Report on a Cancer Cluster in an Antenna Ranges Facility

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***Abstract* — A cancer cluster which occurred among young workers in an antenna ranges facility is reported. Five out of about 30 workers were diagnosed with cancer. The calculated Odds Ratio (OR) was 8.3 with Confidence Interval (CI 95%) of 2.3 to 19. Since this is a single cluster no definite conclusions can be drawn from it by itself, however together with other similar cases reported elsewhere it tends to indicate a severe cancer risk for groups of young people exposed repetitively and over years to non-ionizing radio-frequency radiation at levels limited only by the ICNIRP thermal limits.**

***Index Terms* — Cancer, non-ionizing radiation, radio, RADAR, occupational, military.**

I. Introduction

The possibility of carcinogenic influence of non-ionizing radiation has been studied in various settings and statistically significant findings which indicate the carcinogenic influence have been reported in numerous papers. Some interesting examples are Hardell [1], Sadetzki [2], Lonn [3] and references within in the setting of mobile phones and Szmigielski[4] and Richter [5] in the occupational military setting. Various possible cancer-inducing mechanisms were studied, see for example Korenstein et. al. [6] and its references. The questions of carcinogenic influence and of safe radiation levels have not been resolved yet and the uncertainty drives differences of many orders of magnitude in radiation levels considered to be safe by regulators in different countries. Important radiation levels limits valid at the frequency of 1 GHz and presented here in microwatts/cm^2 are the ICNIRP occupational limit of 2000 used excessively, including in the IDF [7], the Israeli non-ionizing radiation law limit of 50, the limits of 3 to 10 used in Switzerland and Italy and even a lower limit proposed in Lichtenstein. The influences of additional factors such as frequency and Peak to Average Power Ratio (PAPR), which can be extremely high in RADAR applications, are yet to be determined. Progress toward resolving these important and difficult questions can be facilitated by extensive research and by evaluating the information already available on this topic. Thus rendering all the relevant data open to the scientific community is essential. To this end this paper reports the details of a cluster of cancer cases which occurred in an antenna ranges facility. The data is supportive of the carcinogenetic hypotheses. As it is not possible to draw conclusions based on a single cluster, the main contribution of this paper is presenting the data which may be used together with other sources to achieve progress.

This paper is presented in an engineering conference since in the absence of established universal safe radiation levels engineers are frequently involved in tradeoffs between well defined technical requirements and between radiation risks the quantitative evaluation of which awaits the results of the ongoing worldwide research.

II. The Facts

The cancer cluster occurred in an antenna ranges facility in Rafael in the years 1982 to 1995. The site was distinct by frequent and long term exposure to diverse forms of radio-frequency non-ionizing electromagnetic radiation. The exposure was controlled to be within the then legal ICNIRP limits.

Five young workers working at the site were diagnosed with cancer. The information was collected by interviews and the basic medical facts such as cancer diagnosis, date of diagnosis and age were verified by the company physician based on the workers medical records.

The ages at diagnosis were: 34, 36, 39, 40, and 48. Periods of time in years which each of the above workers spent at the site before diagnosis were approximately: 11 (most of them on the exact site), 8, 3, 9 and 17 respectively.

The cancer types diagnosed, listed here out of order, were leukemia, plasmacytoma of the nasopharyx, breast cancer, lymphoma and cancer of the larynx.

The diagnosed workers lived in various towns and villages within about 40 kilometers from the workplace, were not relatives of each other and their professional background varied from technician to PhD. Their only common factor the author is aware of, apart of profession in the general area of electronics, is the particular working site.

The total number of workers, denoted by N, who worked at the site for more for than 2 years during the relevant period of about 15 years till 1995 was estimated in 2002, by interviewing workers in the relevant groups, to be between 20 to 50, best estimate is 30, almost surely not more than 40.

