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CHROMOSOME ABERRATION ANALYSIS IN PERSONS LIVING IN THE VICINITY OF THE NUCLEAR POWER PLANT KRÜMMEL IN NORTHERN GERMANY.

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Abstract

Exceptional elevation of children's leukaemia appearing 5 years after the 1983 startup of the Krümmel nuclear power plant, accompagnied by a significant increase of adult leukaemia cases, led to investigations of radiation exposures of the population living near the plant. The rate of dicentric chromosomes in peripheral blood lymphocytes of 12 relatives of children with leukaemia and in 14 other inhabitants near the plant was significantly elevated and indicated ongoing exposures over the years of operation. These findings led to the conclusion that chronic reactor leakages had occured. This was supported by the identification of man-made radioactivity in air, rainwater, soil, and vegetation by the environmental monitoring program. Calculation of the corresponding source terms show that the emissions must have been well above authorized annual limits.

The chromosome studies had also shown a significant overdispersion of dicentric chromosomes in the affected cells which is an indicator of exposure by high LET radiation. Alpha emitters are not controlled specificly by routine monitoring in the environment. We therefore looked for transuranic contaminations. Samples of house dust taken from attics in the proximity of the plant were analysed by gamma and alpha spectroscopy. They showed elevated amounts of Am 241 and Pu isotopes including high levels of Pu 241 which are to be explained neither by fallout of the former atomic bomb tests nor by Chernobyl contaminations.

Introduction

Biological dosimetry by chromosome aberrations using the dicentric chromosomes in peripheral lymphocytes as an indicator for radiation has been used now for several decades of years. It continues to be the most sensitive method up to now although these aberrations are

unstable and do not allow a quantitative dose estimate in the case of unknown exposure time in the past or for chronical exposure.

The advantage of the instability is, however, that the background rate of dicentric chromosomes in adults does not significantly increase with age. The background frequency is rather low and certainly determined mainly by the background radiation, and therefore the range of sensitivy for additional exposures starts not far above background doses [1]- not in individual cases but for population exposures.

Two kinds of information can be gained also in the case of unknown exposure time: 1) if there has been an exposure above the normal level and in which order of magnitude as a minimum value, 2) if there has been a relevant contribution of high LET radiation as could be expected with incorporated radioactivity including alpha-emitters or originated by neutrons as e.g. in flight personnel [2]. While the distribution of dicentric chromosomes in the cells for low LET low dose irradiation is strongly Poissonian, this pattern looks otherwise for high LET irradiation showing overdispersion that means often 2 or more dicentric chromosomes per cell.

The method was applied in order to answer the question if a radiation exposure is causative for a leukaemia cluster in Germany observed in the proximity of 2 nuclear establishments. Fig. 1 shows the small community of „Elbmarsch“ at the river Elbe, not far from the city of Hamburg (about 35 km). The village is opposed by a nuclear power plant - a boiling water reactor of 1300 MW_{el} (KKK) - and a former nuclear research center (GKSS) running 2 research reactors since the 60ties. 5 Years after the start-up of the great plant several children began suffering from blood diseases [3,4]. One case of an aplastic anaemia occured in 1989, then 5 leukaemias in 1990 and 1991 and later on 3 more cases in 1995 and 1996, also at the other side of the river, see Fig.1 and Table 1.

The elevation of childhood leukaemia in the 5 km-region is about 6-fold compared to German rates, and while a cluster analysis for leukaemia done by the German registry for Cancers in Childhood showed that clustering is a very rare event in Germany [5], this one appeared to be exceptional and the most significant elevation since 1980 (when the registry started) [6].

