CHAPTER 10

Health Risks Due to Artificial Electromagnetic Energy in the Environment

Introduction

In 1873, on the basis of a mathematical analysis, English physicist James Clerk Maxwell concluded that light was a propagating wave composed of electricity and magnetism. Some of Maxwell's contemporaries rejected his theory because it seemed to predict too much—an infinite number of non-light waves, none of which had ever been detected. But other scientists began searching for the invisible waves and in 1888 Heinrich Hertz, a German physicist, succeeded. Using what today would be called a transmitter and a receiver, he proved the existence of electromagnetic waves having a frequency of 30 MHz.

Hertz died in 1894 and Guliermo Marconi, then only twenty, read his obituary in an Italian electrical journal. It seemed to Marconi that Hert zian waves had a vast potential in the field of communications; by 1896 he had repeated Hertz's experiments, but with the receiver more than two miles away, not just on the other side of the room. Many successes followed, leading directly to the development of radio in 1910.

In 1922, while accepting the Medal of Honor of the American Institute of Radio Engineers, Marconi said:

> In some of my tests, I have noticed the effects of reflection and deflection of [electromagnetic] waves by metallic objects miles away. It seems to me that it should be possible to design apparatus by means of which a ship could radiate or project a divergent beam of these rays in any desired direction, which rays, if coming across a metallic object, such as a ship, would be reflected back to a receiver … and thereby immediately reveal the presence and bearing of ships.

Marconi's vision—radar—became a reality in the 1930's, and following World War II many other practical uses for electromagnetic waves were developed.

Paralleling these developments was the birth and growth of the electrical power industry. From a modest beginning in New York City in 1882 under the guidance of Thomas Edison, the industry began the systematic electrification that resulted in a steady increase in power-line construction and in the proliferation of the devices and appliances which they served.

Table 10.1. SOME USES OF EMFS

300,000 MHz	Microwave relay Short-range military communications
30,000 MHz	Commercial satellites Direct-broadcast TV satellites Microwave relay Military communications Air navigation Radar
3000 MHz	UHF television Police and taxi radios Microwave ovens Medical diathermy Radar Weather satellites
300 MHz	FM radio VHF television Police and taxi radios Air navigation Military satellites
30 MHz	International shortwave Air and marine communications Long-range military communications Ham radio CB
3 MHz	AM radio Air and marine communications Ham radio SOS signals
0.3 MHz	Air and marine navigation
0.03 MHz	Time signals Military communications
0.003 MHz	Electric power Military communications Bone stimulation Electric transportation systems
0 MHz	Electric power Batteries Bone stimulation

The passage of electricity from a scientific curiosity to a role of major importance in society (Table 10.1) resulted in a profound alteration in the earth's electromagnetic environment. From the origin of life on earth to the beginning of the twentieth century this environment was determined by the sun and other cosmic sources, and by the geomagnetic properties of the earth itself; the intensity was extremely small even by the standards of today's ultrasensitive instrumentation. But by the beginning of the last half of the twentieth century, man-made EMFs were the overwhelmingly dominant constituent of the earth's electromagnetic environment. With the benefit of hindsight, we can now see that it was dangerous to have made such a drastic alteration in our environment without first studying its potential biological impact. But the fact is that the only immediately obvious effects of electricity are shock and heating, and no experimental study before about 1960 and no theoretical study before about 1970 seriously suggested otherwise. It is therefore not surprising that, from a public health standpoint, the best that can be said of the present artificial EMF levels in the environment in the U.S. is that they do not cause shock or heating. Unfortunately, there may be public health consequences of environmental EMFs that are not obvious and which, therefore, are not protected against by the unofficial U.S. EMF exposure limit of 10,000 $\mu W/cm^2$.

Typical levels of artificial EMFs in the environment, their consequences, and the basis for our conclusion that they may constitute a public health risk are described below.

Levels in the Environment

The artificial EMF environment of the U.S. is a superimposition of contributions from many sources having diverse operating characteristics. They include high- and low-power emitters that can be omnidirectional or directional, and that can operate continuously or intermittently. At high frequencies, the general EMF background consists predominantly of the AM radio band (0.535-1.604 MHz) and the FM and TV band (54-806 MHz). About half the U.S. population is exposed to these sources at levels above 0.005 $\mu W/cm^2$ at any given moment, and about 1% is exposed above 1 $\mu W/cm^2$ (Fig. 10.1) (1). The actual number of people exposed above 1 $\mu W/cm^2$ in any given day, week, or month is considerably greater because of population mobility.

