unexposed	166	16	11.61	1.38				0.51	0.24
	Exposed -low half	12	0	0.41	0.00	0.0042	0.00	6.55		
	Exposed - top half	1	0	0.032	0.00	0.0036	0.00	83.96		
JB4	Unexposed	176	16	11.82	1.35				0.41	
	Exposed	3	0	0.24	0.00	0.016	0.00	11.53		
JB6	Unexposed	176	15	11.92	1.26				0.0004	0.003
	Exposed -low half	3	0	0.13	0.00	0.013	0.00	22.70		
	Exposed - top half	0	1	0.00	0.00	(Top vs Low & Unexp, Exact p = 0.082)				
JB7	Unexposed	176	16	11.70	1.37				0.31	
	Exposed	3	0	0.35	0.00	0.007	0.00	7.74		
JB8	Unexposed	168	15	11.25	1.33				0.90	
	Exposed	11	1	0.81	1.24	0.88	0.10	7.53		
JB9	Unexposed	167	16	11.63	1.38				0.52	0.25
	Exposed -low half	11	0	0.41	0.00	0.009	0.00	6.53		
	Exposed - top half	1	0	0.017	0.00	0.018	0.00	155.3		
JB12	Unexposed	172	16	11.32	1.41				0.14	
	Exposed	7	0	0.73	0.00	0.0031	0.00	3.58		

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Table A-58 (cont.)		Controls	Cases Obs	Exp	O/E	OR	95% CI from	to	p	p for trend
JB16	Unexposed	164	15	11.20	1.34				0.0001	0.42
	Exposed -low half	15	0	0.86	0.00	0.0020	0.00	3.21		
	Exposed - top half	0	1	0.00	0.00	(Top vs Low & Unexp, Exact p = 0.082)				
JB17	Unexposed	174	15	11.83	1.27				0.30	
	Exposed	5	1	0.23	4.39	4.10	0.39	43.2		
JB18	Unexposed	174	16	11.85	1.35				0.44	
	Exposed	5	0	0.20	0.00	0.019	0.00	13.52		
JB19	Unexposed	172	15	11.68	1.29				0.50	
	Exposed	7	1	0.38	2.64	2.36	0.23	24.6		
JB20	Unexposed	177	15	11.93	1.26				0.076	
	Exposed	2	1	0.12	8.40	34.4	0.68	1755		
JB21	Unexposed	154	14	10.77	1.30				0.028	0.36
	Exposed -low half	24	1	1.26	0.79	0.55	0.07	4.19		
	Exposed - top half	1	1	0.017	57.9	258	3.82	17408		
JB22	Unexposed	178	16	11.93	1.34				0.56	
	Exposed	1	0	0.12	0.00	0.020	0.00	22.93		
JB25	Unexposed	169	15	11.56	1.30				0.86	0.77
	Exposed -low half	9	1	0.46	2.16	1.71	0.18	15.9		
	Exposed - top half	1	0	0.032	0.00	0.078	0.00	89.14		
JB29	Unexposed	178	15	12.02	1.25				0.018	
	Exposed	1	1	0.029	34.3	114	2.73	4804		
JB31	Unexposed	173	15	11.98	1.25				0.10	
	Exposed	6	1	0.078	12.9	11.9	1.13	126		

Table A-59: Summary analyses of post-conception exposure factors for lymphatic leukaemia and NHL cases (LLNH)

Contamination variables					Increase in OR for unit increase in variable			
				Crude		95% CI		
Variable		Controls	Cases	OR	Estimate	from	to	P-value
NDCN	0	158	8					0.055
	1-5	16	3	3.7	1.28	1.05	1.57	
	>5	1	1	19.8				
NALP	0	172	11					0.019
	>0	3	1	5.2	2.04	1.26	3.31	
NBEG	0	160	8					0.187
	>0	15	4	5.3	1.28	0.95	1.71	
HEAV	0	171	11					0.339
	>0	4	1	3.9	1.70	0.71	4.09	
CLEA	0	173	11					0.175
	>0	2	1	7.9	6.05	0.75	48.72	
CON1	0	130	9					0.086
	>0	45	3	1.0	1.12	1.00	1.25	
CON2	0	85	5					0.209
	>0	90	7	1.3	1.07	0.96	1.20	