III. Analysis and Discussion

The analysis presented here answers the two following questions:

1. What was the Odds Ratio (OR) in the group of workers being diagnosed with cancer up to the age of 40 and what is the corresponding 95% Confidence Interval (CI 95%)? (OR is the ratio of cancer risk of the studied group to that of the general population or, equivalently, the number of cases relative to that expected in normal population.)

2. What is the statistical p-value? That is:

If a group of N (20 to 50) people is chosen at random from the general population what is the probability, denoted as Pt, that at least 4 of them will be diagnosed with cancer up to the age of 40 and at least one of them up to age of 60?

The cancer statistics for the general population used was that of an USA registry:
Probability of the general population to be diagnosed with cancer from birth to age 40: P_1=0.016 (1.6%).
Probability of the general population to be diagnosed with first cancer from age 41 to 60: P_2=0.085 (8.5%).
Probability of the general population not to be diagnosed with cancer from birth to age 60: $P_3=1-P_1-P_2$.

The analysis is presented in the appendix. The results of the analysis are a function of the number N of people who worked at the site which was about 30 and could not be determined exactly. The results are presented in table 1.

TABLE I
THE ANALYSIS RESULTS

N	25	**30**	35	40	50
Pt (p-value)	0.00054 1:1800	**0.0012 1:860**	0.0022 1:461	0.0036 1:275	0.0083 1:120
OR (Odds Ratio)	10	**8.3**	7.1	6.25	5
CI 95%	2.8 – 22.5	**2.3 - 19**	2 – 16.7	1.7 – 14.8	1.4 - 12

That is, for population size of N=30, the probability of this occurring at random is 1:860, the odds ratio is 8.3 and its 95% confidence interval is 2.3 to 19, thus the results are certainly statistically significant.

There is a possibility of selection bias since this analysis was performed on the affected group of workers. The combination of population size N=30 and Pt=1:860 indicates that such a cluster is expected to occur at random without causation by radiation in about one group of 30 people in a population of 30 x 860=25800, that is once in every small town. Still the results reported here are significant because the site was very distinct by its radiation; there are only a few sites with this exposure to radiation in one country. More importantly, there are reports of similar cancer clusters in similar other radiation affected sites in Israel as reported for example in [5] and [7]. The probability of all of them occurring at random is very small.

Other possible causes of the cancer at the site were not investigated, however no abnormal cancer cases are known among people who worked nearby for many years, including in an adjacent building and in other parts of the same building with lower radiation exposure.

This analysis could be refined by using statistics with better resolution than 20 years and by obtaining and incorporating data about the ages of the exposed population and about the specific cancers.

The process on unveiling the data reported here has interesting characteristics. Two events had to happen to bring it to the open literature. First, somebody had to become aware of the abnormality. This happened years after the last case, due to an unrelated event in the organization. The occurrence of such group of cancer cases is not very obvious due to small number of cases dispersed over many years, some occurring after the affected people moved to other diverse locations. Second, presenting this information in the open literature, while being a clear obligation under the codes of ethics such as those of Rafael and of the IEEE, still involves complex processes with uncertain outcomes and cannot be taken for granted either. Thus it is likely that many events of this kind are not reported.

IV. RELEVANCE OF THE MOBILE PHONE DATA

The personal cancer risk of 16% presented here and risks of a similar order of magnitude reported in other cases in the occupational and military setting such as in [4], [5] and [7] are much higher than the personal risks reported in the mobile phone setting [1], [2] and [3]. (Any risk in the mobile phone setting is important because of the huge number of users.) This section addresses qualitatively those differences.
The authors of [1] , [2] and [3] report tumor risks of heavy mobile phone users increased by OR of 1.8 to 3.9 for organs very near to the mobile phone and on the side of head the phone is usually used on (ipsilateral). Heavy use means here some combination of factors such as long period of use (exceeding 5 or 10 years), many hours of weekly use, rural areas and no use of headsets.
A worker exposed to the full extent of radiation permitted by the ICNIRP limits suffers whole body radiation of intensity roughly comparable to that produced within a few centimeters from a mobile phone transmitting near its maximal power. Thus OR of the worker suffering any cancer may be expected roughly similar to the OR of cancer appearing in the organs in close proximity to the mobile phone. Since the workers in the antenna ranges were younger on the average then the population in the mobile phone studies the OR ratio is expected to be higher if the absolute risk is not very age-dependent because of the lower baseline cancer risk in young people. Thus the high OR reported in the antenna ranges should be not surprising. As said above, this comparison is qualitative only and no direct comparison between the numbers is attempted due to many differences between the studies including different populations, different methods of data gathering and different frequencies and waveforms.

