La Hague

The incidence of childhood leukaemia around the La Hague nuclear waste reprocessing plant (France): a survey for the years 1978–1998

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Abstract

***Background*—A previous study has suggested an increased incidence rate of leukaemia from 1978 to 1992 in people aged 0 to 24 years and living in the vicinity of the La Hague nuclear waste reprocessing plant without considering age and cytological type.**

***Setting*—The Nord Cotentin region (France) and the island of Alderney (United Kingdom).**

***Study objective*—To describe the occurrence of leukaemia for each age group and cytological type from 1978 to 1998 in the same area, using accurate reference incidence rates and adequate estimation of the at risk population.**

***Design*—A geographical study of incidence using three zones defined according to their distance from the site (0 to 10 km: Beaumont-Hague electoral ward, 10 to 20 km and 20 to 35 km) has been conducted. The risk of leukaemia was estimated from the standardised incidence ratio (SIR) of the number of cases observed to the number expected. Exact 95% confidence intervals (CI) have been computed.**

***Participants*—All people under the age of 25 years living in the study region between 1978 and 1998.**

***Main results*—The observed number of cases of leukaemia in the study region as a whole was consistent with the expected value (SIR=1.03; 95%CI: 0.73, 1.41). No cases were observed on Alderney. The SIR in the Beaumont-Hague electoral ward was 2.17 (95%CI: 0.71, 5.07). The highest SIR was observed in the 5 to 9 years age group (SIR=6.38; 95%CI: 1.32, 18.65). This consists in acute lymphoblastic leukaemia cases.**

***Conclusion*—This study indicates an increased incidence of leukaemia in the area situated at less than 10 km from the plant. Monitoring and further investigations should be targeted at acute lymphoblastic leukaemia occurring during the childhood incidence peak (before 10 years) in children living near the La Hague site and may be other nuclear reprocessing plants.**

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The Nord Cotentin region of France has a particularly high density of nuclear installations. The La Hague nuclear waste reprocessing plant, a surface storage facility for nuclear waste, the Flamanville nuclear power station and the Cherbourg military arsenal are all within 20 km of each other.

The clusters of leukaemia in children and young adults discovered near the nuclear reprocessing plants of Sellafield (England)[1] and Dounreay (Scotland)[2] have been largely investigated. Complete overviews, emphasing the crucial role of population movements, have been recently published.[3 4] In France, several epidemiological studies were conducted to analyse the mortality rate attributable to leukaemia or the leukaemia incidence among children and young adults living in the vicinity of the La Hague reprocessing plant.[5–7] The incidence of leukaemia between 1978 and 1992 in the Beaumont-Hague electoral ward (10 709 inhabitants in 1990), in which the plant is situated was found to be higher than expected (4 cases observed versus 1.4 expected; standardised incidence ratio (SIR) =2.8; 95% confidence intervals (95%CI): 0.8, 7.2).[7] In this paper, the expected numbers of cases were calculated with reference rates based on small population size and short period (1978–1982) and person years were estimated by linear interpolation and extrapolation methods. This observation led to a case-control study that showed that the occurrence of leukaemia was associated with the mother, while pregnant, or the children themselves, going to the beach, and the children eating locally caught fish and shellfish.[8] These findings have been much debated especially concerning choice of the controls, possible recall bias, number of associations tested and interpretation of the results.[9–13] They reinforced the misgivings of the local population.

The La Manche cancer register (ARKM) has been collecting extensive data on sex, age, cytological type and case history in the "département" (county) since 1994. It has also access to a professional relations network allowing the incidence of child and young adult leukaemia in Nord Cotentin to be determined retrospectively. In the context of an increased childhood and young adulthood leukaemia incidence rate in the small Beaumont-Hague electoral ward, the aim of this study was first to extend the surveillance time period by 40% and to describe the incidence of leukaemia in the Nord Cotentin region between 1978 and 1998, with more accurate estimation of the expected number. Secondly, the extension of the study period permitted the data to be analysed by age and cytological type, which provides guidance for further aetiological investigations.