EMFs emanating from the electrical power system (60 Hz in the U.S., 50 Hz in Europe and the U.S.S.R.) constitute most of the artificial low-frequency electromagnetic background. They are extremely pervasive;

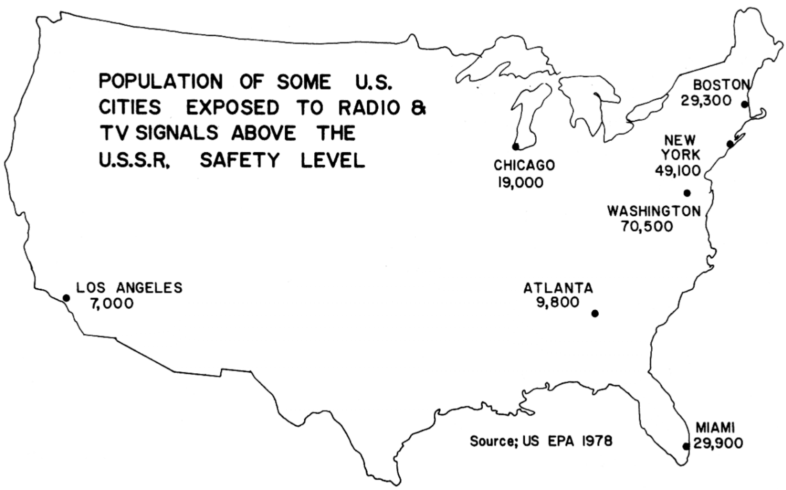

Fig. 10.1. Population of some U.S. cities exposed to radio and TV signals above 1 μW/cm^2 (the level considered safe in the U.S.S.R.). Nationwide, the total population exposed above 1 μW/cm^2 at any given time is about 2 million (1).

except for remote areas such as forests, it is difficult to find places where the electric and magnetic fields are less than 0.1v/m and 100 μgauss respectively. But even these fields are several orders of magnitude greater than the naturally present 60-Hz fields. The average man-made background electric field is probably in the order of 1 v/m (2), and the average background magnetic field is about 800-900 μgauss (3).

EMFs much greater than the background are found in the vicinity of specific sources. The power density at various distances from a typical 50,000-watt AM radio station is shown in table 10.2 (4); within a radius of about 3,280 feet, the level does not decrease below 1 μW/cm^2. FM radio stations vary considerably in strength and antenna design, but it has been estimated that 193 of 2750 such stations in the U.S. could have levels exceeding 1000 μW/cm^2 within 200 feet of the antenna (5). In large urban

Table 10.2. POWER DENSITY AT VARIOUS DISTANCES FROM A 50,000 WATT AM RADIO STATION

DISTANCE (feet)	POWER DENSITY (μW/cm^2)	DISTANCE (feet)	POWER DENSITY (μW/cm^2)
15	838	482	23
29	284	663	12
69	196	1571	2
152	43	3280	1
308	33	5760	0.3

NOTE: Data from ref. 4.

Table 10.3. EMF IN TYPICAL TALL BUILDINGS

CITY	LOCATION	POWER DENSITY ($\mu W/cm^2$)
New York	102nd Floor, Empire State Building	32.5
Miami	38th Floor, One Biscayne Tower	98.6
Chicago	50th Floor, Sears Bldg.	65.9
Houston	47th Floor, 1100 Milam Building	67.4
San Diego	Roof, Home Tower	180.3

NOTE: Data from ref. 12.

areas, the elevation necessary for transmission of radio and TV signals is sometimes attained by mounting the antenna atop a tall building. This produces high EMF levels in nearby buildings (Table 10.3) (12). When radio and TV antennas are grouped, they produce relatively intense EMF levels over broad areas. Mount Wilson, California, for example, has 27 radio and TV antennas serving the Los Angeles area (Fig. 10.2). This produces EMFs of 720-1200 $\mu W/cm^2$ in the backyard of the post office

