Polish Journal of Occupational Medicine and Environmental Health Vol. 4, No 3, 281-289, 1991

ANALYSIS OF EXPOSURE TO ELECTROMAGNETIC FIELDS DURING PROFESSIONAL USE OF RADIO-TELEPHONES *

HALINA ANIOŁCZYK, and MAREK ZMYŚLONY

Department of Radiation Dosimetry, Institute of Occupational Medicine, Lodz, Poland

Key words: Radiocommunication, Radiotelephones, Microwave, Occupational exposure, Land-mobile radio

Abstract. An environmental survey on exposure to EM fields covered over 300 radiotelephone operating in the range of 300–344 MHz with input power of 5 W, used by 574 radiooperators and 48 radiomechanics employed in sanitary transport, power engineering, municipal traffic and coal mining. The intensity of EM fields was measured and timing of effective radiotelephone transmitter work was done. According to the Polish standards, it was found that 3% of the population examined were subject to excessive exposure, 6% – to conditionally admissible only and 17% – to admissible. Exposure assessment, made for extreme conditions based on literature, theoretical and experimental data, showed that in radiomechanics' necks, eyes and wrists there may occur SAR values: 10–15 W/kg, 1–1.5 W/kg and 1.8 W/kg, respectively.

INTRODUCTION

Land mobile radiocommunication is widely used in various branches of the national economy.

Radiotelephones operate, within microwave frequency ranges, in two bands: 300–308 MHz and 336–344 MHz. According to needs, various stationary, mobile and portable radiotelephones are used. The transmitting antenna, in all types of radiotelephones mentioned, is a source of desirable electromagnetic (EM) field. However, this antenna, as well as leaks in the transmitter casing screen and antenna transmission line, often irradiate undesirable EM fields in the workposts of radiotelephone operators.

* Paper presented at XXIII General Assembly of the International Union of Radio Science, Czechoslovakia, 28 August – 5 September 1990.

Address reprint requests to H. Aniołczyk, Department of Radiation Dosimetry, Institute of Occupational Medicine, P.O. Box 199, 90–950 Lodz, Poland.

Mobile radiocommunication network requires permanent technical supervision: its users organize special radioservice units. During service operations, undersirable EM fields are generated by: unscreened transmitters, improper tuning instruments, transmitting-receiving antennas installed in the service--room. Due to the high number of radiotelephones in use, a relatively large population may be occupationally exposed to EM fields of intensities not concordant with hygienic standards.

MATERIALS AND METHODS

To evaluate the magnitude of occupational exposure to EM fields in workers using radiotelephones, the following measurements were performed:
1. Measurement of EM fields intensity at 307 workposts of radiooperators (using various radiotelephones – stationary, mobile, and portable) as well as 27 workposts of radiomechanics servicing radiotelephones;
2. Measurement of effective duration of stay in EM field zone at 9 stationary radiotelephones and 209 mobile ones as well as exposure time during maintenance and repair of 16 radiotelephones of various types.

The devices mentioned were operated by 574 radiooperators and 48 radiomechanics.

EM fields intensity was measured using broadband RF/Microwave field strength meter type MEH-1A manufactured at Wroclaw Technical University (Poland) with the following probes:

1. Measuring probe type AS-1 (measurement of power density ranging from 0.5×10^{-2} W/m^2 to 0.25 W/m^2; frequency range: 0.3–3 GHz);
2. Measuring probe type AS-2 (measurement of power density from 0.1×10^{-1} W/m^2 to 2500 W/m^2; frequency range: 0.3–3 GHz);
3. Prototype of measuring isotropic probe type 3AE-12 (measurement of electric component of EM field from 1–160 MHz; Measuring accuracy: $\pm$ 30%).

Effective duration of exposure was determined by means of:

1. 24hr tape recording in stationary radiotelephone bases;
2. interviews with radiooperators;
3. direct measurement with a stopwatch in radioservices (during power tuning of radiotelephone transmitter);
4. analysis of documentation on radiotelephones repairs in radioservices.

