DEFENSE INTELLIGENCE AGENCY

BIOLOGICAL EFFECTS OF ELECTROMAGNETIC RADIATION (RADIOWAVES AND MICROWAVES) EURASIAN COMMUNIST COUNTRIES (U)

PREPARED BY U.S. ARMY
MEDICAL INTELLIGENCE AND
INFORMATION AGENCY
OFFICE OF THE SURGEON GENERAL

BIOLOGICAL EFFECTS OF ELECTROMAGNETIC RADIATION (RADIOWAVES AND MICROWAVES) - EURASIAN COMMUNIST COUNTRIES (U)

AUTHORS

Mr. Ronald L. Adams
Dr. R. A. Williams

DST-1810S-074-76

DIA TASK PT-1810-02-75

DATE OF PUBLICATION
March 1976
Information Cut-off Date
10 October 1975

Supersession Notice
This document supersedes ST-CS-01-74-74, dated March 1974

This is a Department of Defense Intelligence Document prepared by the US Army Medical Intelligence and Information Agency and approved by the Directorate for Scientific and Technical Intelligence of the Defense Intelligence Agency.

CLASSIFIED BY DIA-DT
EXEMPT FROM GENERAL DECLASSIFICATION
SCHEDULE OF EXECUTIVE ORDER 11652
EXEMPTION CATEGORY 1,2,3
DECLASSIFIED UPON NOTIFICATION BY THE ORIGINATOR

PREFACE

The purpose of this review is to provide information necessary to assess human vulnerability, protection materials, and methods applicable to military operations. The study provides an insight on the current research capabilities of these countries. Information on trends is presented when feasible and supportable.

The study discusses the biological effects of electromagnetic radiation in the radio- and microwave ranges (up through 300,000 megahertz). It is not within the realm of this study to provide detailed descriptions of every laboratory experiment. Such data have been purposely omitted in favor of an analytical approach. An attempt has been made to identify the principal areas of research and to discuss the significance of experimental results.

The information reported in this study has been drawn from scientific, medical, and military journals, intelligence reports, magazines, news items, books, and other publications. The information cut-off date for this study was 1 October 1975.

(U) Constructive criticism, comments or suggested changes are encouraged, and should be forwarded to the Defense Intelligence Agency (ATTN: DT-1A), Washington, DC 20301.

DST-1810S-074-76
March 1976

TABLE OF CONTENTS

	Page No.
Preface	iii
Summary	vii
SECTION I - INTRODUCTION	1
SECTION II - BIOLOGICAL SIGNIFICANCE OF RADIOWAVES AND MICROWAVES	3
PART 1 - Blood	3
PART 2 - Cardiovascular System	5
PART 3 - Cells	7
PART 4 - Central Nervous System	8
PART 5 - Digestive System	10
PART 6 - Glands	11
PART 7 - Metabolism	12
PART 8 - Reproduction	13
PART 9 - Visual Systems	14
PART 10 - Internal Sound Perception	15
SECTION III - MISCELLANEOUS OBSERVATIONS	17
SECTION IV - DISCUSSION OF RESEARCH METHODOLOGIES	21
SECTION V - SAFETY PRECAUTIONS AND STANDARDS	23
SECTION VI - TRENDS, CONCLUSIONS, AND FORECAST	25
SECTION VII - INFORMATION GAPS	29
Data Handling	31
Distribution List	33

(Reverse Blank)

SUMMARY

(U) The thermal effects of electromagnetic radiation have been reasonably well established through experimental investigation. The nonthermal effects, however, remain a controversial issue between scientists in the West and in the Eurasian Communist countries. The difficulties encountered in conclusively demonstrating the nonthermal effects of electromagnetic exposure are likely responsible for differences in exposure standards; some standards are based largely on the demonstrable thermal effects, while others allow for possible nonthermal effects at subthermal intensities.

