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Cancer morbidity in subjects occupationally exposed to high frequency (radiofrequency and microwave) electromagnetic radiation

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Abstract

Cancer morbidity was registered in the whole population of military career personnel in Poland during a period of 15 years (1971–1985). Subjects exposed occupationally to radiofrequencies (RF) and microwaves (MW) were selected from the population on the basis of their service records and documented exposures at service posts. The population size varied slightly from year to year with a mean count of about 128 000 persons each year; each year about 3700 of them (2.98%) were considered as occupationally exposed to RF/MW. All subjects (exposed and non-exposed to RF/MW) were divided into age groups (20–29, 30–39, 40–49 and 50–59). All newly registered cases of cancer were divided into 12 types based on localisation of the malignancy; for neoplasms of the haemopoietic system and lymphatic organs an additional analysis based on diagnosis was performed. Morbidity rates (per 100 000 subjects annually) were calculated for all of the above localisations and types of malignancies both for the whole population and for the age groups. The mean value of 15 annual rates during 1971–1985 represented the respective morbidity rate for the whole period. Morbidity rates in the non-exposed groups of personnel were used as 'expected' (E) rates for the exposed subjects, while the real morbidity rates counted in the RF/MW-exposed personnel served as 'observed' (O) rates. This allowed the calculation of the observed/expected ratio (OER) representing the odds ratio for the exposed groups. The cancer morbidity rate for RF/MW-exposed personnel for all age groups (20–59 years) reached 119.1 per 100 000 annually (57.6 in non-exposed) with an OER of 2.07, significant at $P < 0.05$. The difference between observed and expected values results from higher morbidity rates due to neoplasms of the alimentary tract (OER = 3.19–3.24), brain tumours (OER = 1.91) and malignancies of the haemopoietic system and lymphatic organs (OER = 6.31). Among malignancies of the haemopoietic/lymphatic systems, the largest differences in morbidity rates between exposed and non-exposed personnel were found for chronic myelocytic leukaemia (OER = 13.9), acute myeloblastic leukaemia (OER = 8.62) and non-Hodgkin lymphomas (OER = 5.82).

Keywords: Radiofrequency radiation, cancer morbidity; Microwave radiation, cancer morbidity; Military personnel; Poland

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1. Introduction

Cancer morbidity in industrialised countries has been growing in the last few decades and it is believed, to a large extent, that the increase in incidence of neoplasms is related to exposure to harmful occupational and environmental factors that may either induce (carcinogens) or promote neoplastic transformation and/or growth and spread of tumours. A number of individual chemicals, groups of chemicals, mixtures, occupational exposures and industries, cultural habits and physical or biological factors have up to now been associated with induction of cancers at various body sites and included by experts of the WHO International Agency for Research on Cancer on the list of factors that are carcinogenic, or probably or possibly carcinogenic to humans [1]. Recognition of new occupational and environmental factors related to cancer morbidity, and investigations of their carcinogenic potency and mechanisms of interaction with respect to neoplasms are among the most important prophylactic tasks leading to lowering of cancer morbidity and protection of the population.

Electromagnetic (EM) fields are a relatively new but rapidly intensifying ecological and occupational factor. With continuous introduction of new equipment and technologies the intensity of occupational and public exposures to a diversity of frequencies and modulations of EM fields has tended to increase steadily during recent years. At present, only two or three generations of human beings have been exposed to man-made EM fields and long-term effects of these exposures are still difficult to foresee. Despite numerous experimental investigations and epidemiological studies (for review, see [2,3]) it is still not possible to prove the existence and character of any specific molecular, cellular or systemic damage that may be related to long-term exposure to weak EM fields. Surprisingly, very little attention was paid to the possible links between exposure to EM fields and development of neoplastic diseases in the past [2], until 1979, when Wertheimer and Leeper [4] published results of their residential study indicating increased incidence of leukaemias and some other neoplasms in children living in homes with higher than average intensities of power frequency magnetic fields. Soon after, the first studies that identified increased occupational risks of leukaemia, brain tumours and certain other neoplasms among electronic and electrical workers appeared (for review, see [5–8]). This opened a 'Pandora box' and released numerous retrospective epidemiological studies published during 1985–1994 from the United States, Canada, France, Sweden, Denmark and United Kingdom (for most recent examples, see [7,9–11]). Analysis of the available data shows clearly that it is almost certain that there exists a real additional cancer risk in workers that are described as 'electricians' and 'electronic' personnel and were potentially exposed during work to generally unknown intensity and character of EM fields. Nevertheless, this additional cancer risk is generally weak (odds ratios of 1.2–3.0) and relates only to particular types of neoplastic diseases (leukaemias, lymphomas, brain tumours, male breast cancer) which occur normally at low or very low incidence and are strongly influenced by well-defined environmental/occupational carcinogenic factors [1]. Dennis et al. [7] have calculated on the basis of mortality rates among workers in the 20–64 age group that the total extra annual risk for neoplasms developing in electric/electronic workers in the United Kingdom is about three cases per 100 000 subjects (one case of leukaemia and two cases of brain tumour) and should therefore be considered within the levels regarded as acceptable for occupational risks in risk assessment criteria recommended by the Royal Society.