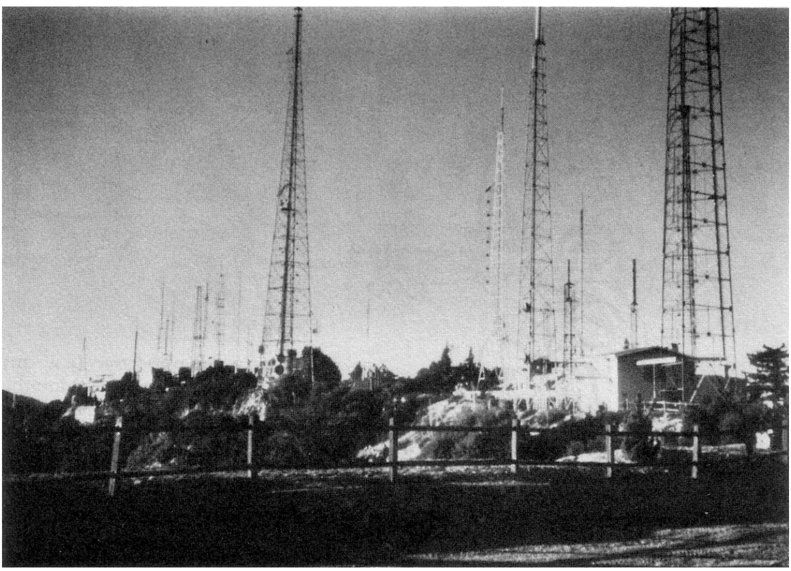

Fig. 10.2. The antenna farm at Mt. Wilson, California. The complex consists of 27 antennas that radiate approximately 10 MW, thereby producing ground-level power den sities of up to 28,000 $\mu W/cm^2$. (Reproduced by permission, from ref. 6.)

on Mount Wilson, and 120-840 μW/cm^2 inside the post office (6). The Sentinel Heights area south of Syracuse, New York, contains about a dozen transmitters and they result in essentially ambient levels of about 1 μW/cm^2 throughout an area of several square miles (7).

The average contribution of high-power radars to the urban EMF environment is low because their beams are directed away from popula tion centers. But, because of stray radiation, exposure levels near airports and military bases can be in the range of 10-100 μW/cm^2 at distances up to one-half mile (8). Airborne radar makes a further contribution to the airport EMF environment.

Microwave-relay antennas, located at intervals of about 20 miles, are used for long-distance telephone service and for private communications. A 10-foot diameter antenna positioned 100 feet above the ground pro duces ground-level EMFs of approximately 0.03-7.5 μW/cm^2 within 376 feet of the tower (9). There are several thousand microwave-relay towers in the U.S., each with two or more antennas.

Mobile communications equipment and hand-held walkie-talkies are relatively low-power sources, but they account for significant exposure levels because the radiating antenna is ordinarily close to the user. Figure 10.3 depicts the power densities in the head area that arise from a typical walkie-talkie (10). Figure 10.4 gives the power densities inside and outside a truck with a roof-mounted antenna (10).

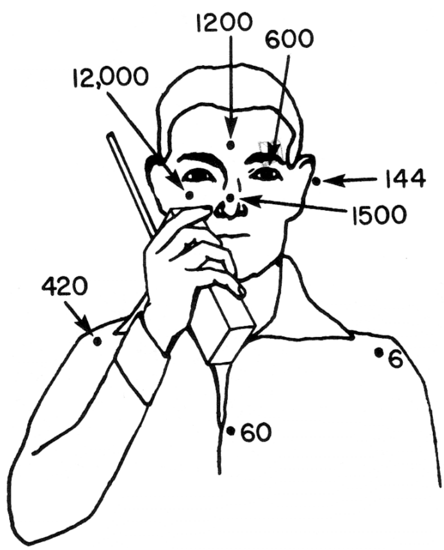

Fig. 10.3. Power density (μW/cm^2) in the area of the head of a Motorola HT-220 walkie-talkie operating at 165.45 MHz with an output of 1.8 W (10). The measurements were made in the near field where the plane wave relation between the electric and magnetic fields does not strictly apply: the listed values are an upper limit for the actual power densities. The same comment ap plies to Figure 10.4.