RESULTS

The analysis of results of field intensity measurements at the workposts of radiooperators has shown that about 74% of the transmitting devices examined (excluding antennas) are a source of undesirable EM fields of measurable values of energy power density; this involves 57% of workposts. The results of field intensity measurements at the workposts of radiomechanics

in radioservice, made during testing and tuning the power unit in unscreened transmitters, indicate that EM fields may occur of intensities ranging from 2 to 140 V/m. The highest values were found during the power unit tuning by means of ordinary metal screw drivers.

The analysis of timings for selected users of a land mobile radio network in the power industry and sanitary transport showed that in 18% of radiotelephones of the stationary type, the effective period of operation amount to over 2h; the effective transmitting period in 63% of mobile radiotelephones exceeds 20 min; whereas the effective transmitting time in portable radiotelephones ranges from 30 to 40 min.

The analysis of timings in radioservices showed that during the repair of one radiotelephone, the radiomechanic is exposed to EM fields for about 30 min. When he tunes the high frequency power unit of transmitter power amplifier, he is exposed to maximum values for about 10 min. The maximum number of repairs, including turning on transmitters, amount to 4–5 per work-shift. Hence, it has been assumed that a radiomechanic may be exposed to EM fields altogether for 120 min per work-shift, and to EM fields of maximum value for about 40 min.

Evaluation of exposure to EM fields at the workposts of radiooperators

According to the Polish hygienic standards concerning EM fields in the microwave range (6), the values of power density, measured at the workposts of radiooperators, were analysed. The power density was measured at predetermined levels i.e. 0.1, 2 and 100 W/m^2 adopted as boundary limit values for intermediate, hazardous and dangerous zones, respectively. The results were analysed, taking into consideration the kind of radiotelephone and conditions under which it was used. It is to be noted that a high percentage of workposts qualify for the hazardous zone (64%) in the case of portable radiotelephones, and that the hazardous zone occurs also in 2% of stationary radiotelephone workposts. As far as mobile radiotelephones are concerned, EM fields of values corresponding to the dangerous zone have been found in 3% of the workposts examined.

Fig. 1 presents the results of analysis of stationary, portable and mobile radiotelephones. In the case of EM field intensities within the limits corresponding to the hazardous zone, the duration of stay of personnel is controlled and reduced. The histographic records concerning duration of radiotelephone effective work are presented in Fig. 2. Based on the results of EM field intensity measuremets at the work-posts and during work-shifts, an actual dose for radiooperators (whose workposts were in the vicinity of hazardous zone) was determined.

The hygienic evaluation of EM fields at the workposts of radiooperators revealed that 3% of the population examined were subject to excessive exposure, 6% to conditionally admissible and only 17% to admissible.