Table 1 Population at risk (person years), estimated by the diagonal method for the period 1978–1998, by age group, sex and zone in Nord Cotentin

Age (y)	Sex	Distance from the plant			
		0 to 10 km	10 to 20 km	20 to 35 km	Total (0 to 35 km)
0 to 4	Male	8 333	76 883	47 206	132 422
	Female	7 926	73 854	45 451	127 231
	Total	*16 259*	*150 737*	*92 657*	*259 653*
5 to 9	Male	8 899	73 016	51 303	133 218
	Female	8 618	70 600	49 550	128 768
	Total	*17 517*	*143 616*	*100 853*	*261 986*
10 to 14	Male	8 654	69 513	53 936	132 103
	Female	8 312	67 407	52 317	128 036
	Total	*16 966*	*136 920*	*106 253*	*260 139*
15 to 19	Male	7 833	68 230	53 367	129 430
	Female	7 186	66 927	50 374	124 487
	Total	*15 019*	*135 157*	*103 741*	*253 917*
20 to 24	Male	7 143	72 205	49 533	128 881
	Female	6 521	70 247	46 222	122 990
	Total	*13 664*	*142 452*	*95 755*	*251 871*
Total 0 to 24	Male	40 862	359 847	255 345	656 054
	Female	38 563	349 035	243 914	631 512
	Total	*79 425*	*708 882*	*499 259*	*1 287 566*

Methods

The studied region lies within 35 km of the La Hague nuclear reprocessing plant. It was divided into three zones according to the distance from the plant: 0 to 10 km (Beaumont-Hague electoral ward), 10 to 20 km and 20 to 35 km.[7] The incidence of leukaemia in the 0 to 24 year old age group living on one of the Channel Islands, Alderney (UK), situated at 15 km from the site was also investigated. The study period covered the years 1978 to 1998. Before 1978, patient files were impossible to trace retrospectively.

COLLECTION AND VALIDATION OF CASES

Cases were all individuals aged between 0 and 24 years old diagnosed with leukaemia between the 1 January 1978 and the 31 December 1998, and living in the study area when diagnosed. Cases during the years 1978 to 1993 were identified by a retrospective survey of the 194 doctors who had practised in the study area at some time during the period. Firstly, the 168 physicians (general practitioners and paediatricians) currently practising in the area under study and in the five surrounding electoral wards were asked about cases of leukaemia among their patients, the year when they started to practise and the name of their predecessor. A total of 167 replies were obtained: 35 had been practising since before 1978; 103 between 1978 and 1993 and 19 since 1993. The replies also named 56 physicians practising in the area between 1978 and 1993 and who had subsequently retired or moved. These doctors were also contacted. The files of hospitals routinely providing healthcare for the inhabitants of Nord Cotentin were used, as were death certificate data. Cases for the period from 1994 onwards were identified from the data of the La Manche cancer register. Data for Alderney were collected from the two general practitioners on the island.

The cytology of all available blood and/or bone marrow samples was examined by one of us (XT) to confirm diagnosis. Cases were scored as acute lymphoblastic leukaemia, acute myeloblastic leukaemia, chronic myeloid leukaemia or unclassified acute leukaemia according to the French-American-British classification (FAB classification).[14]

POPULATION DATA

The following demographic data were supplied by the "Institut National de la Statistique et des Etudes Economiques" (INSEE) for each French electoral ward: population by age and sex for the years 1975, 1982, and 1990, the total population in 1999, and numbers of births and deaths by age and sex from 1975 to 1997. The population for each age, sex and electoral ward was estimated for each year by aging the population.[15] Each of the age cohorts was followed up from a census or from birth by aging one year at a time, and subtracting the number of deaths recorded. The result was then corrected by applying the migratory flux evenly over the period between censuses and for each cohort.

The total population at risk in the 10 electoral wards and for the period studied was 1 287 566 person years (table 1).

For the island of Alderney, census data for age and sex were obtained from the Economics and Statistics Unit, Government of Guernsey, for the years 1981, 1986, 1991 and 1996. In the absence of more detailed data, linear interpolations and extrapolations were used to estimate the size of the inter-census populations (11 300 person years).

REFERENCE INCIDENCE RATES

Reference incidence rates for leukaemia were calculated from published general population French cancer registers (Bas-Rhin, Doubs and Isère 1978–1992, Calvados 1978–1987, Haut-Rhin 1988–1992).[16–18] A single reference value was calculated for each sex and five year age group from the sums of cases and person years of all the reference registers (table 2): for the 0 to 24 year old age group the world standardised incidence was 3.42 per 100 000 person years for boys and 2.59 per 100 000 person years for girls.