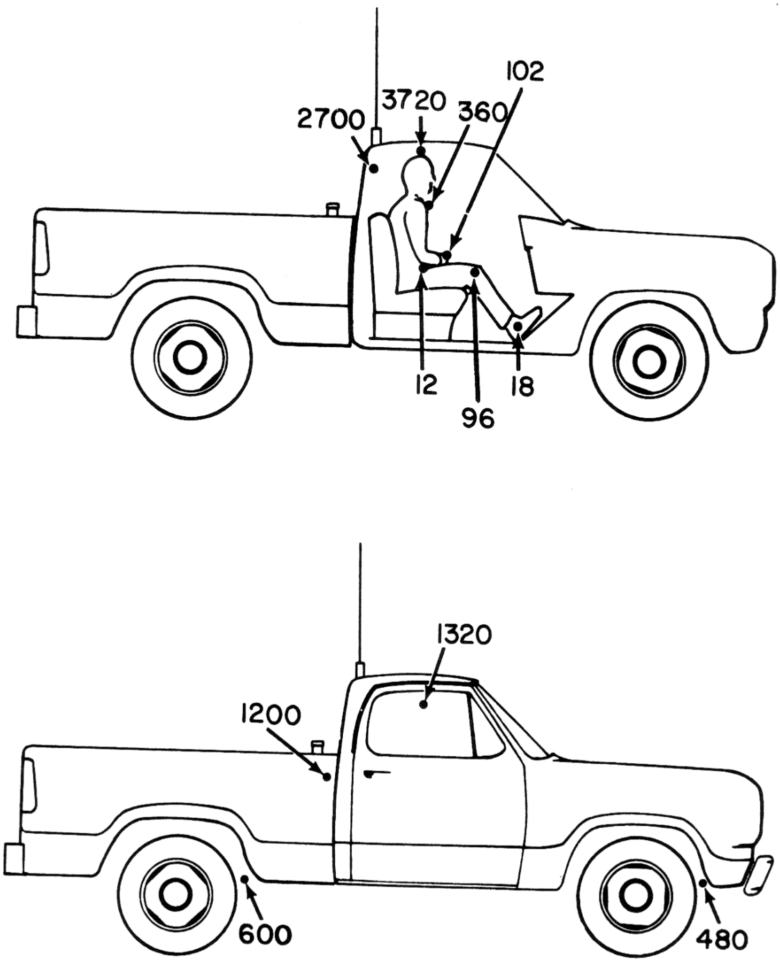

Fig. 10.4. Power density (μW/cm2) inside and outside a truck arising from a roof-mounted 100w transmitter operating at 41.31 MHz (10).

The 60-Hz electric and magnetic fields associated with typical household appliances are listed in tables 10.4 and 10.5 respectively (13). There are about 500,000 miles of high-voltage power lines in the U.S., and they produce fields that depend principally on the line's voltage, current, and geometry. The ground-level electric field at various distances from typical high-voltage power lines is shown in Figure 10.5. Ground-level magnetic

Table 10.4. POWER-FREQUENCY ELECTRIC FIELDS OF HOUSEHOLD APPLIANCES MEASURED AT A DISTANCE OF ONE FOOT

APPLIANCE	ELECTRIC FIELD (v/m)
Electric blanket	250
Broiler	130
Phonograph	90
Refrigerator	60
Food mixer	50
Hairdryer	40
Color TV	30
Vacuum cleaner	16
Electric range	4
Light bulb	2

NOTE: Data from ref. 13.

Table 10.5. POWER-FREQUENCY MAGNETIC FIELDS OF HOUSEHOLD APPLIANCES

RANGE	Appliance
10-25 gauss	Soldering gun Hairdryer
5-10 gauss	Can opener Electric shaver Kitchen range
1-5 gauss	Food mixer TV
0.1-1.0 gauss	Clothes dryer Vacuum cleaner Heating pad
0.01-0.1 gauss	Lamp Electric iron Dishwasher
0.001-0.1 gauss	Refrigerator

NOTE: Data from ref. 13.

fields from high-voltage power lines are generally in the range 0.1-1 gauss within 150 feet of the line.

Low-frequency environmental EMFs are also produced by many other man-made sources. Weapons- and theft-detection systems, for example, produce magnetic fields of 1-2 gauss, 100-10,000 Hz. But not all man-made EMFs are produced by design: it has recently been found, for example, that the starting and stopping of trains in the Bay Area Rapid Transit System in California produced low-frequency EMFs throughout the entire San Francisco Bay Area (11).