Work are/job factors								
				Crude	Adjusted	95% CI		
Variable		Controls	Cases	OR	OR	from	to	P-value
PJ1	<5% of period	149	11					0.974
	>=5% of period	26	1	0.5	0.97	0.12	7.53	
PJ2	<5% of period	161	10					0.367
	>=5% of period	14	2	2.3	2.16	0.47	10.01	
PJ4	<5% of period	170	10					0.053
	>=5% of period	5	2	6.8	6.45	1.37	30.32	
PJ8	<5% of period	163	10					0.471
	>=5% of period	12	2	2.7	1.84	0.39	8.67	
PJ12	<5% of period	165	11					0.833
	>=5% of period	10	1	1.5	1.26	0.16	9.93	
PJ16	<5% of period	160	11					0.817
	>=5% of period	15	1	1.0	0.79	0.10	6.17	
PJ17	<5% of period	169	11					0.253
	>=5% of period	6	1	2.6	4.29	0.54	34.3	
PJ18	<5% of period	170	11					0.638
	>=5% of period	5	1	3.1	1.71	0.21	13.9	
PJ19	<5% of period	167	11					0.392
	>=5% of period	8	1	1.9	2.81	0.36	22.3	
PJ20	<5% of period	172	11					0.402
	>=5% of period	3	1	5.2	2.83	0.33	24.5	
PJ21	<5% of period	146	9					0.303
	>=5% of period	29	3	1.7	2.10	0.56	7.86	
PJ25	<5% of period	164	11					0.77
	>=5% of period	11	1	1.4	1.38	0.18	10.85	
PJ32	<5% of period	164	11					0.677
	>=5% of period	11	1	1.4	1.61	0.20	13.12	

Table A-60: Summary of post-conception exposure factors for all leukaemia & NHL cases (LNHL)

Contamination variables					Increase in OR for unit increase in variable			
				Crude		95% CI		
Variable		Controls	Cases	OR	Estimate	from	to	P-value
NDCN	0	158	11					0.115
	1-5	16	4	3.6	1.21	0.99	1.48	
	>5	1	1	14.4				
NALP	0	172	15					0.052
	>0	3	1	3.8	1.75	1.10	2.80	
NBEG	0	160	11					0.288
	>0	15	5	4.8	1.20	0.90	1.60	
HEAV	0	171	15					0.463
	>0	4	1	2.9	1.50	0.60	3.76	
CLEA	0	173	15					0.26
	>0	2	1	5.8	4.17	0.52	33.3	
CON1	0	130	13					0.289
	>0	45	3	0.7	1.06	0.96	1.18	
CON2	0	85	7					0.131
	>0	90	9	1.2	1.07	0.98	1.17	

Work area/job factors								
				Crude	Adjusted	95% CI		
Variable		Controls	Cases	OR	OR	from	to	P-value
PJ1	<5% of period	149	13					0.205
	>=5% of period	26	3	1.3	2.46	0.69	8.74	
PJ2	<5% of period	161	14					0.586
	>=5% of period	14	2	1.6	1.55	0.35	6.97	
PJ4	<5% of period	170	14					0.109
	>=5% of period	5	2	4.9	4.36	0.95	20.03	
PJ8	<5% of period	163	14					0.818
	>=5% of period	12	2	1.9	1.20	0.26	5.47	
PJ12	<5% of period	165	15					0.887
	>=5% of period	10	1	1.1	0.86	0.11	6.68	
PJ16	<5% of period	160	15					0.566
	>=5% of period	15	1	0.7	0.58	0.08	4.41	
PJ17	<5% of period	169	15					0.374
	>=5% of period	6	1	1.9	2.93	0.37	23.04	
PJ18	<5% of period	170	15					0.914
	>=5% of period	5	1	2.3	1.12	0.14	8.89	
PJ19	<5% of period	167	15					0.549
	>=5% of period	8	1	1.4	1.99	0.26	15.51	
PJ20	<5% of period	172	15					0.595
	>=5% of period	3	1	3.8	1.87	0.22	15.99	
PJ21	<5% of period	146	13					0.58
	>=5% of period	29	3	1.2	1.45	0.41	5.19	
PJ25	<5% of period	164	15					0.99
	>=5% of period	11	1	1.0	0.99	0.13	7.66	
PJ27	<5% of period	171	15					0.728
	>=5% of period	4	1	2.9	1.47	0.19	11.43	
PJ32	<5% of period	164	15					0.96
	>=5% of period	11	1	1.0	1.06	0.13	8.42	

Table A-61: Summary analyses of post-conception exposure factors for cases other than leukaemia or NHL (OCAN)

Contamination variables					Increase in OR for unit increase in variable			
				Crude		95% CI		
Variable		Controls	Cases	OR	Estimate	from	to	P-value
NDCN	0	126	11					0.025
	1-5	28	2	0.8	1.24	1.05	1.46	
	>5	2	3	17.2				
NBEG	0	131	11					0.003
	>0	25	5	2.4	1.41	1.15	1.74	
HEAV	0	149	13					0.046
	>0	7	3	4.9	2.17	1.22	3.87	
CLEA	0	153	15					0.327
	>0	3	1	3.4	3.42	0.41	28.81	
CON1	0	106	11					0.708
	>0	50	5	1.0	1.02	0.92	1.12	
CON2	0	65	8					0.415
	>0	91	8	0.7	1.03	0.96	1.10	

