An Assessment of the Risks of Leukaemia and other Cancers in Seascale from Sources of Ionising Radiation

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Abstract

In 1995, NRPB published revised estimates of the radiation dose and the risks of radiation-induced leukaemias and other cancers in children and young persons living in Seascale, Cumbria. The work was undertaken at the request of the Committee on the Medical Aspects of Radiation in the Environment (COMARE). In all this work, close liaison was maintained with COMARE, which also endorsed the general approach and data used. This paper outlines the approach adopted and summarises the results.

The study population consisted of individuals assumed to be born in Seascale between 1945 and 1992 inclusive and followed to age 24 or 1992, whichever was the shorter period. The results indicate that in the study population of 1348 young persons, the expected number of radiation-induced cases of leukaemia and non-Hodgkin's lymphoma would be 0.46, of which 0.36 would be fatal. Natural radiation contributes most to the radiation risk (almost 80%) and all operations at Sellafield contribute only 10% of the total risk. The number of solid cancers expected from all sources of radiation exposure would be 0.22.

The implications of similar assessments carried out for other sites are also briefly summarised.

Background

The most recent assessment of doses and risks of radiation induced leukaemia and other cancers in young persons in Seascale was the fourth such study that NRPB has undertaken in about 10 years. The first [12] was at the request of an Advisory Group set up in 1983, under the Chairmanship of Sir Douglas Black, to investigate claims of an increased incidence of childhood cancer in the vicinity of the BNFL nuclear fuel reprocessing plant at Sellafield in west Cumbria. This first assessment was revised two years later [13] when further information became available on discharges from the Sellafield site in the 1950s, particularly in relation to releases of irradiated uranium fuel. This information was considered by COMARE in its first report [1].

A further assessment was carried out in connection with a legal case heard in the High Court in 1992-93. This concerned two families resident in west Cumbria who alleged that radiation exposure from the Sellafield plant caused cancer in members of their families [14]. In connection with this case, BNFL undertook a comprehensive review of discharge and environmental monitoring data and have subsequently published discharge chronologies for 1951-1992 [7].

This information was made available to us before publication for use in our latest assessment, which replaces the earlier studies. In addition to the revised estimates of discharges, there has been considerable work in recent years on evaluation of dose coefficients for members of the public from intake of radionuclides by inhalation and ingestion [8] and on risks of radiation exposure [10]. In view of the substantial amount of scientific, dosimetric and epidemiological data that had become available since its first report, COMARE decided to review this information and prepare another report. To assist with this task, NRPB was asked to undertake a reassessment of doses and risks to young persons in Seascale. This was published, as NRPB-R276 [11].

We have also assessed the doses and risks to population groups around other nuclear establishments at the request of COMARE. These assessments are also briefly discussed below.

The Seascale Assessment

The aim of the latest reassessment was to provide best estimates of radiation doses and risks to children and young persons born and living in Seascale since 1945. All major sources of radiation exposure were considered: natural radiation; medical exposures; fallout from nuclear weapons testing; operations at the BNFL Sellafield site including routine discharges, minor releases due to accidents and incidents, the Windscale fire in 1957 and uranium oxide releases in the 1950s; routine discharges from the Albright and Wilson chemical plant at Whitehaven; and the Chernobyl reactor accident in the Ukraine in 1986.

Joint working groups were established between NRPB and a COMARE dosimetry sub-group to consider and agree on : biokinetic data and foetal dosimetry; habit data; radiation risk factors; environmental models; discharge and environmental monitoring data. The study population consisted of individuals born in Seascale between 1945 and 1992, followed from birth to age 24 or 1992, whichever is the shorter period. All pathways of exposure were considered: absorbed doses to tissues from external irradiation and from intakes of radioactive material by ingestion and inhalation were calculated. Where possible, measurements of dose rate and radionuclide concentrations in environmental materials were used. Where insufficient measurement data were available, external doses and intakes of radionuclides were estimated from discharge data and models of environmental transfer.

Calculations of absorbed dose to body tissues were based on the most recent biokinetic and dosimetric models and data. Emphasis was placed on calculation of the doses to red bone marrow and estimations of the risk of radiation-induced leukaemia and non-Hodgkin's lymphoma, since the principal cause of concern was the excess incidence of leukaemia among young people. However, doses to other tissues and the associated risks of solid cancers were also estimated.

