

Rationale for Setting EMF Exposure Standards*

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Radio frequency including microwave radiation at sufficient levels of intensity and duration of exposure could cause harmful effects on a living organism. The biological effects (especially long-term low level) and their mechanism are not yet well known, so that the exposure standard adopted in various countries differ from each other greatly.

Different Types of RF Exposure Standards and their Rationales

The reason why such differences exist is the different basic principles of establishing RF exposure standards. There are two types in the world.

- 1) The exposure limits was set up based on theoretical considerations of power absorption, which was derived from specific absorption rate (SAR). The SAR limits were according to the changes in rat behavior after the animal receiving acute exposure to RF EMF. A safety factor of 10 to 50 was incorporated.
- 2) The exposure limits was set up based on medical examination and epidemiological analyses of personnel exposed to EMFs. It has been demonstrated that chronic exposure to EMFs are associated with a variety of non – specific symptoms. And the results of experimental animals are supplemented with safety factors.

Health Effects of RF EMF

- 1) Health effects of RF (<30 MHz) occupational exposure
A cross sectional epidemiological study with 121 exposed workers and 70 control persons was reported in Beijing, China (ZQ Shao). The results were shown in Table 1.

Table 1 Significant differences in the following incidences

Group	≥100V/m	<100V/m	Control
Neurosis	55.56*	53.73*	17.1
Cardiovascular complaints	46.2*	47.76*	14.29
Changes in ST-T(ECG)	37.03*	13.44	12.86
Incomplete right bundle branch block(ECG)	11.11*	2.99	2.86
Systolic pressure<100mmHg	10.0*	3.92	0

* P<0.05 vs control

*) Original paper

2) Health effects of microwave radiation (occupational exposure)

A medical examination of personnel exposed occupationally to Microwave (300 MHz - 30,000 MHz) was conducted (A research group composed of 18 units, chaired by our Lab.). We roughly divided the 841 exposed workers into $>200\mu\text{W}/\text{cm}^2$ and $\leq 200\mu\text{W}/\text{cm}^2$ groups, and compared with 471 persons as a control group.

The most pronounced complaints in microwave workers were headache, fatigue, insomnia or somnolence and decrease in memory. They are more frequent occurrence during the first one-two years of employment, less during the 3-5 years, and most frequent during >10 -15 years.

The incidences of systolic pressure $<100\text{mmHg}$ in both microwave groups (25.5% and 22.6%) were significantly higher than control group (15.3%). Changes in ECG showed that the incidences of deep brady-cardia ($<50/\text{min}$) and ST-T downward displacement were significantly higher than control.

Effects on peripheral blood were shown in Table 2.

Table 2 Incidences of leukopenia and thrombocytopenia (%)

Group	Leukocyte		Thrombocyte
	$<5,000/\text{mm}^3$	$>9,000/\text{mm}^3$	$<100,000$
$>200\mu\text{W}/\text{cm}^2$	29.41*	1.96*	26.79*
$<200\mu\text{W}/\text{cm}^2$	18.69	8.7	14.02
Control	21.23	7.2	17.2
* $P<0.05$ vs control			

Goldoni et al (Health Physics, 1990) also reported that hematological examinations at a 2 year interval in the occupationally exposed workers showed a decrease in thrombocyte ($P<0.0001$) and leukocyte ($P<0.01$).

The incidences of lens opacity for pulsed microwave workers (27.31) and control (18.8) showed significantly difference.

3) Health effects of environmental EMFs on youngsters

The Exposure groups (1170 subjects) included kindergarten children, third-year students at secondary schools, college students (radar college) and soldiers. Control groups (689 subjects) were the subjects with the same grade, age, and the same education level as the exposure groups.

All the EMF measurements were carried out by an engineer (blinded for biological technician). An index of non-specific immune function-WBC phagocytosis was examined. The results showed in Table 3.

Table 3 WBC phagocytosis in subjects exposed to MWs (Ratio of phagocytosis index)

$4\mu\text{W}/\text{cm}^2$		$10-15\mu\text{W}/\text{cm}^2$	$13-42\mu\text{W}/\text{cm}^2$
Boys	Girls	Male soldiers	Male college students
123.0*	115.8*	99.3	87.2**
(109/73)	(104/84)	(28/22)	(339/197)
* $P<0.05$ ** $P<0.01$			

Ratio= (average phagocytosis function of exposure group / phagocytosis function of control group) $\times 100$; Figures in parentheses are the number of subjects

In summary, the results showed that chronic exposure to EMFs are associated with a variety of non – specific symptoms, including increased frequency of neuroses, liability of vegetation nervous system, and slight changes in peripheral blood, lens, and non – specific immune function. These effects seem to be similar to human acute reaction to microwave exposure, similar to some animal experiments, and similar to other investigations conducted in some foreign countries, but there exist many uncertainties in assessment of health hazards related to exposure to EMFs. The health hazard develops after overpassing of the adaptation/defense processes of the subjects. However, the existence of health hazardous effects of RF and MW could not be denied.