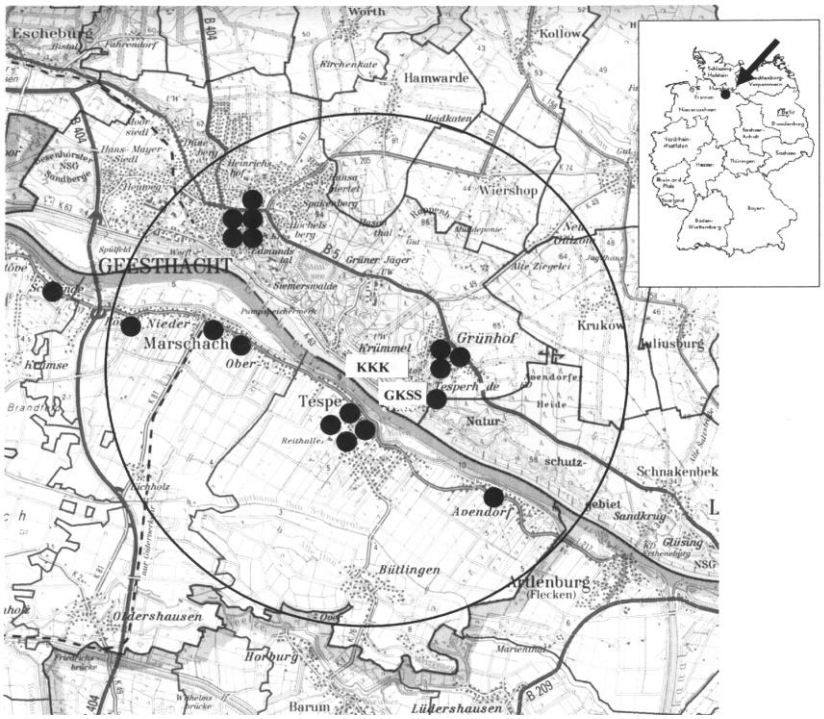


Fig.1 Map of the area around the Krümmel nuclear power plant (KKK). Black circles indicate homes of leukaemia and aplastic anaemia cases with year of diagnosis since 1982. Circles show the distance to KKK. The second nuclear establishment in that region is called GKSS (Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt).

Table 1 Cases of leukaemia and aplastic anaemia observed in a 5 km radius of the Krümmel nuclear power plant

Case no.	Month and year borne	Sex	Disease	Date of diagnosis	Age at diagnosis
1	9/1982	F	AA	12/1989	7
2	8/1986	F	ALL	2/1990	3.5
3	2/1981	M	ALL	3/1990	9
4	3/1981	M	AML	4/1990	9
5	3/1989	F	ALL	1/1991	1.8
6	1970	M	AML	4/1991	21
7	9/1988	M	ALL	5/1991	2.7
8	?	M	ALL	1994	?
9	ca. 1991	M	ALL	1995	4
10	1985	M	ALL	6/1995	10
11	1993	M	ALL	6/1996	3

Abbrevations: ? not known; AA aplastic anaemia; ALL acute lymphatic leukaemia; AML acute myeloid leukaemia; F female, M male

The suspiceon that radioactivity was the cause or contributing to the effect was supported by the fact that the 9 leukaemia children were very young at the time of diagnosis - all below 11 years and 5 of them below the age of 5 (Table 1). Furthermore most of them were boys corresponding to the experience in the Japanese A-bomb survivors.

In the first period after the detection of the leukaemias there was no idea what could have happened with the nuclear plants, because the supervising ministry attested undisturbed operation, and no unpermitted emission was known. We therefore proposed to apply biological dosimetry in order to look for an elevated exposure. First we studied relatives of the leukaemia children.

Investigation of dicentric chromosome aberrations

The subjects were selected after having completed a detailed questionnaire. Exclusion criteria were occupational exposure, medical irradiation, exposure to chemical mutagens, and heavy smoking. 5 ml of venous blood was taken for cell preparation. Lymphocyte cultures and slide preparations were made according to standard methods [7]. Collection of metaphases on the slides was facilitated by a semiautomatic computerized system that included data management. In general, 1000 metaphases were investigated per person for chromosome aberrations. Only first-division metaphases with 46 centromeres were analysed.

The first result was obtained 1992 in 5 brothers or sisters of leukaemia children. They showed a mean frequency of 0.8 dicentrics in 1000 cells. Unfortunately, at that time, the background rate for children was not known. Therefore, we could only state some years later that this result means an 8-fold significant elevation. But because of the instability of this aberration type, which we supposed to be most effective in children we decided to investigate adults.

Seven of them were parents of leukaemia children and the others were also living within 5 km distance from the nuclear plant. The results in 21 adults are shown in Fig.2, an about 4-fold highly significant elevation of dicentric chromosomes in the study population was found. The first conclusion therefore was that a relevant exposure by ionizing radiation had occured. The second result was that there must be a contribution of high LET radiation,

which would mean α-emitters in this case, because we found an overdispersion in the distribution of dicentric chromosomes (Table 2). There was a deviation from the Poisson distribution (the expected values for a Poisson distribution are shown in Table 2 in the second line), including one multiaberrant cell with 6 dicentric chromosomes. The statistical analysis shows that the deviation is significant in both cases - including or excluding the multiaberrant cell [8].

A further result was, that the exposure must have occured somehow chronically, because we had investigated persons who settled in Elbmarsch before and after 1986, and both groups showed similar frequencies of dicentric chromosomes.