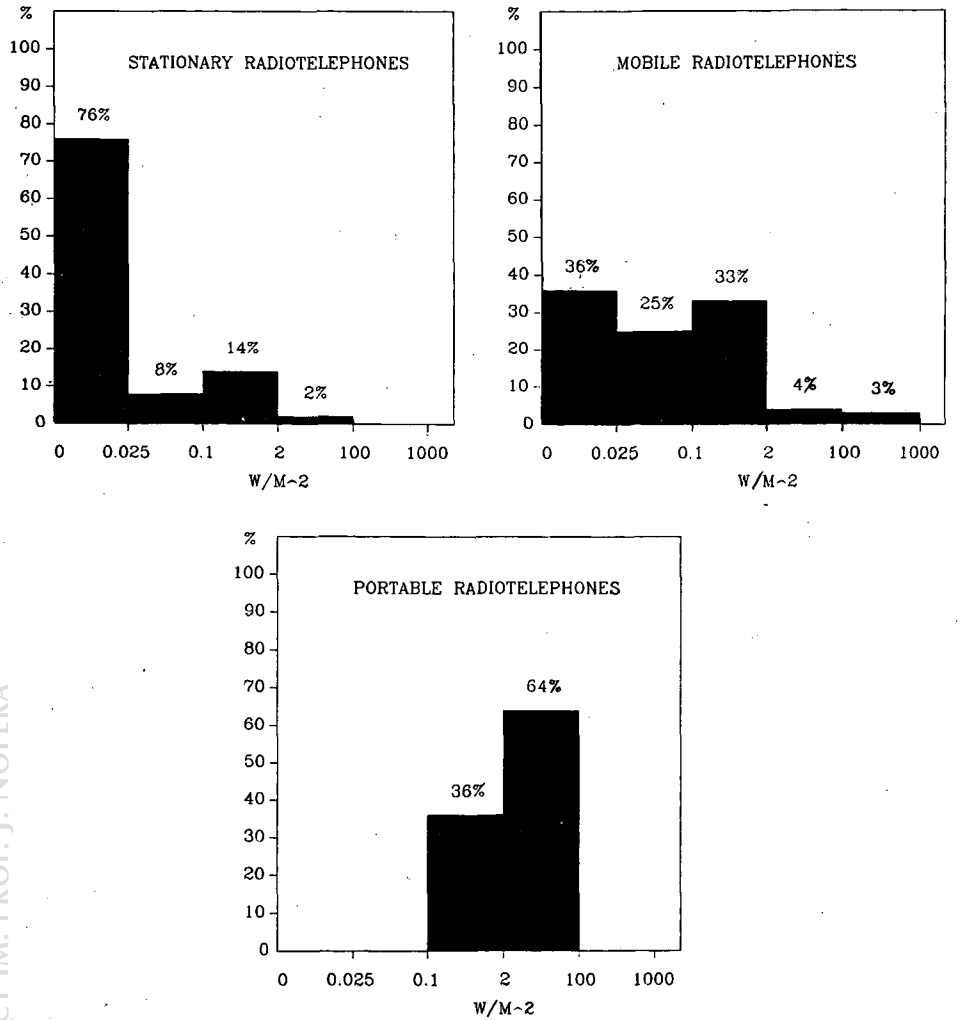

Fig. 1. Analysis of EM fields distribution at the workposts of radiooperators according to the type of radiotelephone (following the Polish hygienic standars).

Evaluation of exposure to EM fields at the workposts of radiomechanics

Hygienic evaluation of EM fields occurring under various service conditions (concurrent occurrence of EM fields of two various frequencies: radiowave and microwave) is more difficult due to a lack of respective hygienic and methodological regulations. A measuring procedure for such cases has been developed at the Institute of Occupational Medicine in Lodz.