Work are/job factors								
				Crude	Adjusted	95% CI		
Variable		Controls	Cases	OR	OR	from	to	P-value
PJ1	<5% of period	130	15					0.703
	>=5% of period	26	1	0.3	0.69	0.09	5.30	
PJ6	<5% of period	151	14					0.081
	>=5% of period	5	2	4.3	5.28	1.08	25.76	
PJ7	<5% of period	151	15					0.63
	>=5% of period	5	1	2.0	1.74	0.21	14.03	
PJ8	<5% of period	141	14					0.9
	>=5% of period	15	2	1.3	0.91	0.20	4.21	
PJ9	<5% of period	137	14					0.403
	>=5% of period	19	2	1.0	2.04	0.43	9.61	
PJ12	<5% of period	144	15					0.667
	>=5% of period	12	1	0.8	0.65	0.08	5.11	
PJ13	<5% of period	147	15					0.772
	>=5% of period	9	1	1.1	1.38	0.17	10.84	
PJ16	<5% of period	137	12					0.105
	>=5% of period	19	4	2.4	2.89	0.89	9.36	
PJ17	<5% of period	150	15					0.488
	>=5% of period	6	1	1.7	2.27	0.28	18.35	
PJ19	<5% of period	150	14					0.149
	>=5% of period	6	2	3.6	3.74	0.79	17.79	
PJ20	<5% of period	153	15					0.873
	>=5% of period	3	1	3.4	1.20	0.14	10.51	
PJ21	<5% of period	126	14					0.951
	>=5% of period	30	2	0.6	0.95	0.21	4.34	
PJ25	<5% of period	147	15					0.971
	>=5% of period	9	1	1.1	0.96	0.12	7.83	
PJ31	<5% of period	152	15					
	>=5% of period	4	1	2.5	7.00	0.61	80.39	0.18

Figure A-1: Cumulative observed/expected case ratios by distance from plant to birth residence