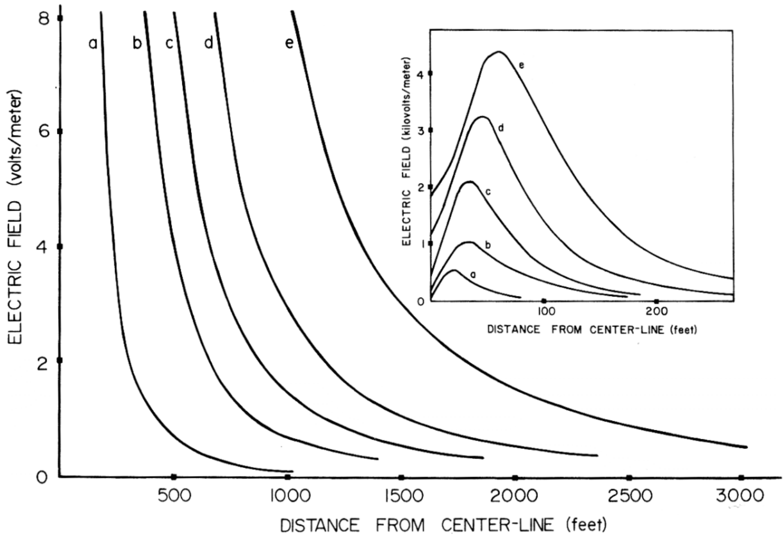

Fig. 10.5. Ground-level electric fields of typical high-voltage power lines. *a*, 115 kv; *b*, 230 kv; *c*, 345 kv; *d*, 500 kv; *e*, 765 kv.

Epidemiological Studies and Surveys

Environmental studies. Suicide is a stress-related phenomenon that may be viewed as a specific manifestation of depressive mental illness. We studied the relationship between suicide and power-frequency field strength (2, 14). We were concerned with how the field strength at the residences of suicides compared with that at appropriately-chosen control addresses. The study group consisted of the 598 suicides that occurred within the study area (in the Midlands of England) during a 7-year period and an equal number of controls. We first examined the relationship between suicide and the computed electric and magnetic fields of nearby high-voltage power lines. We found a statistically significant correlation between both fields and the occurrence of suicide, but we could not determine whether more or less than the expected number of suicides occurred at locations of high field strengths (14). Since the total power-frequency field at any site is due to contributions from many sources—high-voltage lines, low-voltage lines, household wiring and appliances—we then proceeded with a study of measured field strengths. The mean measured magnetic field strength for the suicide group (867 μgauss), was found to be significantly higher than that of the control group (709 μgauss) (2). The proportion of suicide addresses in the high-field-strength region was 40% greater than the proportion of control addresses (Table 10.6).

Table 10.6. PROPORTIONS OF SUICIDE AND CONTROL ADDRESSES FOUND IN REGIONS OF VERY HIGH (1500 μgauss) AND HIGH (1000 μgauss) MEASURED POWER-FREQUENCY MAGNETIC FIELD STRENGTH

GROUP	VERY HIGH FIELD	HIGH FIELD
Suicide addresses	0.158	0.251
Control addresses	0.113	0.180

NOTE: Data from ref. 2.

Wertheimer and Leeper studied the association between childhood cancer (in Denver, Colorado), and living in proximity to power lines. Homes were classified on the basis of their distance to high-current (high magnetic field) and low-current (low magnetic field) line configurations. It was found that the death rate from leukemia, lymphomas and nervous system tumors was about twice the expected rate in high-current homes (15). In a related study (16), which was different in several important respects (17), Fulton et al. failed to find an association between electrical wiring configuration and childhood leukemia in Rhode Island.

In a study involving children exposed to environmental high-frequency EMFs, differences were found in various cardiovascular indices between 100 children (aged 5-14) who lived in areas where the EMF ranged up to 30 v/m, and 70 control children who experienced fields of less than 0.1 v/m (18). The exposed group had faster pulse and respiratory rates, increased blood pressure, and exhibited a slower recovery from a stress test.

These studies, and one other that failed to find an association between living near power lines and visits to a physician (19), are, so far as we have been able to determine, the only epidemiological studies that involve exposure to environmental EMFs.

Occupational exposure. There have been many surveys and studies of the side-effects of EMF exposure in the workplace. At high frequencies, the workers studied have included radar, radio, and TV technicians, and the operators of various specialized industrial equipment. In general, the most frequently found symptoms involved the hematological, cardiovascular, endocrine, and nervous systems of the exposed workers.

In 1970, Glotova and Sadchikova reported the development and clinical course of cardiovascular changes in 105 workers chronically exposed to 30 GHz, 2000-3000 μw/cm^2 (20). They found that the EMF exposure resulted in cardiovascular and autonomic-system alterations, the nature of which varied with the individual. In some persons, there was sinus bradycardia and arterial hypotension without any signs of general or regional hemodynamic disturbances. In others, autonomic-vascular dysfunctions, often with symptoms of hypothalamic insufficiency were found. Subsequently, Sadchikova presented clinical observations on the health status of microwave equipment operators (21). There were three (predominantly male) groups that were matched with respect to age, sex, and job. The first group (1000 persons) was exposed to 2000-3000 $\mu W/cm^2$, the second group (180) to 20-30 $\mu W/cm^2$, and the third group (200) received no exposure. It was found that the first and second groups differed significantly from the controls in frequency of complaints of headache, tiredness, and irritability. Both groups exhibited various cardiovascular changes including bradycardia and abnormalities in blood pressure and ECG. Later studies on 885 radio and electronics workers yielded similar results (22).