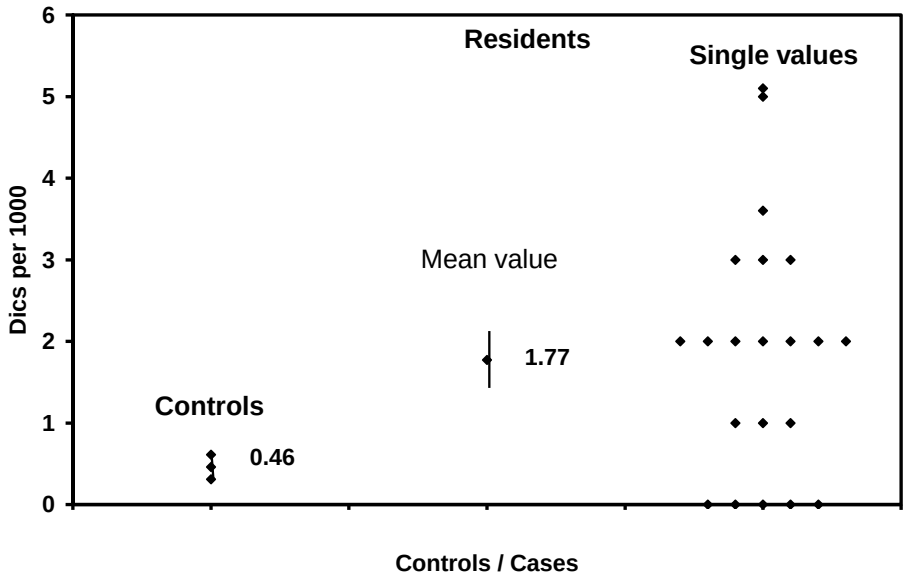


Fig.2 Yield of dicentric chromosomes in 21 adults of Elbmarsch living near the nuclear plants

Table 2 Intercellular distribution of dicentric chromosomes in Elbmarsch inhabitants

		No. of dicentric chromosomes per cell						
		0	**1**	**2**	**3**	**4**	**5**	**6**
Incl. multi-	observed	18341	26	4	0	0	0	1
aberrant cell	expected	18332	39.91	0.04	0	0	0	0
Excl. multi-	observed	18341	26	4	0	0	0	0
aberrant cell	expected	18337	33.94	0.03	0	0	0	0

The chromosome investigation in adults was financed by a citizen's initiative of that region because we got very soon in conflict to the supervising ministry. In the meantime we had also detected elevated environmental radioactivity in that region.

Environmental radioactivity

Elevated concentrations of tritium and other ß-emitters were found by own investigations in trees [4], furthermore fission and neutron activation products were detected in the official environmental monitoring program for the nuclear plants. Cs 137 in rainwater was found to be chronically released in the main wind direction, and man-made radioactivity in air was also elevated. All these measured contaminations were in discrepancy to the permitted emissions.

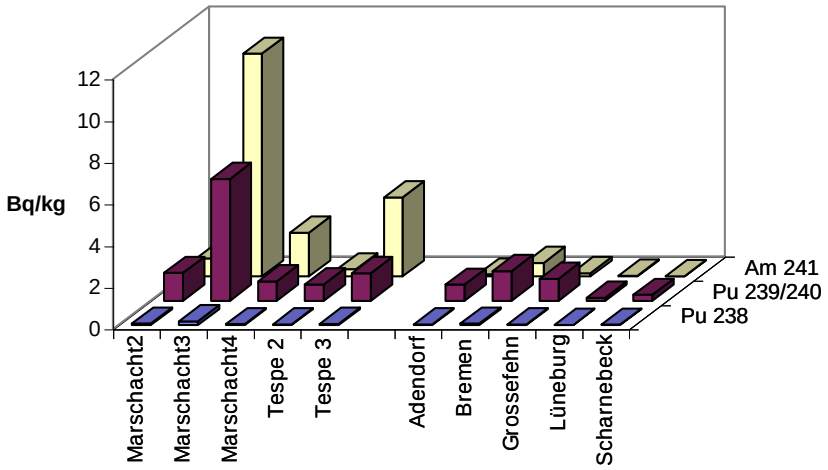
α-emitting nuclides are not routinely monitored specificly in the environment. Because of the findings in the chromosome aberrations it was seeked for relics of α-emitters in old attic dust, from roofs of the houses in the community of Elbmarsch. Fig. 3 shows the results of investigations which took place in 1999. Some of the houses show contaminations by transuranic elements much above the level of normal background by the former atomic bomb testing. (The contribution of the Chernobyl accident by Americium and Plutonium in Germany was neglectable.

Conclusion

Ionizing radiation was the only risk factor for leukaemia identified in the region of Elbmarsch in the proximity of two nuclear establishments. A relevant exposure is shown by the chromosome aberration analysis. For scientific reasons it would be desirable, of course, to estimate the dose-relationship in this population. But the radioactivity which might be responsible was delivered about 15 years ago, and the distribution is not measurable any more.

It would be also desirable to estimate the dose by stable aberrations, i. e. translocations. But this case is also showing the limits of biological dosimetry. We must suppose here that there was a relevant contribution by the bone-seeking ß-emitter Sr 90 and some transuranic α-emitters, but the dose-response for the bone marrow and the other compartments of the body in relation to the yield of chromosome aberrations is not known in case of incorporated radioactivity.

Fig.3 Alpha-emitting transuranic elements in attic dust
left side: locations near nuclear power plant right side: controls



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