The most controversial issue of the increased risk of leukaemias and brain tumours in workers of the electric and electronic industries remains however the postulated causal relation to occupational exposure in EM fields [7]. In none of the available studies, were the exposure conditions clearly stated and/or measured. The best possible description of exposure levels in the investigated population of workers was the arbitrary division into 'possible', 'probable' and 'sure' exposure at the working place with considerable participation of subjective judgement [9,10,12]. Furthermore, there are likely to be considerable

overestimates owing to the confounding factor of occupational classes.

In general, the existing data suggest that the increased risk of certain neoplasms in electric/electronic industry workers, if it is really related to EM exposure, it is associated with power frequency (50- to 60-Hz magnetic fields), either of stable flux density or modulated. The conviction of some authors [13] about the influence of 50- to 60-Hz magnetic field on the process of carcinogenesis is based on results of cellular investigations in vitro indicating exposure-related changes in the activity of certain enzymes associated with the process of carcinogenesis and/or cell transformation/proliferation, but still remains far from being generally acceptable.

However, some experimental and epidemiological data exist that indicate that high frequency EM fields, both radiofrequency (RF) and microwave (MW), may also account for the increased risk of neoplasms in occupationally exposed personnel. Already in 1953, McLaughin listed the various forms of leukaemias as one of the possible effects of exposure to radar radiation [14], but this statement was based generally on anecdotal and epidemiologically unproved small clusters of neoplastic diseases among relatively young men (30–40 years) servicing or repairing radars for several years and exposed to strong MW fields. Therefore, this report was treated with scepticism, criticised by the bioelectromagnetic community, and later forgotten, until new data appeared after 30 years. In 1985, Milham [15] reported a case-control study based on 1691 death certificates of male members of the American Radio Relay League and found a doubled rate of leukaemias in operators of amateur short-wave radio stations. In the investigated group, 12.6 cases of leukaemia were expected and 24 developed ($P < 0.01$). Increased incidence of haemopoietic and lymphatic malignancies in military career personnel in Poland exposed to pulse-modulated RF/MW radiation during 1970–1979 was reported by Szmigielski et al. [16]. These epidemiological findings have received some support from experimental investigations on animals exposed for a long time in weak MW fields. Guy and co-workers [17,18] exposed rats for their life-time to pulsed 2450-MHz MW fields at 0.48 mW/cm^2 and found increased numbers of spontaneous malignant tumours in the older animals from the exposed groups, although there was no predominance of any particular type of malignancy (e.g. lymphomas, leukaemias).

Findings from our group [19,20] indicate that daily exposures of mice to 2450-MHz MW radiation at 5–15 mW/cm^2 continued for 3–6 months, result in the accelerated appearance and growth of skin neoplasms induced by benzopyrene, suggesting a tumour-promoting activity of MWs.

All of the above data from epidemiological and experimental investigations still do not provide convincing data on the potential role of RF/MW radiation in the increased incidence of neoplasms in occupationally exposed personnel and therefore, further investigations are needed to clarify this problem.

In the present paper, we report the increased incidence of neoplasms in a group of military personnel in the 20–59 years age group, who are in active service and exposed occupationally to pulse-modulated RF/MW radiation. The data are based on retrospective analysis of cancer morbidity during the 15-year period of 1971–1985.