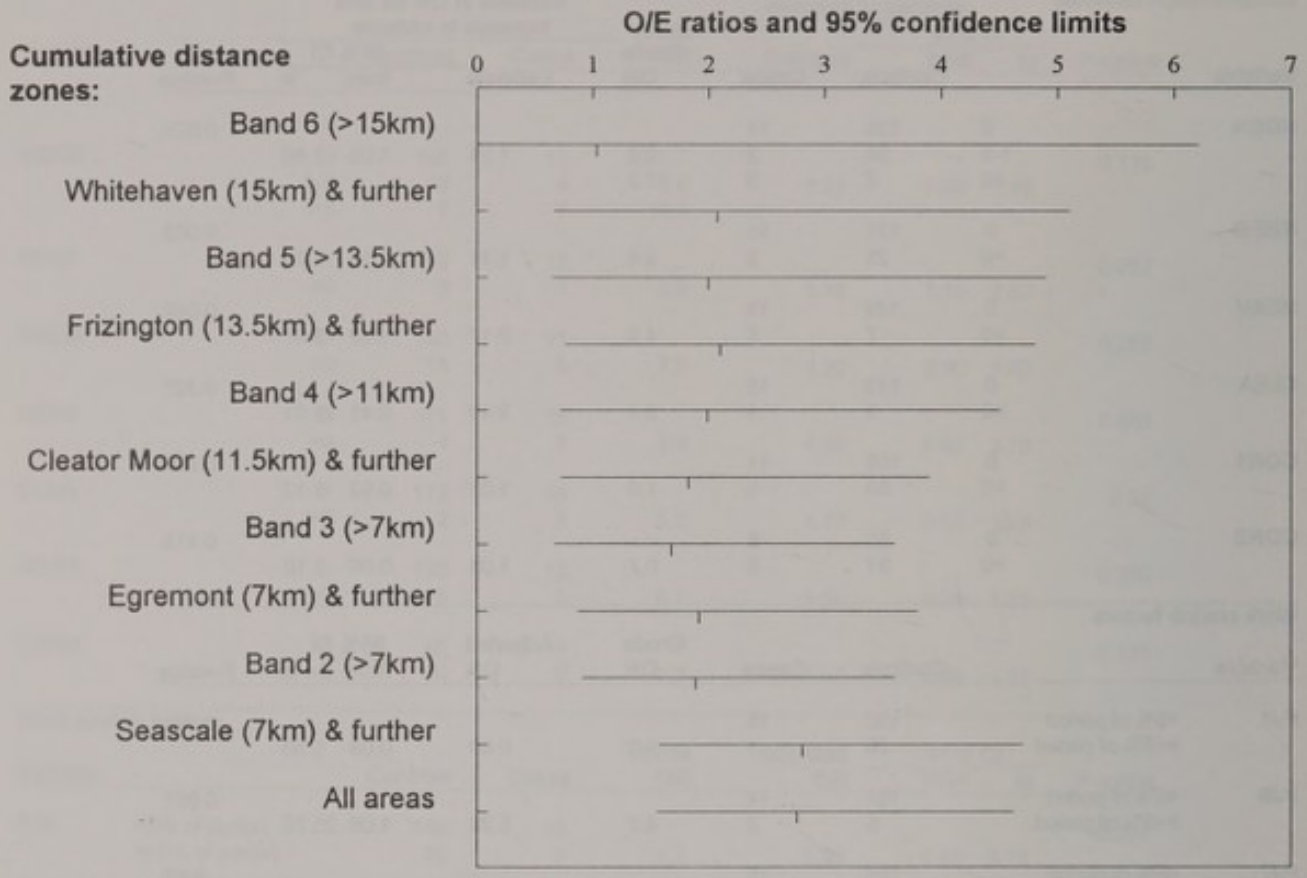
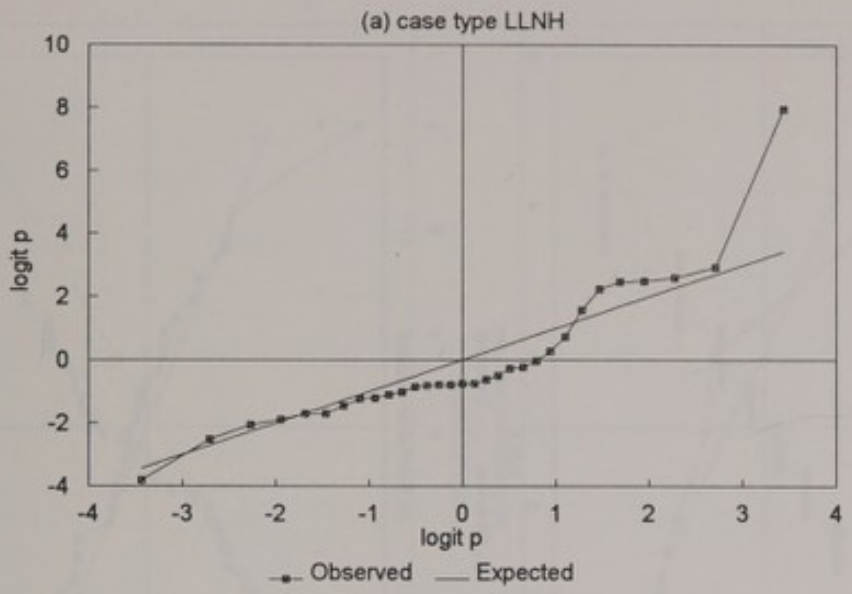
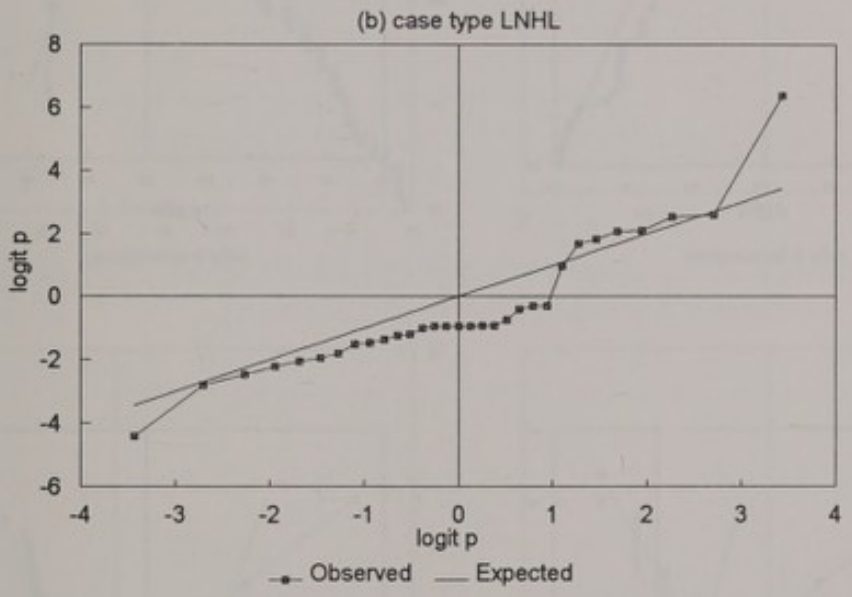


Figure A-2: Observed and expected values for the signed, ranked p-values from fits of 31 Area/job factors to the three case types