The paediatric registers of Lorraine and of the Provence-Alpes-Côte-d'Azur and Corsica regions were also used as references for children under 15 years old and for the analysis according to type of leukaemia.[19–21]

STATISTICAL METHODS

It was decided a priori to analyse the data by the following age bands: 0 to 4; 5 to 9; 10 to 14; 15 to 24. Acute lymphoblastic leukaemia cases were separately considered for the 1 to 6 year old age group, as this age group includes the peak incidence reported for this condition.[22,23]

Table 2 Incidence of leukaemia (per 100 000 person years) by sex and age group, calculated from 5 French registers (Bas-Rhin, 1978–1992; Doubs, 1978–1992; Calvados, 1978–1987; Haut-Rhin, 1988–1992; Isère, 1978–1992)

Sex	Age (y)				
	0 to 4	5 to 9	10 to 14	15 to 19	20 to 24
Male	5.51	3.23	2.29	2.63	2.65
Female	4.65	2.11	2.22	1.68	1.55
Total	5.09	2.68	2.26	2.16	2.11

Table 3 Description of leukaemia cases in people under 25 years between 1978 and 1998 in the study zone

Case number	*Zone 1**	*Zone 2**	*Zone 3**	*Year of diagnosis*	*Age at diagnosis (y)*	*Sex*	*Cytological type†*
1		×		79	1	M	AML
2		×		79	5	M	AML
3			×	79	19	F	CML
4		×		80	14	M	ALL
5			×	80	24	M	CML
6	×			81	6	M	ALL
7	×			81	15	F	CML
8		×		82	3	F	ALL
9		×		83	6	F	ALL
10			×	83	22	F	AML
11		×		84	6	F	ALL
12			×	84	14	F	ALL
13			×	85	1	F	AL
14			×	85	4	M	ALL
15			×	85	8	F	ALL
16		×		87	16	F	ALL
17			×	87	3	M	ALL
18			×	87	4	M	ALL
19			×	87	5	F	ALL
20			×	88	1	M	ALL
21			×	88	23	M	AML
22	×			89	5	M	ALL
23		×		89	1	F	ALL
24		×		90	12	M	ALL
25	×			92	1	M	ALL
26		×		93	2	M	ALL
27		×		93	18	M	CML
28		×		93	23	F	CML
29		×		94	15	F	CML
30			×	94	6	F	ALL
31		×		95	12	F	ALL
32		×		95	12	M	AML
33			×	95	12	M	ALL
34		×		97	14	M	AML
35			×	97	0	M	AML
36			×	97	20	M	ALL
37	×			98	5	M	ALL
38		×		98	15	M	AML

*Zone : 1 : <10 km from the reprocessing plant; 2 : 10 to 20 km from the plant; 3 : 20 to 35 km from the plant. †Type of leukaemia : ALL : acute lymphoblastic leukaemia; AML : acute myeloblastic leukaemia; CML : chronic myeloid leukaemia; AL : unclassified acute leukaemia.

The number of cases expected was calculated in the population in each zone studied by applying the reference incidence for age and sex. The risk of leukaemia in Nord Cotentin was estimated from the ratio of the number of cases observed to the number expected as a SIR. The 95%CI for the SIR were calculated assuming that the number of observed cases followed a Poisson distribution (Stata 6.0 software, College Station, Texas). Confidence intervals should not be considered as a test of statistical significance but as numerical indices providing guidance to the selection of important patterns.[24]

Results

There were 38 cases (22 boys and 16 girls) of leukaemia recorded between 1978 and 1998 in the population of 0 to 24 year olds in the study region (see table 3 for details). The first case was diagnosed in 1979 and the last in 1998. There were 23 cases of acute lymphoblastic leukaemia (60.5%), eight of acute myeloblastic leukaemia (21.1%), six of chronic myeloid leukaemia (15.8%) and one of unclassified acute leukaemia (2.6%). Five of the cases lived in the Beaumont-Hague electoral ward, 16 in the 10 to 20 km zone and 13 in the 20 to 35 km zone. Three of the cases were Down's syndrome patients, none of whom lived in the Beaumont-Hague electoral ward. None of the 38 cases had a known history of cancer, trisomy 8 syndrome,

Table 4 Number of expected (E) and observed (O) cases of leukaemia (0 to 24 year olds) and geographical location in the Nord Cotentin region between 1978 and 1998 (reference incidence rates from five general cancer registers, see table 2)