To make a hygienic evaluation of the results, using our method of EM fields

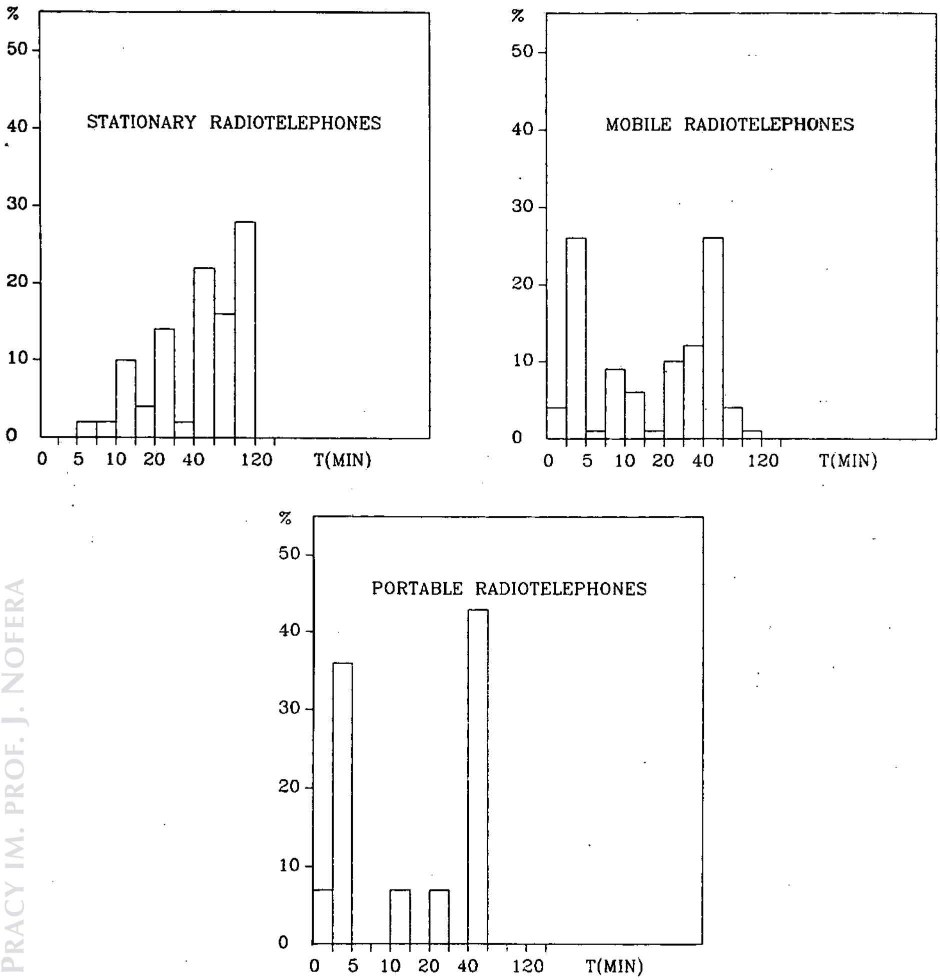

Fig. 2. Distribution of effective duration of exposure to EM fields according to the type of radiotelephone.

measurements at the workposts of radiomechanics, the limits of occupational exposure to EM fields of the radio- and microwave range were compared. It has been found that in the case of the intermediate and hazardous zones (low boundary limit) as well as in the case of the highest values of EM fields intensities, it would be beneficial from the hygienic point of view to use the limits adopted for the radiowave range (5). According to that assumption,

an analysis of EM field intensities was carried out according to the levels determined, ie. 7, 20 and 300 V/m adopted as boundary limits for intermediate, hazardous and dangerous zones, respectively. The results of the analysis are presented in the form of histograms in Fig. 3.