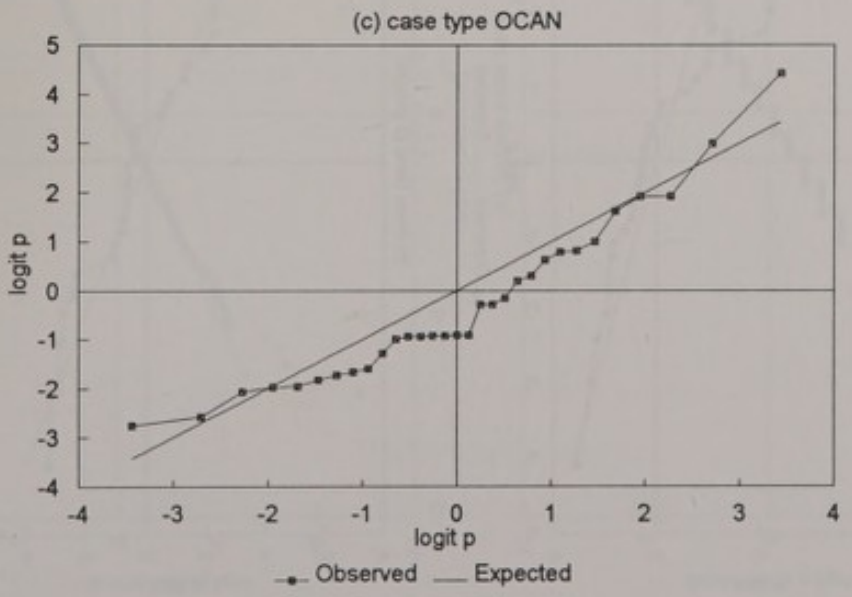
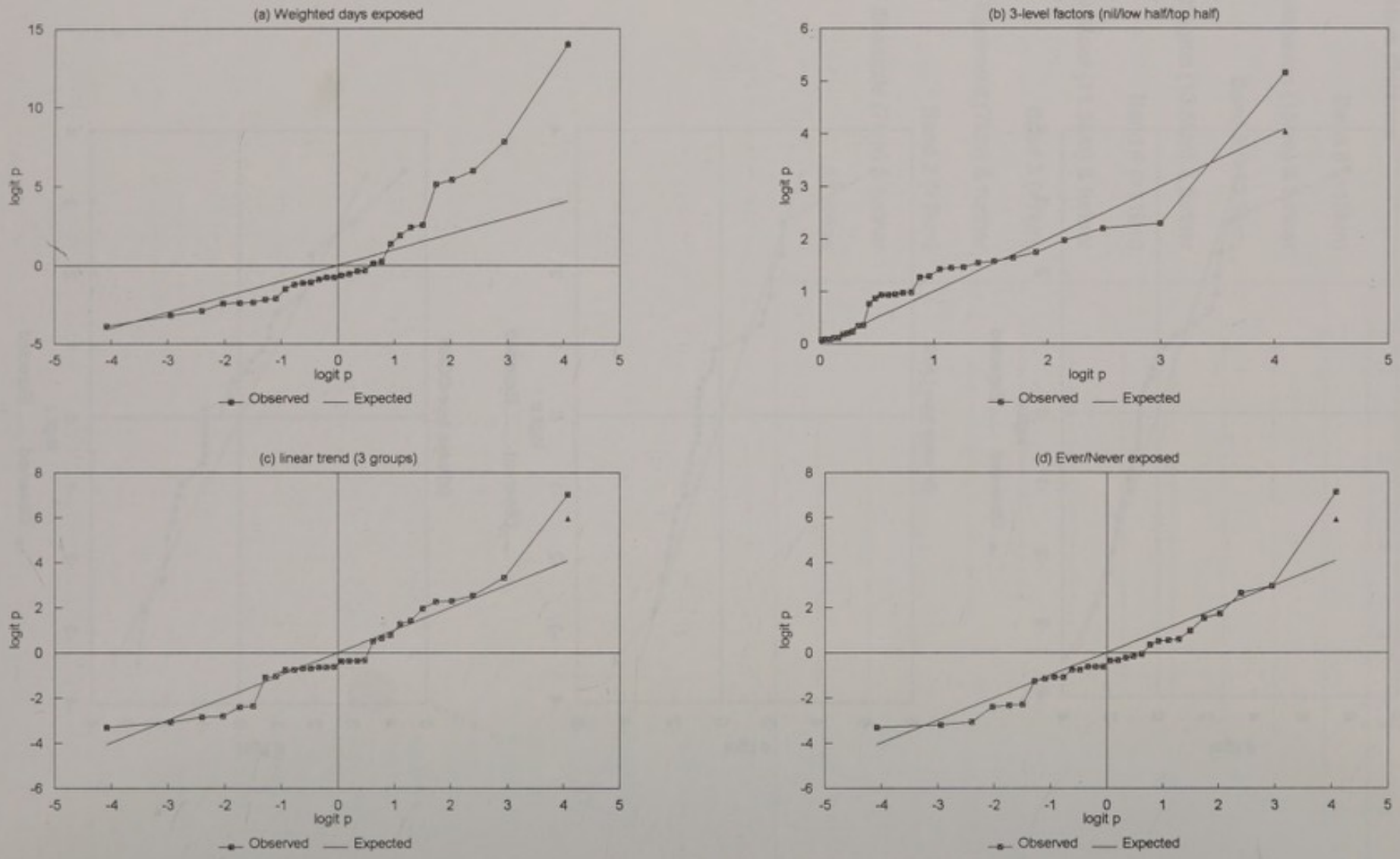


Figure A-3: Observed and expected values for the signed, ranked p-values from fits of 30 assessed exposure factors for LLNH cases



Note: The highest point on each graph represents potential exposure to tritium: variable TRI1 is shown as a square, variable TRI2 as a triangle.