Animal Experiment

Under certain well controlled conditions of exposure, a variety of behavioral, neurological, reproductive abnormalities, and DNA damage were newly demonstrated.

Evidence for biological effects at SAR threshold of the following values were observed:

■ Changes in behavior	SAR=0.6W/kg
■ Decrease in choline uptake in brain	SAR=0.45-0.75W/kg
■ Changes in brain energy metabolism	SAR=0.1W/kg
■ Changes in hematological and immunology system	SAR=0.5W/kg
■ Chromosome aberration and DNA damage	SAR=1.0-1.2W/kg

For example, the behavior study (Lai et al. Bioelectromagnetics 1994), rats were exposed to PW 2450 MHz with 0.6W/kg for 45min. Retarded learning appeared while performing in a radial-arm maze to obtain food rewards. (a model for investigation memory function in human).

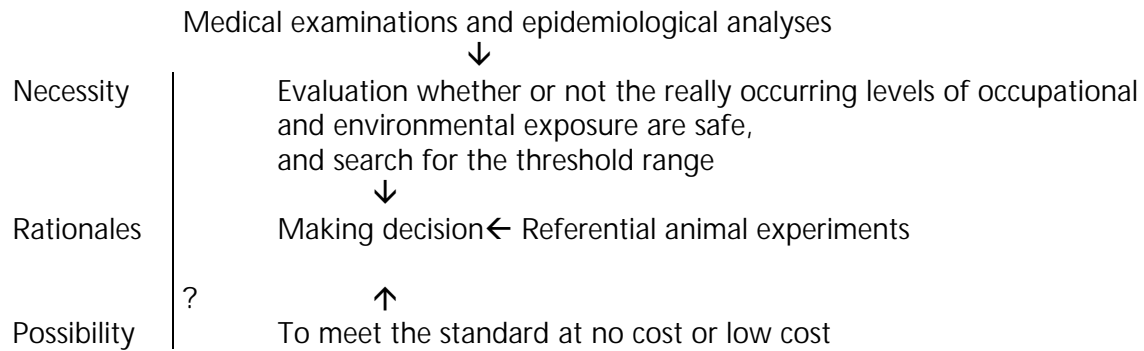
This result confirmed 1989's results, and reconfirmed by the mechanism study: cholinergic and endogenous opioid neurotransmitter systems in the brain are involved in the MW-induced spatial memory deficit.

So, the 4 W/kg threshold SAR need to be revised downward.

Rationales for Establishing RF Exposure Standards

- 1) Assessment of health hazard for setting standards should rely mainly on the health status of personnel exposed to RF EMFs. The results of experimental animals and theoretical calculation should be supplemented to the human exposure data. In this cases, we may evaluate whether the really exposure levels are safe.
- 2) Some investigations on the health effects of occupational and environmental exposure to different frequency band were performed in China. The results showed that the threshold levels for occupational exposure at 0.1 – 30 MHz are in the range of 20 – 100 V/m; at > 30 MHz, in the range of 50 – 200 $\mu\text{W}/\text{cm}^2$.
- 3) Animal experiments. Under certain well controlled conditions of exposure, a variety of behavioral, neurological, reproductive abnormalities, and DNA damage were newly demonstrated. Evidence for biological effects at SAR threshold of about 0.5 – 1.0 W/kg was observed.
- 4) Possibility to meet the standards at no cost or low cost.

It can be expressed as follows:



General public exposure limits to RF in China as an example were shown in Table 4

Table 4 General Public Exposure Limits to RF Radiation in China (Ministry of Health)

Frequency	Exposure limits	
	First class	Second class
0.1-30 MHz	10 V/m	25 V/m
>30-300 MHz	5 V/m	12 V/m
>0.3-300 GHz	10 $\mu\text{W}/\text{cm}^2$	40 $\mu\text{W}/\text{cm}^2$

First class exposure limits: Below these levels are safe for permanent exposure and for all people (including infants, pregnant women, old people, patient, etc.).

Second class exposure limits: Below these levels a temporary dwelling of human subjects is allowed (factories, organs, parks, recreative areas, etc.). However, living quarters, hospitals, schools, kindergartens, etc. are not allowed to be located.

Possibility: Actual exposure for the public is below the exposure standard

Studies (in 3 cities of China) showed approx. 1% of the urban population were exposed to $E > 1\text{V}/\text{m}$ or $2 \mu\text{W}/\text{cm}^2$. Only a very small percentage may be exposed to levels comparable to the limits (in most cases for short time only).

There are only 3 subranges for whole RF in the environment exposure standard-have limits constant over a wide frequency range (not a slope in f).

Reason:

- 1) From practical point of view: complexity of EMFs in environs and easy to perform for inspector
- 2) Many uncertain issues exist in assessment of bioeffects and possible health hazard. We don't know the exact effects.

Summary

The present limited knowledge in assessment of possible health effects related to exposure to EMFs does not provide sufficient rationale for establishing satisfactory and general acceptable exposure limits. Further research is needed. The exposure standard should be amended with progress in Bioelectromagnetics.