From these data, the risks of radiation-induced leukaemias and other cancers were estimated using risk models and risk factors appropriate for a UK population [9].

Results

The analysis indicated that in the study population of 1348 persons aged under 25 years in Seascale, 0.36 fatal cases of leukaemia and non-Hodgkin's lymphoma would be expected as a result of all sources of radiation exposure. As shown in Table 1, natural radiation is the largest contributor to risk (almost 80%) and operations at the Sellafield plant, including the Windscale fire, contribute less than 10%. Medical exposures contribute about 5% and weapons fallout about 6%. The other sources make negligible contributions. These relative contributions to risk are very similar to those found in the previous assessments. The predicted incidence in the study population is 0.46 cases of leukaemia and non-Hodgkin's lymphoma, contrasted with 8 cases of leukaemia and 4 cases of non-Hodgkin's lymphoma observed among young people aged 0-24 years who resided in Seascale at the time of diagnosis between 1953 and 1991. It seems that, on the basis of best estimates of environmental dose assessments, radiation exposure cannot explain the observed incidence of leukaemia. Table

2 provides the expected number of other radiation-induced cancers for this population for ease of reference.

These results raise the question of whether doses and risks, especially those from industrial discharges, could have been substantially underestimated. However, we believe that our assessment is robust, for a number of reasons. Doses arising as the result of discharges from the Sellafield plant have been based, where possible, on measurements in the environment and thus do not depend on accurate information on discharges. Where results from measurements in the environment were not available, dose rates and activity concentrations in environmental media were predicted from discharge data and mathematical models of environmental transfer. Comparison of model predictions with measured values suggests that any discrepancy is not likely to exceed a factor of two and that, indeed, the modelling approach tends to overestimate environmental concentrations.

Doses to tissues were calculated from activity concentrations in environmental media, average habits and mathematical models of the behaviour of radionuclides in the human body. Where it is possible to make comparisons of predicted concentrations of radionuclides in body tissues with measured values, these comparisons suggest that doses to body tissues are not likely to have been underestimated.

The models used to calculate risks of radiation-induced leukaemia and non-Hodgkin's lymphoma and other cancers are based largely on human data. Uncertainties in the risk factors from low dose, low dose rate exposure to X, γ and β radiations are not expected to exceed around a factor of two. Human data on the relative biological effectiveness of a-particles are sparse, but are not out of line with experimental data that would support a value lower than the factor of 20 used in this assessment. Furthermore, there is no reason to expect an a-particle from an artificial source to have a different biological effect from an a-particle from a natural radiation source. Any increase in the radiation weighting factors for a-particles would therefore need to be applied to doses from natural radiation sources as well as to doses from industrial discharges. Such modifications would therefore not be expected to influence the overall conclusion of this study.

One further point considered was whether some individuals, because of their habits, might have received doses substantially in excess of those estimated in this assessment. We therefore considered factors that might lead to higher doses. Significantly higher doses could have been received in the mid-1970s through consumption of large quantities of marine foods, but only a few individuals would consume these large quantities which would not significantly affect the risks to the population as a whole. Furthermore, these relatively higher doses would have been received only for a few years and could not explain the continuation of an observed excess of leukaemia in this population over a longer time period. We also considered deliberate ingestion of soil and sand by an infant with pica. This would also lead to higher doses than those estimated in the assessment but this condition affects few children and, in those affected, does not persist for long. This additional pathway would again not significantly affect the conclusions of this study.

Other Assessments

A similar assessment was performed of the doses and risks experienced by members of the public around Dounreay in Caithness [5], where the United Kingdom Atomic Energy Authority operated a fast breeder reactor and nuclear fuel reprocessing plants. This assessment used the general approach described above. This assessment followed identification of 6 cases of leukaemia in young people within 25 km of Dounreay between the years 1968-1984 [3].

Extensive analyses led COMARE to conclude that there was a statistically significant excess incidence of leukaemia in young people living in the area around Dounreay [3]. Again, the assessment of doses and risks from all sources of ionising radiation indicated that radiation exposures could not explain this increased incidence. The number of radiation-induced leukaemias which could be expected in children born in Thurso between 1950 and 1984 (to age 25 or 1985 whichever is sooner) was a fraction of those observed, and 79% of the radiation risk was attributable to natural sources [5].

