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Comments and Critique

Cancer Mortality around Nuclear Sites

IN 1983, a British television programme reported an increased incidence of leukaemia in children in the village of Seascale, near the Sellafield nuclear reprocessing plant. Following this report, a working group commissioned by the British government concluded that there was an increased incidence of lymphoid leukaemia in children around Sellafield (4 cases vs. 0.25 expected) [1]. This result has been confirmed by Gardner and Winter [2]. Other studies have followed, including one by Gardner *et al.* who found an excess leukaemia mortality among children who had been born in Seascale (5 deaths vs. 0.53 expected) and no excess among children born elsewhere but attending school in Seascale (0 deaths, 0.54 expected) [3]. A study comparing leukaemia cases with control children [4, 5] showed an 8 times higher risk of leukaemia when the father had been exposed to 10 mSv or more in the 6 months before conception of the child. Overall, 5 children with leukaemia had a father with a dose of 5 mSv or more in the 6 months before conception, and a cumulated exposure of 50 mSv or more before conception. 4 of these 5 leukaemias corresponded to children living in Seascale. This observation of an excess risk of childhood leukaemia in relation with preconceptional exposure of fathers to ionising radiation has been confirmed by McKinney *et al.* [6] in a case-control study that included some cases already studied by Gardner [4, 5].

A study of leukaemia incidence was conducted in a 13 km radius area around the Dounreay facility, a reprocessing plant located in the north of Scotland. 6 cases of leukaemia were observed between 1979 and 1984 in the population under age 25, vs. 0.51 expected [7]. A case-control study [8] failed to show any effect of paternal exposure to external ionising radiation before conception. An excess of leukaemia has also been reported in the vicinity of the two nuclear military facilities of Aldermaston and Burghfield [9], and in the vicinity of the Hinkley point nuclear power plant [10].

These studies around individual nuclear sites were confirmed by the analysis of cancer mortality around 15 nuclear plants in England and Wales [11].

There were two studies of mortality around La Hague, a French nuclear reprocessing plant. Dousset [12] compared the cancer mortality in the Beaumont–La Hague canton and in the whole Département de la Manche. The canton corresponds to a radius of about 10 km around the installation and the population of a canton is on average 10 000. Among the 3000 persons below age 25, no cancer nor leukaemia death was observed. Viel and Richardson [13] studied leukaemia mortality between 1968 and 1986 in persons under age 25 who lived in 10 cantons near La Hague. No excess leukaemia mortality was found (21 leukaemia deaths vs. 23.6 expected from death rates for the Département de La Manche).

Hill and Laplanche [14] studied mortality under age 25 between 1968 and 1987 in "communes" located near two reprocessing facilities (La Hague and Marcoule) or near four power plants (Bugey, Chinon, Chooz and Saint Laurent), French nuclear sites operating before 1975. The population under study represents 3 million person-years, which is equivalent to 150 000 persons followed for 20 years. A total of 58 leukaemia deaths were observed, similar to the 67 leukaemia deaths expected from national death rates, and to the 62 leukaemia deaths observed in control communes. The risk of leukaemia did not depend on distance to the installation.

In the USA, numerous studies analysed cancer incidence or mortality around various nuclear sites, with conflicting results. The National Cancer Institute [15] performed a large study of cancer mortality between 1950 and 1984 around 62 nuclear sites operating before 1982. More than 500 000 cancer deaths were observed in the counties located near nuclear sites. There were no excess leukaemia mortality in the total population nor in children. A recent study [16] reported an excess of leukaemias in adults during the period 1979–1983 near the Pilgrim nuclear plant (Massachusetts) and no excess during the period 1983–1986.

A study in Canada [17] and another in Bavaria [18] report no excess of leukaemia in the vicinity of nuclear installations.

Overall, there is reasonable evidence of an excess of childhood leukaemias around nuclear reprocessing plants in Great Britain, while no such excess is observed in other countries. Can we reconcile these apparently conflicting results?

Most British studies included only a handful of cases, studied again and again. Hence the results may quite well be due to the play of chance. However, the negative results observed in the USA and in France were based on large numbers of cases and cannot easily be attributed to a lack of power of the studies.

Restricting the American and French analyses to reprocessing sites does not modify their negative results. The difference in type of installation cannot therefore be an explanation of the difference between countries. Discharges were much higher at Sellafield than at Marcoule or La Hague [19], but the excess risk of leukaemia around Sellafield is much too high to be explained by the level of radioactive discharges.

How can we interpret the excess risk of leukaemia in children whose fathers were occupationally exposed at Sellafield?

In the study of 7400 children of male survivors of the Hiroshima and Nagasaki bombs, 5 leukaemias were observed vs. 5.2 expected [20]. The atomic bomb survivors had been exposed to doses about four times greater than the Sellafield workers. The risk of leukaemia incurred by the Sellafield workers' children is therefore too high to be explained by the level of radiation of their fathers. An alternative explanation

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is that the relevant measure of exposure is not the external contamination, which is routinely monitored by the workers' dosimetric badges, but the internal contamination on which no data are available. It is also possible that the Japanese data on a massive and unique exposure are totally irrelevant to the study of a prolonged exposure at a lower dose.

Some of the workers exposed to radiation may have been exposed to other carcinogenic agents, for instance to chemical carcinogens. Kinlen [21] suggested that the excess risk of leukaemia around nuclear sites might be related to the pattern of infection associated with the large influx of population caused by the building of the installation. The exposure to viruses at a young age associated with the mixing of population of different origins might lead to an increased risk of leukaemia. This hypothesis has been tested in Scotland by studying the only new town located in a rural area and with a demographic increase comparable to the increase in Thurso, the town near Dounreay. An excess risk of leukaemia was observed in this new town in the population under age 25. To confirm this result, leukaemia mortality has been studied in 14 new towns of Great Britain [22]. An excess leukaemia mortality under age 5 was observed in "rural" new towns and not in "overspill" towns of London and Glasgow. In both sets of towns, there was a deficit of leukaemia deaths between age 5 and 24. The rural new towns differ from overspill new towns in the proportion of young children and in the diversity of origin of the population, which are both larger in rural towns. The results are consistent with an infectious aetiology for leukaemia, the mixing of population of diverse origins increasing the risk of exposure to infections particularly *in utero* or during early childhood.

An excess leukaemia and Hodgkin's disease mortality has been observed in the population under age 25 living near sites where the construction of nuclear stations had been considered (potential sites) [23]. This excess is similar to that observed in the vicinity of existing nuclear sites. This is an argument against attributing the excess around nuclear sites to environmental radiations.

In conclusion, 6 years after the first alert in the UK, the results obtained in other countries are reassuring and the excess risk of leukaemia observed around nuclear sites in Great Britain remains unexplained. The play of chance would be a ready explanation if the excess had been observed around one site only. To suggest radiation pollution as an explanation is in contradiction with all available data on the leukaemogenic effect of radiation, given the low level of radiation discharges around the nuclear sites. An infectious aetiology to leukaemia is an interesting hypothesis, although based on indirect evidence, notably on an analogy with feline leukaemia and viral infection. Exposure to other pollutants is another hypothesis which deserves consideration. Lastly, it might be interesting [24] to study children of radiologists or of parents treated with radiotherapy, for instance for Hodgkin's disease.

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