2. Materials and methods

2.1. Population and assessment of RF / MW exposure

The subject of this study was the whole population of military career personnel in Poland during a 15-year period (1971–1985). Annual data on the population size (number of career servicemen, types of individual service posts and exposure to possible harmful/carcinogenic factors during service) were available from respective personnel and military health departments. These data were used for calculation of morbidity rates of cancer. Data on all newly diagnosed cases of malignant neoplasms were collected from records of central and regional military hospitals and the central military medical board. These data included diagnosis of the disease, localisation and type of the malignancy, results of basic medical tests related to diagnosis, duration and type of service, exposure to possible carcinogenic factors during ser-

vice, life habits, social/family status and exposure to EM fields. Care was taken against possible duplication of cases registered from different sources (e.g. hospital and medical board).

Data on exposure of personnel to RF/MW were collected from EM military safety groups operating as health hygienic services. These groups are responsible for measurements of RF/MW field intensities at and around service posts where EM emitting equipment is used, repaired or serviced, and keep health records of personnel working on these posts. The number of personnel considered to have been exposed occupationally to RF/MW was easily established, but evaluation of the exposure rate appeared to be quite difficult. Evaluation of the exposure intensities revealed that at 80–85% of posts, the fields (mostly pulse-modulated RF/MWs at 150–3500 MHz) do not exceed 2 W/m^2 (0.2 mW/cm^2), while the others have intensities 2–6 W/m^2, and exposures exceeding 6 W/m^2 were registered incidentally. However, individual exposure of the personnel (daily or monthly exposure 'dose') was difficult to assess, as both period of the exposure may be variable and short-lasting incidences of overexposure appear to occur quite frequently.

2.2. *Analysis of cancer morbidity*

All career personnel in active service were divided into four age groups (20–29, 30–39, 40–49 and 50–59 years) and data for cancer morbidity (first diagnosis of malignant disease) were expressed both for the above age groups and for the whole population. All neoplasms were divided into 12 localisations (Table 1) and for each of them, the incidence (per 100 000 subjects annually) was calculated based on newly diagnosed cases every year and during the whole period of analysis (15-year period, 1971–1985). The incidence for non-exposed subjects served as the 'ex-

Table 1
Incidence of neoplasms (per 100 000 subjects annually) in military personnel exposed and non-exposed (control) to radiofrequency and microwave radiation

Localization of malignancies	Incidence per 100 000 annually non-exposed (expected)	Incidence per 100 000 annually exposed (observed)	Exposed/non-exposed ratio (observed/expected)	95% confidence limits	Significance (*P*-value)
Oral cavity	2.65	1.82	0.71	0.42–1.32	N.S.
Pharynx	1.96	2.12	1.08	0.82–1.24	N.S.
Esophageal and stomach	4.83	15.64	3.24	1.85–5.06	< 0.01
Colorectal	3.96	12.65	3.19	1.54–6.18	< 0.01
Liver, pancreas	2.43	3.58	1.47	0.76–3.02	N.S.
Laryngeal, lung	21.89	23.26	1.06	0.72–1.56	N.S.
Bones	1.53	1.03	0.67	0.36–1.42	N.S.
Skin, including melanomas	3.28	5.46	1.67	0.92–4.13	< 0.05
Kidney and prostatic	4.58	3.96	0.86	0.54–1.67	N.S.
Nervous system, including brain tumours	2.28	4.36	1.91	1.08–3.47	< 0.05
Thyroid	1.38	2.12	1.54	0.82–2.59	N.S.
Haematopoietic system and lymphatic organs	6.83	43.12	6.31	3.12–14.32	< 0.001
All malignancies	57.60	119.12	2.07	1.12–3.58	< 0.05

Data are based on registration of all newly diagnosed cases of neoplasms during 1971–1985 in the whole population (aged 20–59 years) of military career personnel in Poland. Exposed, subjects exposed occupationally to radiofrequency and microwave radiation; Non-exposed, subjects non-exposed to the radiation, used as control group for calculation of expected morbidity for the exposed group.

pected' rate of morbidity for the whole population, including the RF/MW-exposed personnel. The number of newly diagnosed cases of neoplasms in the RF/MW-exposed group allowed a calculation of the group incidence (per 100 000 subjects annually) and this served as the 'observed' rate of morbidity. This in turn allowed the calculation of the observed/expected ratio, its confidence intervals at 95% probability and the statistical significance of the ratio. Statistical calculations were performed using the SIGMA-STAT Win ver. 1.00 software and worksheet from Jandel Scientific Co., Germany (reg. number 950 559).

3. Results and discussion

The size of the investigated population varied slightly from year to year during 1971–1985 with a minimal value of 118 500 and maximum of 142 200; the mean value for the whole period was 127 800 (S.D. 9620). The exact age distribution of the personnel is still classified information and therefore, the results may be given only in the form of incidence rates and odds ratios (Table 3). Nevertheless, from these data, it may be concluded that the majority of subjects was divided between the age groups of 30–39 and 40–49 years.