NRPB also performed an analysis of the doses around the Atomic Weapons Research Establishment at Aldermaston, the Royal Ordnance Factory at Burghfield and the Atomic Energy Research Establishment at Harwell [6], as an input into COMARE's third report [4]. This assessment differed from those for Seascale and Thurso because there was no established location or population group in which an excess in the number of leukaemia cases had been advanced. As a result, the lifetime doses (taken as 70 years) from each year's discharge were calculated. The peak red bone marrow dose equivalents from discharges from each of the three sites, at a distance 5 km from the sites were estimated and compared with the corresponding doses from natural sources. The peak dose from discharges from AWRE Aldermaston, ROF Burghfield and AERE Harwell were respectively 25,000, 140,000,000 and 1,600 times lower than the annual dose from natural radiation [6].

In these assessments, the doses resulting from discharges from the sites were less, often very substantially less than doses from natural radiation. This implies that the additional exposures due to the operations of these sites are unlikely to significantly influence the risk of leukaemia experienced in these areas.

Conclusions

In summary, the assessments of doses and risks around a number of sites indicate that radiation exposure from environmental sources cannot explain the observed incidence of leukaemia and non-Hodgkin's lymphoma in young persons. Other hypotheses have been advanced elsewhere, as indicated in reference 15.

COMARE have taken account of the most recent assessment for Seascale in their most recent report, in addition other factors, such as exposure to chemicals and infections, that may be involved in childhood leukaemia [2]. On the basis of this assessment this committee have concluded that it is highly unlikely that radioactive discharges from Sellafield have been the sole cause of the excess Seascale cases (of leukaemia), which is in agreement with the view expressed above.

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Table 1: The expected number of radiation-induced leukaemia and Non-Hodgkin's lymphoma(NHL) up to age 24 y or 1992 (incl) in a cohort of 1348 persons in Seascale

Source	Expected number of leukaemia and NHL	
	Mortality	Incidence
Routine discharges	$1.6\ 10^{-2}$	$2.0\ 10^{-2}$
Uranium dioxide releases	$8.6\ 10^{-3}$	$9.4\ 10^{-3}$
Windscale fire	$1.3\ 10^{-2}$	$1.3\ 10^{-2}$
Albright and Wilson*	$4.9\ 10^{-4}$	$6.8\ 10^{-4}$
Weapons fallout	$2.1\ 10^{-2}$	$2.5\ 10^{-2}$
Chernobyl	$1.3\ 10^{-4}$	$2.8\ 10^{-4}$
Medical	$2.0\ 10^{-2}$	$2.5\ 10^{-2}$
Natural radiation	$2.8\ 10^{-1}$	$3.6\ 10^{-1}$
Total	$\mathbf{3.6\ 10^{-1}}$	$\mathbf{4.6\ 10^{-1}}$

* chemical plant

Table 2: Risks of all cancers other than leukeamia and non-Hodgkin's lymphoma (NHL) up to age 24 y or 1992, whichever is sooner, in a cohort of 1348 personsin Seascale

Source	**Expected number of radiation-induced cancers other than leukaemia and NHL**	
	Mortality	**Incidence**
Routine discharges	$3.7\ 10^{-3}$	$1.4\ 10^{-2}$
Uranium dioxide releases	$7.2\ 10^{-4}$	$3.1\ 10^{-3}$
Windscale fire	$6.6\ 10^{-3}$	$6.2\ 10^{-2}$
Albright and Wilson*	$1.5\ 10^{-4}$	$2.0\ 10^{-4}$
Weapons fallout	$1.6\ 10^{-3}$	$6.5\ 10^{-3}$
Chernobyl	$2.7\ 10^{-5}$	$2.0\ 10^{-4}$
Medical	$5.0\ 10^{-3}$	$1.7\ 10^{-2}$
Natural radiation	$3.6\ 10^{-2}$	$1.2\ 10^{-1}$
Total	$\mathbf{5.4\ 10^{-2}}$	$\mathbf{2.2\ 10^{-1}}$

* chemical plant