In a study of 60 men exposed to 30-GHz EMFs during their working day (normally 10-170 $\mu W/cm^2$, but up to 500 $\mu W/cm^2$) six or seven times per month, bradycardia and a decrease in the pumping efficiency of the heart were found (23). Similar results were reported in 34 persons, aged 30-49 who had been exposed for 5-15 years (24). Various cardiovascular disorders were also seen in a study of 73 men and 27 women that had been occupationally exposed to microwave EMFs (25). Symptoms generally subsided 1-2 weeks after cessation of work around the radiation sources, but in some cases they persisted for more than 2 years. Klimkova studied 162 workers who had been exposed to 3-30 GHz, and reported headache, fatigue, and EEG changes as a consequence of the EMF (26).

Sokolov et al. compared various blood and bone-marrow cell indices of 131 persons (115 males, 16 females)who had been occupationally exposed to high-frequency EMFs, with the corresponding values from 800 clinically healthy persons. Decreased leukocyte counts and an increased red-blood cell formation were observed in the exposed individuals, and the results, which were progressive with increasing exposure, were found to be reversible upon cessation of exposure (27). Hematological disorders have also been reported in several other similar studies (29-32).

Prolonged occupational exposure leads to a stress reaction manifested by changes in corticoid metabolism (33) and in the general endocrine system (28, 34-36).

In a study of gonadal function in workers exposed to microwave EMFs (3.6-10 GHz, 10-100 $\mu W/cm^2$, for an average of 8 years) significant differences between the exposed and control workers were found in the number, motility, and morphology of the spermatozoa. Following cessation of exposure, most subjects showed improvement in the various gonadal indices (37).

In an evaluation of the relationship between mongolism (Down's syndrome) and parental exposure to radiation, it was found that 8.7% of fathers of mongoloid children had contact with radar as compared to 3.3% of control fathers-the difference was statistically significant (38). A later study failed to confirm this higher incidence of paternal radar microwave exposure in fathers of Down's cases (39).

Sadchikova has described three progressively more serious syndromes associated with exposure to high-frequency EMFs (collectively referred to as microwave disease) (21-40).

1. Asthenic: seen in the initial stages of the disease and characterized by vagotonia, arterial hypotension and bradycardia.
2. Astheno-vegetative: more pronounced than asthenic phenomena and the most often observed form. Characterized by excitability of the sympathetic branch of the autonomic nervous system, with vascular instability and hypertension.
3. Hypothalamic: arises with increasing disease pathology. Characterized by the development of paroxysmal states in the form of sympatho-adrenal crises. Frequently leads to ischemic heart disease.

Although the conclusion is hotly contested by industry spokesmen (41, 42), the evidence clearly indicates that exposure to high-frequency EMFs produces various abnormalities in the eye, particularly cataracts. In 1963, in one of the earliest studies of this relationship between EMFs and ocular anomalies, Zaret et al. (43) examined 73 6 workers involved in the maintenance and testing of radars, and 559 control individuals. The ophthalmic examinations included visual acuity tests, slit-lamp examinations, and stereophotography of the lens. They found significant differences between exposed and control groups in the frequency of polar defects and opacities. Subsequent re-evaluations of Zaret et al.'s data reinforced the original conclusions (44,45).

Mejewska (46) studied 200 workers who were exposed to 0.6-10.7 GHz and 200 control individuals: a statistically significant increase in lens opacities in the exposed individuals was found. The severity of the disease increased with the duration of exposure. In another study, which involved 600 workers and an age-matched control group of 300 individuals (47), it was found that exposure to 0.3-300 GHz correlated with an increased incidence of a specific kind of lens opacity. Appleton surveyed military personnel who had been exposed to microwave EMFs and found a trend in older age groups toward a greater incidence of opacities among exposed personnel (48). Odland (49) also studied the relation between exposure to military radars and ocular anomalies. There were 377 exposed individuals and 320 controls: among the exposed workers who had a family history of eye diseases, it was found that the incidence of eye defects was almost twice as great as that among the controls who had such a family history. Among 68 electronics workers and 30 control individuals, it was found that the incidence of lens opacities and retinal lesions were both greater in the exposed group (50, 51). Zydecki studied 1000 exposed workers (mostly between 100-1000 $\mu W/cm^2$) and 1000 controls and found that the number of lenticular opacities was significantly greater in the exposed individuals (52).