The number of personnel exposed occupationally to RF/MW during 1971–1985 fluctuated annually from 3400 to 4600 (mean value 3720 $\pm$ 360) with an increasing tendency in 1980–1985, due to introduction of new types of electronic equipment for use in military units.

The group of military career personnel in active service, amounting to over 120 000 subjects, appears to be large enough to establish the 'expected' cancer morbidity rates for RF/MW-exposed personnel (Table 1). The incidence of all malignancies in this group reached nearly 60 per 100 000 subjects annually, including 22 laryngeal or lung cancers, about 4–5 cases for each of stomach, colorectal, and kidney or prostate neoplasms, and about seven malignancies of the haemopoietic system and lymphatic organs developing each year in 20- to 59-year-old career servicemen. Nevertheless, for rare forms of neoplasms, not typical for middle-aged men, the calculated incidences (Tables 1,2) are based on single cases appearing incidentally and therefore, all incidence rates not exceeding 1.5 per 100 000 annually should be treated with caution. For example, in the analysed group of non-exposed personnel, there was no single case of myeloma (plasmocytoma) registered during the 15-year period of analysis (Table 2). The standardised rates for plasmocytoma in Poland appear to range between 3 and 5 per 100 000, but this is a disease of old age and reaches its maximum in people over the age of 75 [1]. On the other hand, acute lymphoblastic leukaemia is most common in children (aged under 15) and accounts for 75–80% of leukaemia cases in the 2- to 4-year-old white populations of children [1]. In the personnel exposed and non-exposed to RF/MWs, only single cases of acute lymphoblastic leukaemia were diagnosed during 15 years (all in the age group 20–29 years) (Table 2) and thus, the incidence rates and odds ratio for this type of leukaemia should be treated with caution and need confirmation on larger studies.

In general, the RF/MW-exposed group of 3700 subjects has to be considered as relatively small for valid assessment of cancer morbidity at the 'observed' rates below 12.5–25 per 100 000 subjects annually (0.5–1 case annually in a group size of 4000 subjects is 'expected'). The longer period of observation (15 years), in spite of permanent annual recruitment, retirement and aging of the remaining members of the group, validate the incidence rates, but still those numbering below about 10 cases per 100 000 annually are strongly influenced by single cases of particular types of neoplasms. For example, one case of malignancy in the group of 3700 subjects during 15 years accounts for the incidence of 1.8 cases per 100 000 annually.

The data presented in Tables 1–3 indicate that cancer morbidity rates are high enough to prove that the incidence of all malignancies is doubled ($P < 0.05$) in RF/MW-exposed personnel, compared to their unexposed colleagues of the same socio-economic status and living under similar environmental and working conditions (Table 1). This difference is due to higher morbidity rates of

Table 2
Incidence of haemopoietic and lymphatic malignancies (per 100000 subjects annually) in military personnel exposed and non-exposed (control) to radiofrequency and microwave radiation

Type of haemopoietic/lymphatic malignancy	Incidence per 100000 annually non-exposed (expected)	Incidence per 100000 annually exposed (observed)	Exposed/non-exposed ratio (observed/expected)	95% confidence limits	Significance (*P*-value)
Malignant lymphogranulomatosis (Hodgkin's disease)	1.73	5.12	2.96	1.32–4.37	< 0.05
Lymphoma (non-Hodgkin) and lymphosarcoma	1.82	10.65	5.82	2.11–9.74	< 0.001
Chronic lymphocytic leukaemia	1.37	5.04	3.68	1.45–5.18	< 0.01
Acute lymphoblastic leukaemia	0.32	1.84	5.75	1.22–18.16	< 0.05
Chronic myelocytic leukaemia	0.88	12.23	13.90	6.72–22.12	< 0.001
Acute myeloblastic leukaemia	0.71	6.12	8.62	3.54–13.67	< 0.001
Myeloma (plasmocytoma)	No cases (0.00)	2.12	ND	ND	
Total	6.83	43.12	6.31	3.12–14.32	< 0.001

Data are based on registration of all newly diagnosed cases of malignancies of the haemopoietic system and lymphatic organs during 1971–1985 in the whole population (aged 20–59 years) of military career personnel in Poland. Exposed, subjects exposed occupationally to radiofrequency and microwave radiation; Non-exposed, subjects non-exposed to the radiation, used as control group for calculation of expected morbidity for the exposed group; ND, not determined.