	Age (y)																	
	0 to 4				*5 to 9*				*10 to 14*				*15 to 24*				*Total 0 to 24*			
Zones	*O*	*E*	*SIR*	*95% CI*	*O*	*E*	*SIR*	*95% CI*	*O*	*E*	*SIR*	*95% CI*	*O*	*E*	*SIR*	*95% CI*	*O*	*E*	*SIR*	*95% CI*
0 to 10 km	1	0.83	1.20	0.03, 6.71	3	0.47	6.38	1.32, 18.65	0	0.38	0.00	0.00, 9.70*	1	0.62	1.61	0.04, 8.99	5	2.30	2.17	0.71, 5.07
10 to 20 km	4	7.67	0.52	0.14, 1.34	3	3.85	0.78	0.16, 2.28	5	3.09	1.62	0.53, 3.78	5	5.92	0.84	0.27, 1.97	17	20.53	0.83	0.48, 1.33
20 to 35 km	6	4.72	1.27	0.47, 2.77	3	2.70	1.11	0.23, 3.25	2	2.40	0.83	0.10, 3.01	5	4.28	1.17	0.38, 2.73	16	14.10	1.13	0.65, 1.84
entire study zone: 0 to 35 km	11	13.22	0.83	0.42, 1.49	9	7.02	1.28	0.59, 2.43	7	5.87	1.19	0.48, 2.46	11	10.82	1.02	0.51, 1.82	38	36.93	1.03	0.73, 1.41
10 to 20 km including Aldemey	4	7.79	0.51	0.14, 1.31	3	3.91	0.77	0.16, 2.24	5	3.15	1.59	0.52, 3.70	5	6.02	0.83	0.27, 1.94	17	20.68	0.81	0.48, 1.32

*One tail, 97.5% confidence intervals.

Table 5 Numbers of observed (O) and expected (E) cases of acute lymphoblastic leukaemia (ALL) by five year age group, and of acute myeloblastic leukaemia (AML) in the 0 to 14 year old group (reference incidence rates from the paediatric registers of Lorraine and Provence-Alpes-Côtes-d'Azur and Corsica regions)

	Cytological type and age (y)																			
	ALL, 0 to 4				ALL, 5 to 9				ALL, 10 to 14				ALL, 0 to 14				AML, 0 to 14			
Zones	O	E	SIR	95% CI	O	E	SIR	95% CI	O	E	SIR	95% CI	O	E	SIR	95% CI	O	E	SIR	95% CI
0 to 10 km	1	0.89	1.12	0.03, 6.26	3	0.52	5.77	1.19, 16.86	0	0.25	0.00	0.00, 14.75*	4	1.66	2.41	0.66, 6.17	0	0.27	0.00	0.00, 13.66*
10 to 20 km	3	8.24	0.36	0.08, 1.06	2	4.28	0.47	0.06, 1.69	3	2.03	1.48	0.30, 4.32	8	14.55	0.55	0.24, 1.08	4	2.36	1.70	0.46, 4.34
20 to 35 km	4	5.06	0.79	0.22, 2.02	3	3.01	1.00	0.21, 2.91	2	1.58	1.27	0.15, 4.57	9	9.65	0.93	0.43, 1.77	1	1.60	0.63	0.02, 3.48
entire study zone: 0 to 35 km	8	14.19	0.56	0.24, 1.11	8	7.81	1.02	0.44, 2.02	5	3.86	1.30	0.42, 3.02	21	25.86	0.81	0.50, 1.24	5	4.24	1.18	0.38, 2.75

*One tail, 97.5% confidence intervals.

Bloom syndrome, ataxia telangiectasia, Fanconi anaemia, Li-Fraumeni or immunodeficiency syndromes.

The expected total number of cases in the study area was 36.93, and 38 cases were observed (SIR=1.03; 95%CI: 0.73, 1.41) (table 4). In the 0 to 10 km zone (Beaumont-Hague), there were five cases whereas 2.30 were expected. The SIR for the entire 0 to 24 year old group was 2.17 (95%CI: 0.71, 5.07). The highest SIR for an age group was for the 5 to 9 year olds: there were three cases observed in this group although 0.47 were expected (SIR=6.38; 95%CI: 1.32, 18.65). There was no excess in number of cases for the 10 to 35 km zones for any sex or age group. In the 0 to 24 year old population of Alderney, there were no cases of leukaemia.

Table 5 shows the results classified according to type of leukaemia (acute lymphoblastic leukaemia and acute myeloblastic leukaemia) for children under the age of 15. The SIR was 5.77 for acute lymphoblastic leukaemia in the 5 to 9 year old age group (95%CI: 1.19, 16.86). All three cases involved were boys born in the "département" of La Manche. These cases were diagnosed in 1981, 1989 and 1998.