Figure A-4: Monte Carlo assessment of the distribution of deviance changes for measures of external radiation exposure.

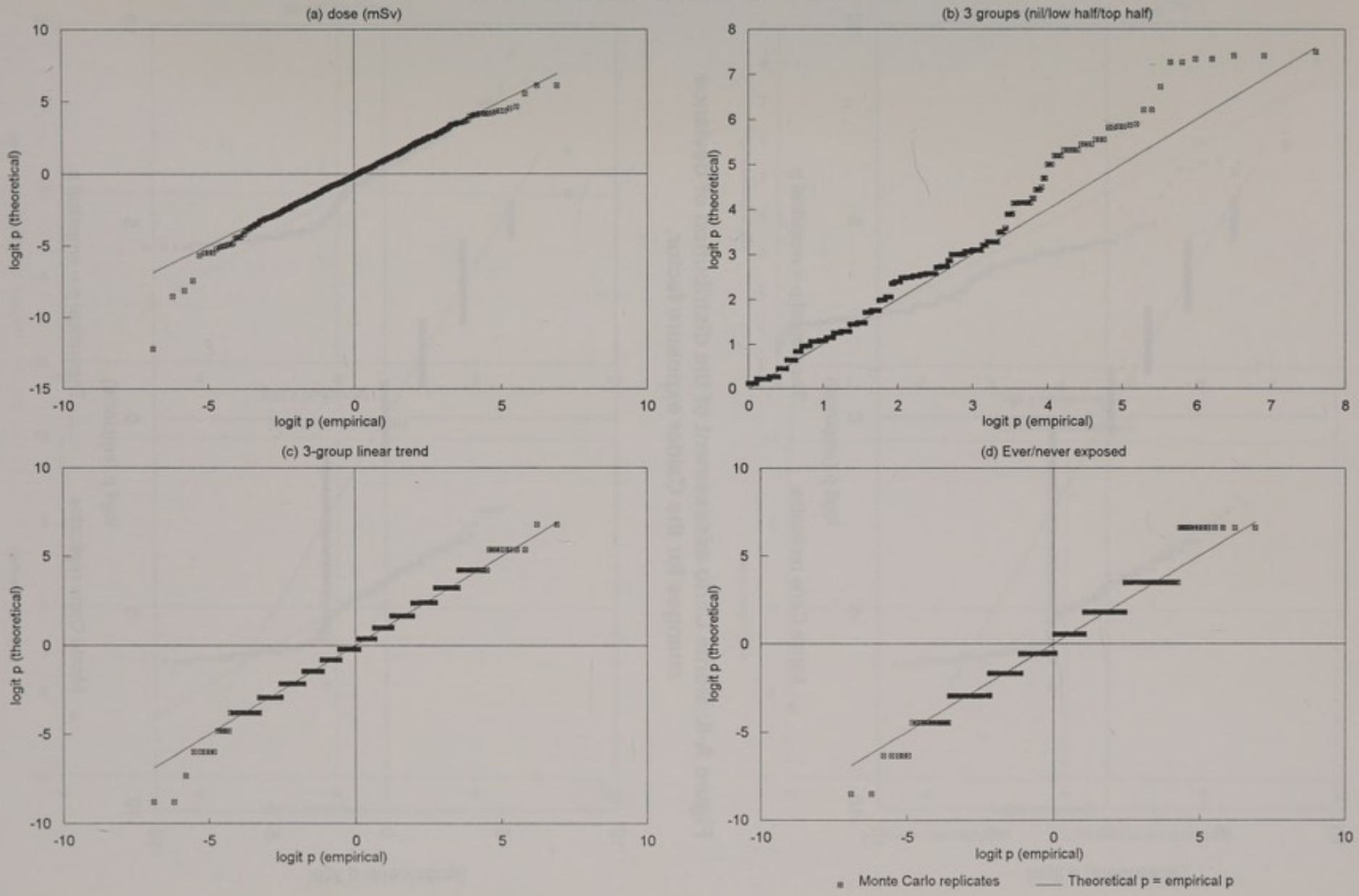


Figure A-5: Monte Carlo assessment of the distribution of deviance changes for the Seascale residence factor.