Table 3
Incidence of neoplasms (per 100000 subjects annually) in age groups of military personnel exposed and non-exposed (control) to radiofrequency and microwave radiation

Age group (years)	All forms/localizations of neoplasms					Haemopoietic/lymphatic malignancies				
	Incidence per 100000 subjects annually non-exposed expected	Incidence per 100000 subjects annually exposed observed	Exposed/non-exposed ratio (observed/expected)	95% confidence limits	Significance *P*-value	Incidence per 100000 subjects annually non-exposed expected	Incidence per 100000 subjects annually exposed observed	Exposed/non-exposed ratio (observed/expected)	95% confidence limits	Significance (*P*-value)
20–29	11.62	27.11	2.33	1.23–3.12	< 0.05	2.12	17.30	8.16	3.11–22.64	< 0.01
30–39	18.37	42.28	2.30	1.04–3.06	< 0.05	3.08	26.43	8.58	3.46–19.58	< 0.01
40–49	84.29	161.62	1.92	0.98–2.84	< 0.05	8.32	73.25	8.80	4.13–15.27	< 0.01
50–59	186.71	274.13	1.47	0.92–2.12	N.S.	24.31	108.62	4.47	2.56–6.81	< 0.01
All age	57.60	119.12	2.07	1.12–3.58	< 0.05	6.83	43.12	6.31	3.12–14.31	< 0.001

Data are based on registration of all newly diagnosed cases of neoplasms during 1971-1985 in the whole population (aged 20–59 years) of military career personnel in Poland. Exposed, subjects exposed occupationally to radio frequency and microwave radiation; Non-exposed, subjects non-exposed to the radiation, used as control group for calculation of expected morbidity for the exposed group.

malignancies of the haemopoietic system and lymphatic organs (odds ratio 6.31, with the incidence for RF/MW-exposed subjects exceeding 40 cases per 100 000 annually) and to cancers of the alimentary tract (odds ratio about 3.2 with the incidence of more than 15 of oesophageal and stomach cancers and 12 colorectal adenocarcinomas per 100 000 RF/MW-exposed personnel annually). A statistically significant difference ($P < 0.05$) has also been found for skin neoplasms and tumours of the nervous system, including brain tumours (Table 1), but in this case the incidence of these cancers in RF/MW-exposed personnel was relatively low (4–5.5 cases per 100 000 subjects annually or 2–4 cases of each type registered during 15 years of observation) and therefore, requires confirmation.

Neoplasms of the alimentary tract appear to be among the most frequent types of cancer in middle-aged men in Poland. In the investigated population of military personnel, the incidence for stomach and colorectal adenocarcinoma (the rate for oesophageal cancer was marginal) reached nearly nine cases annually (about five for stomach and four for colorectal) per 100 000 subjects aged 20–59 years. Most of these neoplasms developed in the age groups of 40–49 and 50–59 years (Table 3), 6–8 times higher than in younger subjects. Neoplasms of the alimentary tract appear to be related to certain dietetic habits, including over use of salted, corned and smoked food products, and therefore, are characterised by a considerable diversity of rates throughout the world [1] with Eastern European countries being considered as high-risk regions. These neoplasms were rarely linked with exposure to EM fields in epidemiological studies. Only in one study based on a cancer registry in Canada [21] was there a threefold increase of the rate of intestinal neoplasms in high-voltage power line workers, while in other studies of cancer incidence in electricians and electronic workers [5,6,9,10] no increase rates for cancers of the alimentary tract have been reported.

At present, it is not possible to offer a reasonable explanation for the threefold increase of the rate of stomach and colorectal adenocarcinoma in RF/MW-exposed military personnel in Poland or to be certain about causal links with the exposures. Nevertheless, we were not able to find any differences in dietetic or life habits, consumption of alcoholic beverages or possible exposure to other occupational carcinogenic substances that may explain the differences in morbidity between the exposed and non-exposed servicemen. Surprisingly, the most common type of cancer in middle-aged men, lung cancer, did not show differences between the RF/MW-exposed and non-exposed groups of the personnel and in both groups the incidence of laryngeal and lung cancer reached 22–23 cases per 100 000 subjects annually (Table 1). This type of cancer is strongly related to cigarette smoking and to indoor air pollution with certain carcinogenic factors [1]. The equal incidence in both investigated groups of personnel confirms similar exposure to both these elements in the investigated populations. In other studies of cancer morbidity in workers of electric/electronic industries [7,11], no increased rates of incidence of lung cancer could be documented. Therefore, it may be concluded that EM fields of any frequency and/or intensity do not interfere with the multiple environmental factors that initiate and/or accelerate development of lung cancer.