V. POSSIBLE PREVENTIVE ACTIONS

The concrete possibility of severe cancer risk caused by high exposure to non-ionizing radiation in the occupational military setting requires addressing complex problems in the areas of engineering, medicine, ethics and more. The right solutions will certainly not be provided by a single conference paper, still, some elements which may be useful are listed here:

1. Set and implement safe radiation limits not exceeding those used for the general population and adjust them according to current research results. Furthermore, reduce human exposure per setting below these limits as low as feasible.
2. Control the peak power not to exceed the average power limit by more than a specified factor such as 10. This may be important especially in RADAR applications with high PAPR. See the strong non-thermal biological effects of extremely high PAPR (pulsed) waveforms in [8].
3. If there are exceptions, that is if some workers exposure exceeds the above limits, by accident or by design due to some extreme need, the exact quantitative description of the exposure should be filed for each worker and the health of the affected workers should be monitored for a lifetime to gather the important information on health effects and to enable fair assistance to the victims.
4. All relevant information, such as reported here, should be shared openly; it is almost useless at the local level.

VI. CONCLUSIONS

A cancer cluster in an antenna ranges facility was reported. The p-value and the odds ratio are statistically significant and, together with similar cases reported elsewhere, support the hypotheses of carcinogenic influence of non-ionizing radiation and, more specifically, that of an extreme cancer risk when the exposure is prolonged, repetitive and limited only by the thermal ICNIRP limits. The 16% cancer incidence among a group of young people over a period of about a decade reported here serves as an example of the magnitude of this possible risk. This study may contribute to more definite conclusions when examined together with similar data reported elsewhere, till then human radiation exposure should be reduced deeply below the ICNIRP thermal limits.

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APPENDIX

The p-value, that is the probability Pt, is evaluated conservatively. Each of the N workers is associated with a statistical experiment with three possible outcomes: diagnosed with cancer at age up to 40 years; diagnosed with cancer at age in the range of 41 to 60; not diagnosed with cancer until the age of 60. Pt is given by

$$Pt = \sum_{N_1=4}^{N} \sum_{N_2=1}^{N-N_1} P(N; N_1, N_2, N-N_1-N_2; P_1, P_2, P_3)$$

where P is defined in [9] eq. (3-62) (generalized Bernoulli trials) as:

$$P(N; N_1 \ldots N_k; P_1 \ldots P_k) = N! \prod_{i=1}^{k} \frac{P_i^{N_i}}{N_i!}$$

where N is the number of experiments (population size in our case), k is the number of possible, mutually exclusive, outcomes (in our case k=3, the number of age groups at diagnosis), N_i are the numbers of experiments with the different outcomes (numbers of cancer cases in each age group in our case), P_i are the probabilities of those outcomes in the general population and ! denotes the factorial.
Since the statistics used were the general population probabilities over whole lifetime and the actual observation period was 10 to 20 years, the exact p-value is even lower (more significant) then the one calculated here.

The odds ratio among the group of workers relative to the general population of being diagnosed with cancer up to the age of 40 is denoted by OR. Its 95% confidence interval CI was computed along the lines presented in [10] while conservatively disregarding the single worker diagnosed at age over 40.

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