Through painstaking analysis of many clinical cases, Zaret has been able to describe a particular lens opacification for which EMFs are the primary etiological factor (the microwave cataract) (53-57). In contrast to other types of cataracts (heredity, metabolic, and senile) which originate in the lens, the microwave cataract originates in the elastic membrane that surrounds the lens (the capsule). Microwave cataracts occur following exposure to either thermal or nonthermal EMFs, and have a latency period of months to years.

The Soviet Union has enacted a high-frequency EMF occupational exposure limit of 10 $\mu W/cm^2$ (58). Since the general public is a much more heterogeneous group than the work force—which does not generally contain the very young or old, or the sick—an additional safety factor of ten was incorporated in choosing a standard for the general environment, which was set at 1 $\mu W/cm^2$ (59).

Personnel working in electrical sub-stations or near high-voltage power lines are exposed to relatively intense power-frequency electric and magnetic fields. In the early 1960's, Soviet scientists conducted several studies of the effects of power-frequency EMFs on exposed workers (60-62) and found a variety of ills including headaches, fatigue, chest pains, and sexual impotence. These studies led to the first (and only) health standards designed to regulate exposure to power-frequency EMFs in the workplace (63) (Table 10.7). Spanish investigators found similar problems among 9 workers (64), but among 11 American service personnel the only finding was a reduced sperm count in 2 workers (65).

Table 10.7. SOVIET OCCUPATIONAL-EXPOSURE SAFETY LEVELS FOR POWER-FREQUENCY ELECTRIC FIELDS

ELECTRIC FIELD INTENSITY (kv/m)	PERMISSIBLE DURATION OF EXPOSURE DURING A 24-HOUR PERIOD (min.)
5	unlimited
10	180
15	90
20	10
25	5

NOTE: Data from ref. 63.

The original Soviet studies have led to an expanded effort to study the health risks of EMF exposure to service personnel (66). Studies in other countries have begun to confirm the early evidence that alterations in gonadal function are associated with workplace exposure. The results of a Swedish study seemed to indicate that fewer children were born to exposed high-voltage workers than to controls, and that the difference increased with the number of years of exposure (72). Later studies showed that 8% of the offspring of exposed workers suffered from birth defects as compared to 3 % of the offspring of the control-group members. In a Canadian study it was found that, prior to commencement of employment, the 56 high-voltage workers studied had fathered approximately equal numbers of male and female offspring, but that in children conceived thereafter, the number of males born was almost six times the number of females (67).

Analysis

As was seen in chapter 1, the ability of electricity to cause tissue heating and shock was well known even before the tum of the century. In the United States these became the only recognized biological effects of electricity. As a consequence, from a side-effects viewpoint, tissue heating and shock were the only hazards guarded against during the development of the electrical power and communications industries. This approach translated into the 10,000-μW rule for permissible exposure which was adopted by the military services and industry (but not by the federal government which pre-empted the right to regulate EMFs and then elected not to establish any environmental or occupational safety levels). In the Soviet Union, however, EMF regulation developed very differently. Soviet investigators reported that electromagnetic energy could affect the central nervous, cardiovascular, and endocrine systems without causing tissue heating or shock. These results led to the adoption of a 10-μW rule for the workplace and a 1-μW rule for the general environment. The Soviets also adopted regulations governing exposure to levels of power-frequency fields considered to be completely safe in the West. The evidence (part four) now shows, overwhelmingly, that the Soviet approach was the correct one. Indeed, no other outcome was possible given both the demonstrated role of intrinsic EMFs in physiological regulation (chapter 2), and the sensitivity of living organisms to natural EMFs (chapter 3).

Since one or more mechanisms of interaction facilitated EMF-induced bioeffects in a laboratory, and since the levels of EMFs studied in the laboratory are omnipresent in the environment, it must be expected that the same or similar mechanisms will facilitate an interaction between environmental EMFs and exposed subjects. It is therefore clear from the laboratory studies that, because nonthermal EMFs are capable of altering physiological functions, chronic exposure to them in the environment can result in some risk to health.