The highest difference in morbidity rate between RF/MW-exposed and non-exposed personnel was found for malignancies of the haemopoietic system and lymphatic organs (Table 2) with the odds ratio exceeding 6 and the incidence of above 40 new cases per 100 000 of exposed subjects annually. The most frequent type of this form of malignancy in the RF/MW-exposed group appeared to be non-Hodgkin lymphoma and lymphosarcoma (10.65 new cases annually per 100 000) and chronic lymphocytic leukaemia (12.23 cases per 100 000 annually), both developing mainly in the 40–49 and 50–59 years age groups. Neoplasms of the haemopoietic system and lymphatic organs are among the malignancies that are to a considerable degree related to multiple environmental and occupational factors, including ionising radiation, organic solvents, some synthetic stains, resins, higher alcohols and

numerous other substances [1]. Therefore, many industrial occupations, including e.g. aluminium production, petroleum refining, painting, mining, driving and car servicing, are considered to increase the risk of development of leukaemias and lymphomas. Electric and electronic industry workers have also considerable possibilities for exposure to potential leukaemiogenic factors and substances during their routine or additional duties. This may strongly influence and bias the morbidity rates of haemopoietic and lymphatic malignancies occurring in these populations and their relation to EM fields.

Nevertheless, in the majority of published epidemiological studies of cancer incidence in workers exposed to EM fields, haemopoietic and lymphatic neoplasms are indicated as those being most possibly linked to the exposure, with extremely low frequency magnetic fields as the most probable causal agent [5,8,13]. In populations defined in job descriptions as electric and electronic industry workers, the odds ratios for morbidity from haemopoietic/lymphatic malignancies show substantial variations between studies [7,9,10], but are generally statistically significant and range from 1.4–3.0. These values are considerably less than the odds ratio for all haemopoietic /lymphatic malignancies (6.31), found in the present study. Populations described by occupation as 'electricians' and 'electronics' may experience exposure in the workplace to a variety of frequencies, intensities and modulations of EM fields with a predominance of extremely low (power) frequency electric and magnetic fields, possible exposure of part of the population to higher frequencies (RF and MW) and equally possibly negligible occupational exposure to EM fields for some members of the population. Thus, it is very difficult to assess exposure conditions and levels, both for the whole population and for the victims of neoplastic diseases.

Diverse exposure conditions among electric/electronic workers analysed retrospectively in one group for cancer morbidity may result in 'dilution' of the effects (lowering of real odds ratios), if the postulated links are related to specific types of exposure (e.g. only to 50-Hz magnetic fields or to pulse-modulated high frequency EM fields). Also, there may be an inability to identify any specific carcinogenic factors that may be frequently present in the occupational environment of 'electricians' and 'electronics' that could explain the increased morbidity of leukaemias and lymphomas. In the present study, the exposure conditions of the investigated personnel were almost limited to pulse-modulated high frequency EM fields (150- to 3500-MHz RF/MW radiation). Exposures to continuous waves and lower frequencies, including power frequency, were marginal. Although assessment of the individual exposure levels ('dose') was not possible, it is known from measurement of field power density at working posts that about 80% of the investigated personnel were exposed to RF/MW fields of 0.1–2 W/cm^2 and 15% to mean power densities of 2–6 W/m^2. This allows us to state that the investigated Polish group of RF/MW-exposed subjects was considerably more uniform in terms of exposure conditions, compared to similar populations [5–7].

The main results obtained in the present study were a doubled incidence of all neoplasms with a threefold increase of cancers of the alimentary tract and a sixfold increase of malignancies of the haemopoietic system and lymphatic organs in 20- to 59-year-old career military servicemen exposed occupationally to pulse-modulated 150- to 3500-MHz RF/MW radiation. However, this does not prove a causal link between development of neoplastic diseases and direct interaction of EM fields, since retrospective analysis cannot provide convincing evidence for such links. Nevertheless, the high incidence of certain forms of neoplasms in personnel exposed to pulse-modulated RF/MW radiation clearly shows a need for urgent identification of causal factors present in the occupational environment.

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