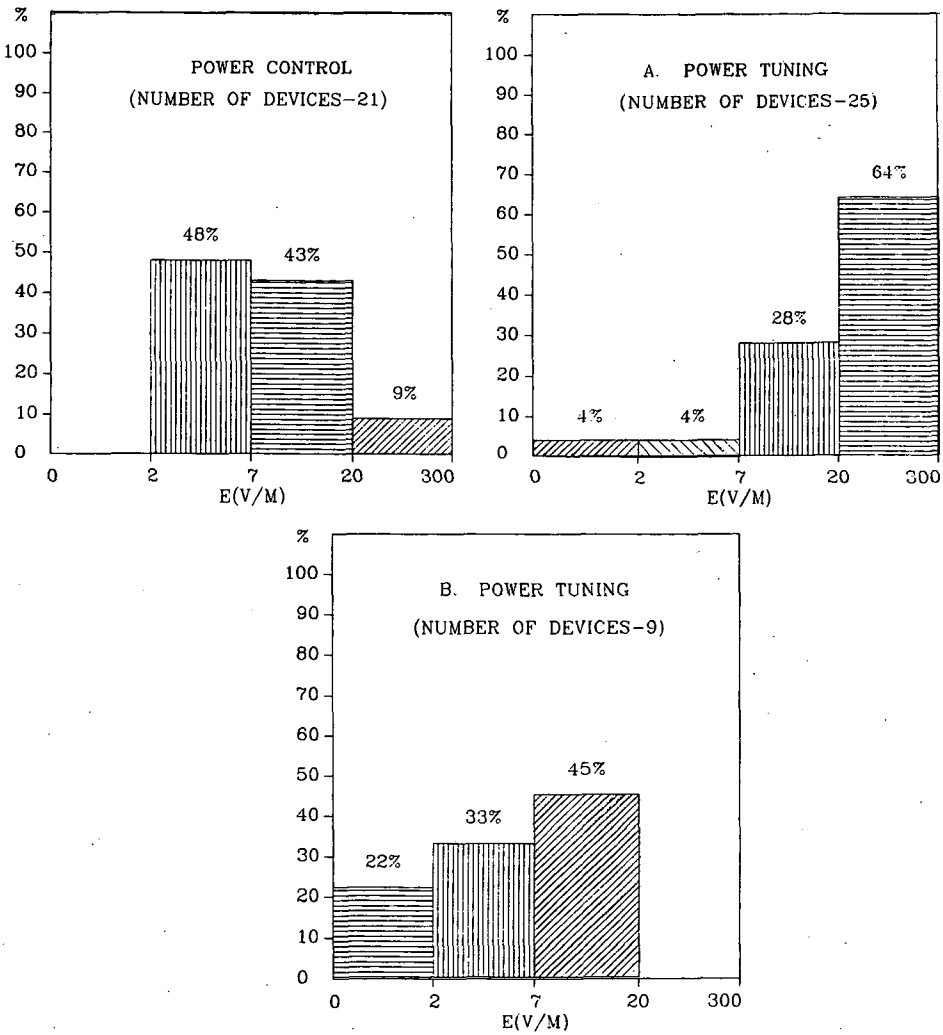

Fig. 3. Distribution of EM fields intensities at the workposts of radiomechanics. A. at the level of the forearm, B. at the level of the eyes.

The analysis of EM fields distribution showed that during radiotelephone transmitter testing (screens removed), 9% of the devices revealed a hazardous zone, whereas during tuning the high frequency power unit of the transmitter,

the hazardous zone occurred in 64% of the devices tested. Due to the short range of the zone mentioned it has not always covered the worker's whole body. In nine cases analysed, it was found that the hazardous zone occurred at the level of radiomechanic's heart and eyes at four workposts.

The analysis of timing showed that the radiomechanic may be exposed to EM field altogether for 120 min per work-shift, included in this EM fields of maximum values for about 40 min.

Because of evaluation of exposure to EM fields at the workposts of radiomechanics it was found that: 13% of the population concerned were subjected to excessive exposure; 56% to conditionally admissible only; and 23% to admissible.

DISCUSSION

Evaluation of exposure of EM fields occurring during the use of microwave radiotelephones was carried out following the Polish hygienic regulations (5, 6).

The results obtained from measurement of EM fields, occurring at the workposts of the personnel employed at the devices of relatively small power (microwave radiotelephones), are disquieting as 3.5% of the population examined is subject to excessive exposure to EM fields (exceeding max. admissible intensity) and over 9% of the population is subject to conditionally admissible exposure only (unexceeded duration of stay in the hazardous zone).

The magnitude of exposure to EM fields in our study, as compared with the exposure limits set in some other countries, indicates that in the case of radiotelephones operating in the range 300–350 MHz, about 11% of devices do not meet the requirements of even more liberal standards and recommendations adopted e.g. in the USA or FRG. This percentage is even higher when compared with the USSR standard.

Literature provides data indicating the increased absorption of EM field energy within the frequency range occurring in the case of the radiotelephones tested by us: the frequency 150 MHz (over the high frequency power unit of transmitter) is a frequency for resonance absorption of EM fields energy in the area of man's arms.

The frequency of about 350 MHz corresponds to resonance absorption for man's head. Within the frequency range from 300–2000 MHz, a known phenomenon of "hot spots" occurs (1, 2, 3). The studies carried out in Canada on the magnitude and distribution of EM field energy absorption in heterogenous models of man, allowed to determine the value of absorption for the whole body and in particular parts, for the frequency range of 160 and 350 MHz (8, 9). It was found that maximum EM field absorption occurs in the area of the neck and it amounts to about 1 W/kg/W in the near-field exposure. As is known, the neck is a site of an important endocrine gland (the thyroid). It may be a target organ in the operators of portable radiotelephones of frequency bands 148–192 MHz and 300–344 MHz. Sullivan et al. (7) determined maximum absorption in the area of the wrist, a frequency of

100 MHz (far-field exposure) as amounting to 0.04 W/kg/W/m^2; this value is particularly important for evaluation of radiomechanics' exposure as they are subject to exposure to the highest values of EM fields at the level of the forearm and palm. It must be remembered that the exposure conditions influence the magnitude and distribution of EM field energy absorption.