Discussion

For the area studied as a whole, the number of cases observed was consistent with the number expected. When comparing the three areas around the La Hague plant, the highest SIR of leukaemia among people aged less than 25 years was observed in the 0 to 10 km area (SIR=2.17; 95%CI: 0.71, 5.07). In this zone, the highest SIR concerned the 5 to 9 year olds. These cases were three children aged 5 or 6 and suffering acute lymphoblastic leukaemia.

Of the 194 doctors practising in the area at some time during the study period, nine (4.6%) were dead, four (2.1%) could not be traced, and 23 (11.9%) did not reply. The highest response rates were in the zones less than 10 km and 10 to 20 km from the plant (83.3% and 86.7% respectively). The response rate was 76.9% for the 20 to 35 km zone and 73.7% for the surrounding area, and these relatively low response rates raise the possibility of underascertainment of cases in these areas. It is likely, in any event, that physicians with no cases to report would tend to be found among the non-responders. The files of the usual healthcare system were used, as far as possible, to validate the data, but are not exhaustive for the earlier part of the period under study. All the diagnoses were validated by the same investigator who had no information about the patient (sex, age or place of residence).

In France, general population cancer registers cover the population of a "département", with the consequence that the population sizes are small. The reference values used were calculated by combining data from registers from five "départements" in which the incidence rates of cancer are stable over time. There are also three registers in France recording paediatric cancer (under 15 years old). According to these paediatric registers, the expected number of cases in the under 15 year old group in our study is 32.42, and 27 were observed (SIR=0.83; 95%CI: 0.55, 1.21). Using these registers for reference, the SIR in the Beaumont-Hague electoral ward in 5 to 9 year old group is smaller (SIR=4.62; 95%CI: 0.95, 13.49; 0.65 expected cases). Because of a more accurate data collection, the paediatric registers give reference incidence rates higher than those from general population registers. Indeed, the expected number of cases of acute lymphoblastic leukaemia in the 5 to 9 year old group calculated from the paediatric registers is higher than the expected numbers in the same age group of all forms of leukaemia calculated from the general population registers.

Linear interpolations between census dates provide an inaccurate estimate of the population because there was substantial migration to and from the study region. During the study period, there were two major building projects in the Nord Cotentin region: the nuclear power station at Flamanville (1978 to 1986) and the construction of a new nuclear waste reprocessing unit on the La Hague site (1982 to 1991). The diagonal interpolation method we used takes account of the aging of the population and of the numbers of births and deaths.[15] The methodological options taken for both the estimation of the at risk population and the reference incidence rate explained the higher expected number obtained in this study as compared with the previous ones.[6 7]

Acute lymphoblastic leukaemias are the most prevalent forms of leukaemia among those under 15 years old, and account for the peak in leukaemia incidence observed in young children in industrialised countries.[22] In our study, there were four cases of acute lymphoblastic leukaemia in 1 to 6 year olds in Beaumont-Hague, whereas the number expected from the Lorraine paediatric register is

0.96 (SIR=4.17; 95%CI: 1.14, 10.67).[20] The incidence of acute myeloblastic leukaemia is more regular during childhood. These observations motivated our detailed analysis of cytological types of leukaemia. In Beaumont-Hague, the excess number of cases of leukaemia seems to be entirely due to the 2.48 excess cases of acute lymphoblastic leukaemia in the 5 to 9 year old group. For the 1 to 6 year old group, the excess was 3.04 over a period of 21 years. For acute myeloblastic leukaemia, the number of cases was insufficient to detect any excess.

Although the La Hague plant began its reprocessing activities in 1966, it was technically impossible to reconstruct the incidence of childhood leukaemia before 1978. A mortality study had been conducted for the years 1968 to 1978.[5] For the overall Nord Cotentin area, no excess mortality was observed with no death from leukaemia in the Beaumont-Hague electoral ward. Although mortality is a crude indicator of morbidity for childhood leukaemia, this result may indicate that nothing dramatic occurred around La Hague in the period prior to 1978, when the site was operational.

There have been three previous studies of the incidence of leukaemia in the neighbourhood of La Hague for the periods 1978–90,[6] 1978–92,[7] and 1978–1996.[25] Though these suggested a small excess of childhood leukaemia in comparison with expected, the numbers in each study were very small, and the results therefore somewhat equivocal, leading to the conclusion that it was important that the situation be kept under review. This is the major reason for this study. All cases diagnosed before 1997 (table 3) had already been included in previous analyses. The period 1993–1998 is too short to be analysed separately from the period 1978 to 1992, especially when considering detailed age classes and cytological types of leukaemia. Adding this period confirmed that the incidence of leukaemia in young people in the Beaumont-Hague electoral ward was quite high (SIR=2.17) and showed that it consisted mainly in acute lymphoblastic leukaemia occurring during the childhood incidence peak.