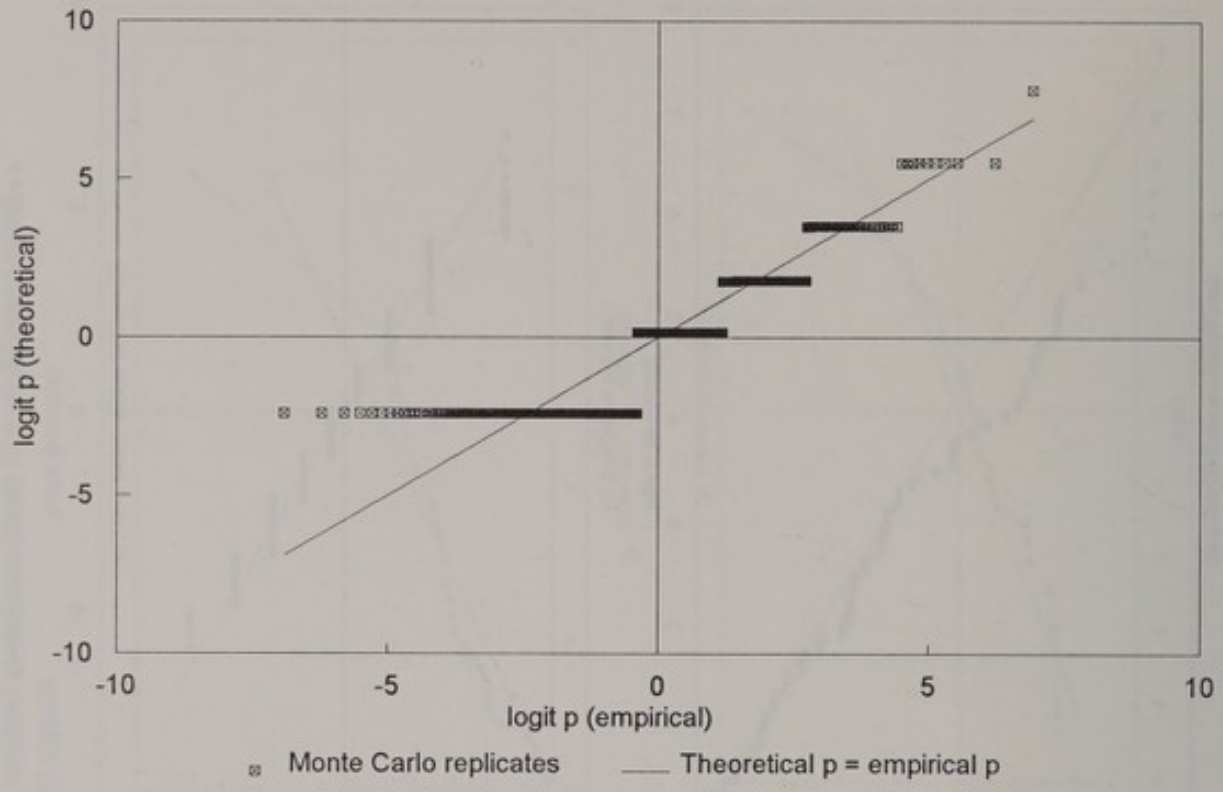


Figure A-6: Monte Carlo assessment of the distribution of deviance changes for the Calder exposure factor.