(U) The Eurasian Communist countries are actively involved in evaluation of the biological significance of radiowaves and microwaves. Most of the research being conducted involves animals or *in vitro* evaluations, but active programs of a retrospective nature designed to elucidate the effects on humans are also being conducted. The major systems, system components, or processes currently under study include the blood, the cardiovascular system, cells, the central nervous system, the digestive system, the glandular system, metabolic effects, and the reproductive and the visual systems. Other aspects of exposure are also being studied, but the limited number of reports uncovered makes assessment of the importance placed upon this research impossible. These lesser reported research areas include nonthermal effects, immunological studies, and use of radiowaves for functional control of organ systems.

No unusual devices or measures for protection from radiowave exposure were noted, but a continued stress upon personnel protection in occupational situations was apparent. Here, protective goggles and clothing are recommended when working in regions of microwave radiation. Although some differences in standards remain between the various Communist countries and between military and civilian standards, the Communist standards remain much more stringent than those of the West. An exception to this may be Poland where a recent relaxation of their standards has occurred. This is the first significant shift of an East European country away from the standard first set by the USSR in 1958.

If the more advanced nations of the West are strict in the enforcement of stringent exposure standards, there could be unfavorable effects on industrial output and military functions. The Eurasian Communist countries could, on the other hand, give lip service to strict standards, but allow their military to operate without restriction and thereby gain the advantage in electronic warfare techniques and the development of antipersonnel applications.

The potential for the development of a number of antipersonnel applications is suggested by the research published in the USSR, East Europe, and the West. Sounds and possibly even words which appear to be originating intracranially can be induced by signal modulation at very low average-power densities.

Combinations of frequencies and other signal characteristics to produce other neurological effects may be feasible in several years. The possibility of inducing metabolic diseases is also suggested. Animal experiments reported in the open literature have demonstrated the use of low-level microwave signals to produce death by heart seizure or by neurological pathologies resulting from breaching of the blood-brain barrier.

(U) As may be expected, the bulk of the research being done in this area is in the USSR. However, a notable volume is also being produced by Poland, Czechoslovakia, Bulgaria, Rumania, and Hungary.

Western scientists who have followed the Soviet research efforts on the biological effects of microwaves have expressed a variety of reactions ranging from disbelief to passive acceptance. The overall impact of current Soviet work is not overly significant, at least on their civilian sector. One possible exception may be their studies of the central nervous system where some interesting work is being done. Elsewhere, most of their work tends to be outdated, some of their experiments cannot be duplicated, and others are of doubtful credibility. No real new developments or fresh approaches have been identified. Nevertheless, a large volume of material continues to be published on the effects of radiowaves and microwaves on biological systems, indicating a fairly high degree of interest and a genuine desire to pursue these investigations. No significant research and development has been identified that could be related to work in this field in the People's Republic of China, North Korea, and North Vietnam.

DST-1810S-074-76
March 1976

SECTION I

INTRODUCTION

(U) The effects of radiowaves and microwaves on biological systems have traditionally been separated into two basic classifications, (1) thermal effects, and (2) nonthermal effects. The thermal effects are widely recognized and the mechanism of action reasonably well understood. Nonthermal effects, however, are controversial since the mechanisms involved are not clearly understood. Soviet and East European scientists believe that biological side-effects occur at power densities that are too low to produce obvious thermal effects. Such effects have been questioned in the West because experimental evidence, obtained largely in US laboratories, does not corroborate occurrence of nonthermal side-effects.

(U) Divergences in opinion between Bloc and Western researchers concerning the effects of microwave radiation are the result of nonstandardized research protocols and materials. In addition, mechanisms underlying observed biological effects are at present poorly understood by any of the world's scientists engaged in microwave research. The exchange of scientific information on microwave hazards has increased greatly since the active participation of Soviet, Czechoslovak, and Polish scientists in the International Symposium on Biological Effects and Health Hazards of Microwave Radiation in Warsaw in October 1973.