Our data have already been partially analysed, which increases the risk of erroneously concluding that there is an excess. Multiple comparisons performed by age, zone and, cytological type could give rise to at least one significant result by chance alone. In these circumstances, the type I error is not controlled anymore and confidence limits should be regarded only as numerical indices providing guidance for further research. Our findings are consistent with those in similar circumstances: near Dounreay where the SIR is 3.3,[26] and at Seascale where the SIR is 10.2.[1]

Several possibilities have been suggested to explain the excess number of cases of leukaemia observed around nuclear reprocessing plants. They include paternal exposure to radioactivity prior to conception,[27] environmental exposure to radioactivity,[8] and population movements.[28] As the results of the case-control study by Gardner *et al* had never been reproduced, the hypothesis of paternal preconceptional exposure to ionising radiation was dismissed.[29] Moreover, the case-control study by Pobel and Viel was not in favour of this hypothesis.[8]

KEY POINTS
- Surveillance of childhood and young adulthood leukaemia around the La Hague nuclear waste reprocessing plant continued until 1998.
- An increased incidence of leukaemia is reported in the 5 to 9 years age group in the nearest area from the site.
- Analysis of cytological type shows that this increased incidence could be attributable mostly to acute lymphoblastic leukaemia.
- No cases were observed on Alderney from 1978 to 1998.

A study of environmental radiation concluded that it is very unlikely that exposure to radioactive discharge from the nuclear installations in Nord Cotentin could cause a detectable increase in the incidence of leukaemia in Beaumont-Hague[30]: of the four cases observed from 1978 to 1996, 0.83 could be attributed to ionising radiation, including only 0.0015 due to radioactive discharge from the various nuclear installations in Nord Cotentin. Although the results seemed robust, they correspond to an average estimation and some reserves have been expressed about the lack of an uncertainty analysis. Genetic susceptibility has been evoked as an effect modifier that could potentiate the effect of ionising radiation.[31]

Dickinson and Parker recently quantified the association between the occurrence of childhood leukaemia and non-Hodgkin's lymphoma, and population mixing among children born in Cumbria.[23] The association was all the more stronger when acute lymphoblastic leukaemia among children aged 1 to 6 years were examined. Our study indicates the predominance of acute lymphoblastic leukaemia over childhood leukaemia cases diagnosed in the Beaumont-Hague electoral ward. Although not conclusive, this observation could be linked to the dramatic intensity of population movement that occurred in this particular area. A study is currently underway to analyse population movement and childhood leukaemia in Nord Cotentin. Indeed, it currently seems difficult to dissociate the correlation between the incidence of leukaemia and proximity to the plant from that between leukaemia and population movements.

Several diseases increase the risk of leukaemia.[32,33] Individuals with Down's syndrome have a 10-fold to 18-fold increased for leukaemia, FAB M7 megacaryoblastic subtype before 3 years and acute lymphoblastic leukaemia after 3 years of age.[32] In our study, three patients suffered Down's syndrome and developed acute leukaemia: two of them were acute lymphoblastic leukaemia, the third one could not be characterised. It could have been interesting to produce the analysis without cases

suffering Down's syndrome. However, leukaemia reference incidence rates excluding patients with Down's syndrome are not available in France. Moreover, no patient with Down's syndrome was living in the Beaumont-Hague electoral ward when diagnosed. Exclusion of patients with Down's syndrome from the analysis could increase the SIR in this particular area. The 35 other patients presented no clinical or history evidence for trisomy 8 syndrome, Bloom syndrome, ataxia telangiectasia, Fanconi anaemia, Li-Fraumeni or immunodeficiency syndromes. Neither was a pure familial leukaemia observed in these patients.

In view of statistically significant clusters of childhood leukaemia near other European nuclear reprocessing sites, and the concerns of the local population, these findings argue in favour of continued investigations in Nord Cotentin. Three lines should be followed: measuring the incidence of child leukaemia among people who have lived at any time in Beaumont-Hague; identifying possible causes of leukaemia in the area (studies of population movements); and measuring the incidence of other diseases the occurrence of which could be linked to radiation (other cancers, and reproductive function disorders).

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