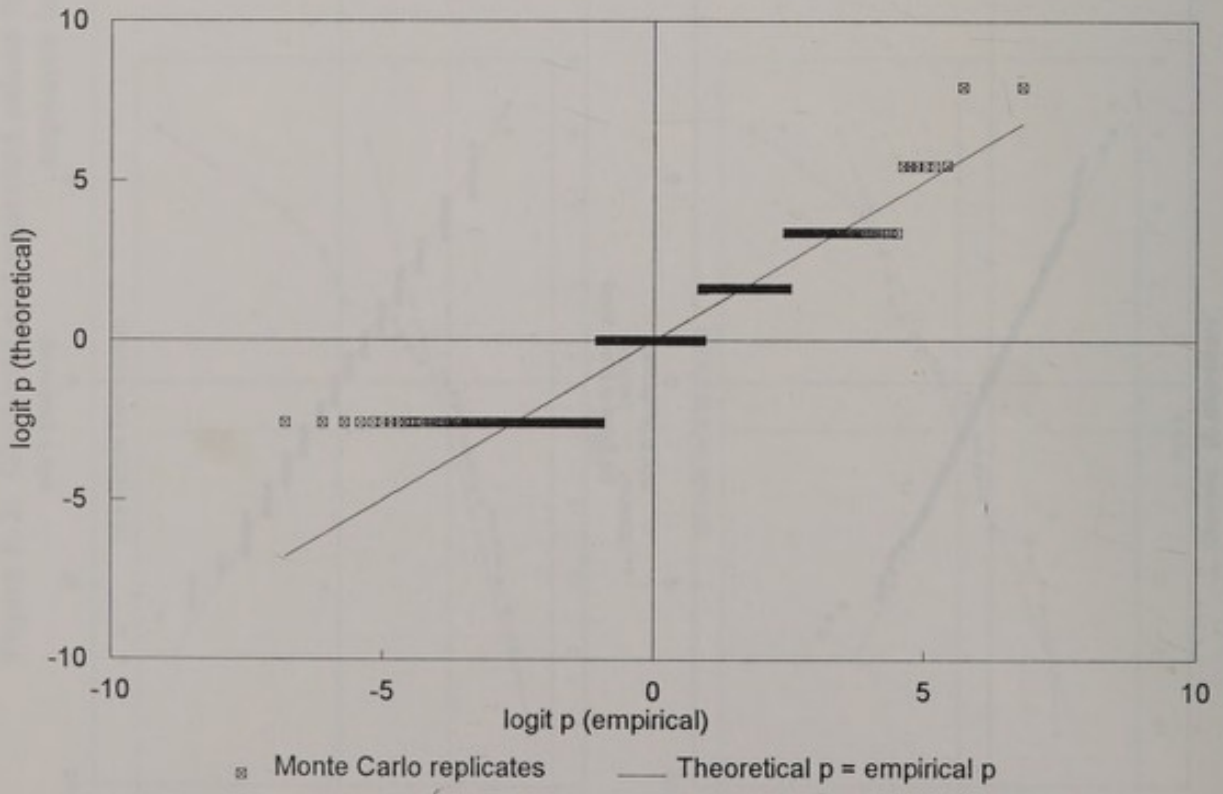
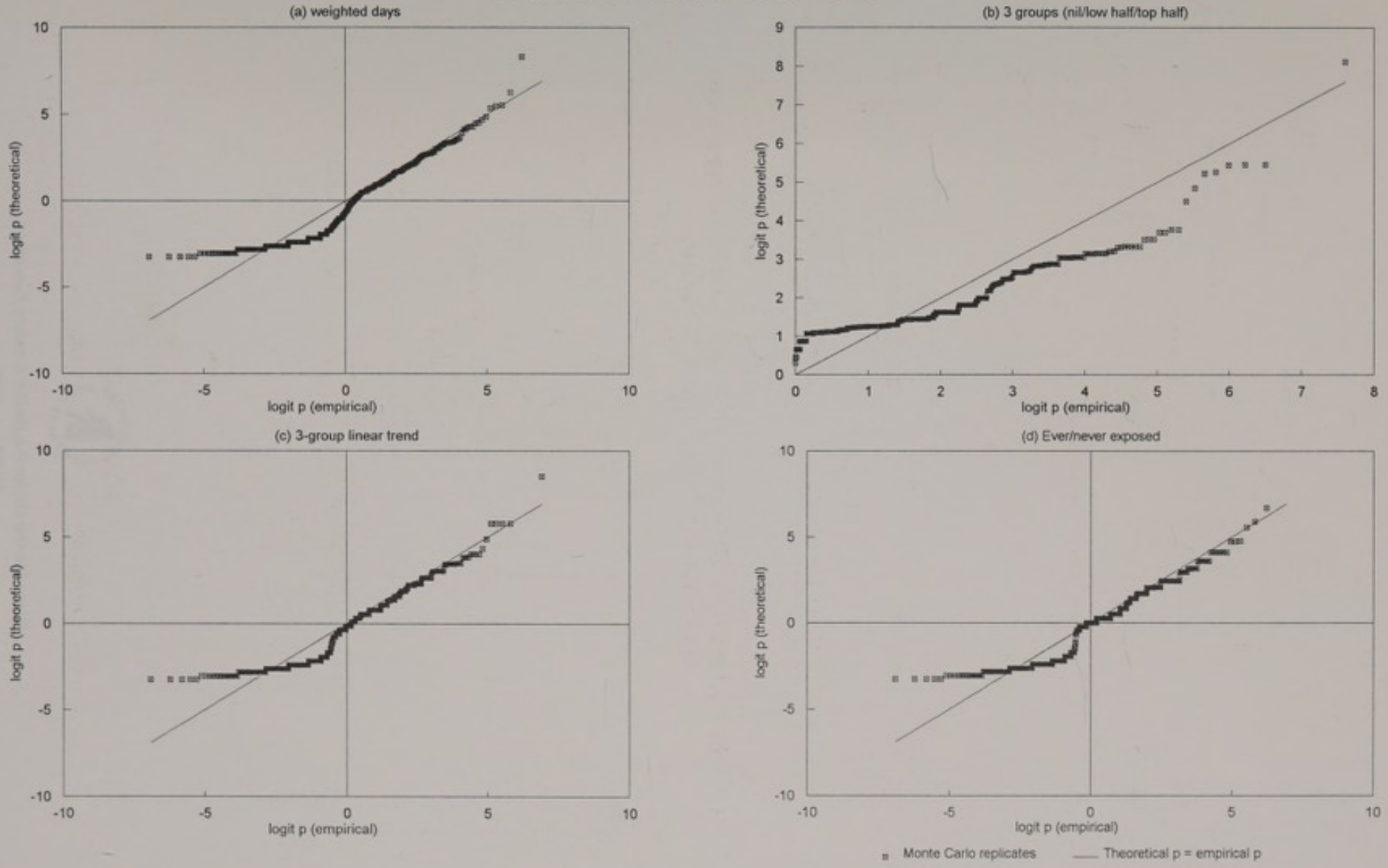


Figure A-7: Monte Carlo assessment of the distribution of deviance changes for measures of potential tritium exposure



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