(U) It is now generally agreed that biological systems irradiated with electromagnetic waves in the radiowave and microwave frequency ranges (one kilohertz to more that 10^5 megahertz) absorb varying amounts of energy depending on the irradiation frequencies and the physical properties of the system. Typically, however, 40-50 percent of the incident energy is absorbed by the biological system and the remainder reflected. In reality, only the shorter wavelengths represent any appreciable hazard as a result of thermal heating. Radiation fields in the microwave range vary in wavelength from about one meter to very short wavelengths on the order of a millimeter. The depth of penetration of the waves is also variable and again depends on the frequency, wave polarization, and the physical properties of the system (i.e., dielectric and geometric), but typical penetrations are on the order of 1/10 of the wavelength. Therefore, very short waves are absorbed primarily by the skin, while long wavelengths penetrate to much greater depths.

(U) The degree of heating appears to be a function of the water content of the tissue and probably results from oscillations of water molecules or dipoles. Another possibility is a resonance absorption of energy by protein molecules of the cell. As might be expected, the actual damages resulting from a given exposure are functions of the thermal regulatory

and active adaptation processes of the organ or animal. Less vascularized tissues are more susceptible to thermal damage because of a poorer ability to dissipate the heat, therefore, crystalline lens damage or cataract formation may be observed.

(U) Many techniques and indices have been employed to study the effects of irradiation on biological systems. These include:

Body weight.
Biochemical studies.
Cardiovascular studies.
CNS effects (including conditioned and unconditioned reflexes).
Electrophysiological measurements.
Fertility and mutation studies.
Histology and pathology studies.
Metabolic studies.
Temperature.

While these and other experimental studies have been conducted on animal and cellular models, knowledge regarding human exposure has been almost exclusively obtained retrospectively. Accordingly, information regarding the amount and/or portion of the body exposed, field intensities, and duration of exposure are usually ill defined.

(U) As can be seen from the above, quantitation of the biological responses to electromagnetic exposure is a very complex problem because of the wide frequency spectrum, the large number of physical and biological variables, and the interrelationships of those variables. Factors requiring consideration include the frequency, intensity, waveform, (pulsed, CW, or modulated) configuration of the body, its orientation with respect to the source, portion of the body irradiated, exposure time-intensity factors, environmental conditions (temperature, humidity, and air currents), and shielding. Other complicating factors include the subject's state of health and previous or concomitant medication. In addition to the above factors, the animal species used and its comparative relation to man is important. Accordingly, experimental results from animals cannot easily be extrapolated and assumed to apply to human exposure because of size differences relative to exposure wavelength which can markedly influence the system or organ being damaged.

(U) With these complicating factors in mind, the evaluation contained in this report was undertaken. The data presented were obtained from the sources outlined in the preface and sometimes contained insufficient information to make absolute decisions regarding their significance. The sources were, however, indicative of the types of effects being reported and suggested those areas of research being emphasized, thereby permitting assessment of recent Eurasian Communist attempts to define the biological effects of radiowaves and microwaves.

DST-1810S-074-76
March 1976

SECTION II

BIOLOGICAL SIGNIFICANCE OF RADIOWAVES AND MICROWAVES

PART 1 - BLOOD

(U) Effects of electromagnetic irradiation on the blood include biochemical variations, effects on erythrocytes, changes in coagulation, and alterations in the blood forming system. As would be expected, most communist country reports originate from in vitro or in vivo animal experiments rather than from human data.

(U) Long-term ultrahigh frequency (UHF) exposure in rats reportedly reduced the iron and copper content in both the blood and muscle with a concomitant increase in iron content in the liver. Similar exposure in chicks caused an increase in total proteins and globulins, but decreased the albumin in the plasma. Rats exposed to 0.04 W/cm^2 for 25 days demonstrated similar shifts. In some studies with dogs, irradiation with microwaves significantly decreased the lifetime of erythrocytes, while other studies indicated no changes in the granulocytic system after exposure. In the lymphocytic system, however, mitotic disturbances and changes of nuclear structure occurred. Rabbits exposed to "an electromagnetic field" showed significant increases in the number of monocytes, basophils, and lymphocytes/mm. Although undesirable, these shifts are not significant enough to impair the functional performance of humans. However, they are significant enough to warrant further experimentation. Soviet researchers will emphasize more experiments with animals and they will continue to try and relate these experiments to data on human exposure to microwave environments. They will most likely work toward relating such changes in different species of animals to particular intensities or exposures.