The extent of the risk is, at present, only dimly perceivable. For one thing, most laboratory studies have been relatively short-term efforts that involved exposure to the test system for days or weeks, but rarely longer. Human exposure in the environment is obviously longer-term, and the present laboratory studies can only provide an inkling of the true consequences. Another point is that the laboratory studies have usually involved only one frequency or field in contrast to environmental EMFs which consist of a superimposition of many frequencies and fields, and the possibility of a synergistic interaction in the environment is virtually unexplored.

As we have shown, the biological concept of stress affords the most useful approach to the analysis of bioeffects caused by EMFs. Applied to environmental exposure, the stress hypothesis leads to the conclusion that the disease or effect produced in exposed subjects will depend on the genetic predisposition and previous history of each subject, as well as on the electrical characteristics of the EMF and the conditions of exposure. Thus, epidemiological studies would be expected to show a correlation between environmental EMFs and a broad class of ills, rather than a specific disease, because that is the expected result in an animal population chronically subjected to any stressor. This is precisely what has been found in the epidemiological studies and surveys. Associations have been reported between environmental EMFs and diverse phenomena including cancer, suicide, and cardiovascular function. In the occupational setting, a disease syndrome has been identified in individuals exposed to EMFs that leads to a clinically diagnosable state of biological stress, and to specific effects such as cataracts and, apparently, changes in human reproduction.

What is the appropriate basis upon which to regulate environmental EMFs? Recently, the Public Service Commission of West Virginia in approving construction of a high-voltage power line with no provision for protection of the public from the electric and magnetic fields, reasoned that there were no known biological effects of such fields in people who were regularly exposed to similar fields of other lines (68). This finding, while technically correct, is hardly surprising because there have been *no* studies of the health consequences of such chronically exposed subjects. Under this regulatory approach—known as the dead-body theory—the regulator demands legal evidence of actual harm to exposed subjects. The absence of such evidence—for whatever reason—is construed against the interests of the exposed subjects, usually product users of local landowners. We think that this approach is wrong because it is both unfair and unethical. EMF-producing industries, which have resources to support epidemiological studies but have failed to do so, should not be allowed to shift the onus to the consumer or local landowner who is in no position at all to supply such proof. The dead-body approach, moreover, wrongly presupposes the acceptability of using human beings in an involuntary program of damage assessment of EMF levels known to be biologically active from laboratory studies. Federally-supported investigators in the U.S. cannot lawfully and ethically apply, for example, 10 μW or 500 v/m or 0.5 gauss to human subjects in a laboratory study without *first* follow ing all the rules and safeguards attendant to human experimentation protocols. It seems grossly inconsistent, therefore, for private industrial groups, and others, to do so.

Risk-evaluation is an alternative, and we suggest much superior, approach to the regulation of environmental EMFs. Here the regulatory agency focuses on the laboratory studies and tries to determine their relevance to the particular health-and-safety evaluation at hand, and the degree of risk that may permissibly be imputed to the human-exposure situation. It asks: was the strength and frequency used in the laboratory comparable to that which will be produced by the hardware under consideration? How does the duration of laboratory exposure compare to the normal patterns of human exposure that will occur? What was the test species? (Clearly results from monkeys merit more weight than those obtained from bean plants.) Was the optimum species used for the particular physiological characteristic monitored? (The pig, for example, in studies of skin-healing, or the rabbit for studies of EMF-induced cataracts.) Were there any biophysical factors—the size or shape of the test species, for example—that require consideration in relating the animal tests to human beings? Based on these and other similar factors, and with knowledge of the particular EMF levels that will occur in the environment, the agency is in a reasonable position to fix the risk aspect of its risk/benefit analysis.

The risk-evaluation approach to the regulation of nonthermal environmental EMF was followed in the 1970s, for the first time, by the Bureau of Radiological Health (BRH) in connection with its regulation of emission levels of microwave ovens. BRH set the allowable leakage levels of new ovens at 1000 μW/cm2 (69). The approach was subsequently followed in 1977 by the California Energy Commission (70), and in 1978 by the New York Public Service Commission (71); in both cases rules were drawn to protect the public from exposure to power-frequency fields from high-voltage power lines.

Summary

Man-made EMFs are present in the environment at levels shown by experiment to be capable of affecting biological function. It follows, therefore, that uncontrolled exposure to such EMFs is a potential public-health risk. The regulatory response to the environmental EMF problem has been slow, and the nature of the proof demanded has frequently been inappropriate.

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[1]See footnote 1 in References, chapter 5.

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