It was found (4) that the presence of metal planes may increase the maximum absorption almost five times. The above premises justify the need for undertaking the environmental survey; among other aims to cover devices of high frequency, eg. commonly used radiotelephones' and making a prognostic evaluation of the EM fields effect on radiotelephone operators' and radiomechanics' organisms. Based on the literature data on the distribution of EM field energy absorption in experimental and theoretical models of man, as well as on the results of our own research in the working environment of radiooperators and radiomechanics, the extreme absorption values were assessed. In the case of the neck level of an operator of portable radiotelephone it amounts to 2 W/kg, of a radiomechanic – 1.8 W/kg, while average values for a whole body amount to 0.11 W/kg and 0.004 W/kg, respectively.

The value of EM field energy absorption assessed for radiomechanics, allowing for transmitter power output, ranges from 10 to 15 W/kg in the neck area. SAR values, determined for the actual conditions and exposure magnitude in radiotelephone operators and radiomechanics, may be compared with the literature data on the possible biological effects of EM fields in workers staying in the zone of their action. The analysis allowed us to ascertain that some biological effects, eg. changes in behaviour (of reversible type) may occur, as well as some local thermal effects, in individual cases. The above authorizes us to make the following conclusions.

CONCLUSIONS

1. Hygienic evaluation of workposts using various radiotelephones showed that 57% of workposts of radiooperators and 96% of workposts of radiomechanics are within the EM field zone (at the level of the hand it occurs in all workposts).

2. Evaluation of exposure values of occupational exposure to EM fields in the population examined (based on: own measurement, literature data on the distribution of EM fields energy absorption in experimental and theoretical human models and results of epidemiological studies) permits to draw a conclusion that some biological effects, chiefly in the form of functional changes of reversible type, may occur.

3. In view of the above it seems that abandoning the hygienic control of professionals using the radiotelephones is not justified. Besides, the actual system of control of exposure to EM fields requires some modifications. For example, in the case of radiotelephones, a technical control at the user stage should be introduced.

REFERENCES

1. Chen KM, Guru BS. Induced EM fields inside human bodies irradiated by EM waves of up to 500 MHz. J Microwave Power 12, 1973–183, 1977.
2. Gandhi OP. Conditions of strongest electromagnetic power deposition in man and animals. IEEE Trans Microwave Theory Tech. MTT-23, 1021–1029, 1975.
3. Gandhi OP, Hagman MJ, D'Andrea JA. Part-body and multibody effects on absorption of radiofrequency e-m energy by animals and by models of man. Radio Sci 14, 15–21, 1979.
4. Gandhi OP, Hunt HL, D'Andrea JA. Deposition of electromagnetic energy in animals and in models of man with and without grounding and reflector effects. Radio Sci 12, 39–47, 1977.
5. Regulation issued by the Minister of Labour, Wages and Social Security and the Minister of Health and Social Welfare (February 19, 1977) on labour safety and hygiene in applying devices which produce EM fields in ranges from 0.1 to 300 MHz (in Polish).
6. Regulation of the Minister's Council (May 5, 1972) on labour safety and hygiene in applying devices which produce microwaves. Law Gazette 21, 153, 1972 (in Polish).
7. Sullivan DM, Gandhi OP, Taflove A. Use of the Finite-Difference Time – Domain Method for Calculating EM Absorption in Man Models. IEEE Trans Biomed Engi 35, 179, 1988.
8. Stuchly MA, Kraszewski A, Stuchly SS, Hartsgrove GW, Spiegel RJ. RF Energy Deposition in a Heterogenous Model of Man: Near-Field Exposures. IEEE Trans Biomed Eng 12, 944-950, 1987.
9. Stuchly SS, Kraszewski A, Stuchly MA, Hartsgrove GW, Spiegel RJ. RF Energy Deposition in a Heterogenous Model of Man: Far-Field Exposure. IEEE Trans Biomed Eng 12, 951–957, 1987.

Received for publication: December 5, 1990.
Accepted for publication: August 8, 1991.