(U) One study involved the observation of several thousand persons working in microwave-irradiated workshops, as well as animal experiments. In the human subjects, three kinds of damage were found:

(1) Lymphocytosis and monocytosis.
(2) Granulocytopenia, monocytosis, and eosinophilia frequently accompanied by absolute lymphocytosis.
(3) Moderate neutrophilia.

The degree of changes in the blood could be correlated with exposure and/or duration of working period. This determination was based on the relative changes as a function of period of employment, which was felt to indicate a cumulative effect of microwaves in the human body. The type and intensity of the exposure was not documented.

DST-1810S-074-76
March 1976

(U) Blood coagulation indices of dogs subjected to high intensity super-high frequency fields were studied at intervals of ten minutes to thirty days after irradiation. Initially the coagulation time was prolonged, but two hours after irradiation it was accelerated as a result of protective compensatory changes in neurohumoral factors. The protective reaction was, however, of short duration; the irradiation-induced prolongation of coagulation time reappeared and the animals' clotting times did not return to normal until at least fifteen days after exposure. Another study showed that long-term exposure to microwaves at a power density of $10mW/cm^2$ decreased the overall activity of butyrylcholinesterase in the blood serum of rats. Under conditions of whole-body exposure, the microwaves did not exert a consistent effect on the enzyme molecule. The decrease in the overall activity of butyrylcholinesterase was correlated with a decrease in its concentration in the blood of the irradiated animals.

(U) The action of microwaves on human erythrocyte permeability to potassium and sodium ions was also investigated. The mechanism of action appears to be an inhibition of active transport and an altered diffusion through the pores in the membrane. The latter may be caused by the influence of UHF energy on the membrane itself or on the hydrated sodium cation and potassium cation. The microwaves either change the membrane structure thereby increasing the passive sodium cation and potassium cation diffusion and reducing the concentration gradient, or somehow block the mechanism of active ion transport.

(U) The question of stability of microwave-induced changes in blood components was addressed in chronic and acute tests using dogs and rabbits. The irradiation was at a frequency of 2375 MHz with a field strength of thirty microwatts per square centimeter. The rabbits were subjected to between one and ten irradiations of sixty minutes duration each, and the dogs were subjected to repeated irradiations over a period of more than a year. The changes in the blood and marrow of rabbits were found to be unstable and to pass after a period of five to ten days. Changes observed in the chronically exposed dogs were more stable, but became normalized over a period of twenty-five days. Investigation of chronic microwave irradiation on the blood-forming system of guinea pigs and rabbits was also reviewed. Both continuous wave (CW) and pulsed microwaves were utilized at an intensity of $3.5\ mW/cm^2$ and a wavelength of 10 cm. Increases in absolute lymphocyte counts in peripheral blood, abnormalities in nuclear structure, and mitosis in the erythroblastic cell series in the bone marrow and in lymphoid cells in lymph nodes and spleen were observed. The changes appeared to be a cumulative result of repeated irradiations and were attributed to nonthermal effects. There is limited evidence to support the belief that these cumulative effects are reversible upon cessation of exposure. It is still not quite clear if similar results could be observed in humans since wide species-variations have been observed by Soviet researchers working with animals.

(U) The primary concern of the present study was with electromagnetic field effects, but numerous reports regarding the effects of constant magnetic fields on the blood system were noted during the review. As with electromagnetic effects, effects on coagulation, biochemical properties, and formed elements were observed.

(U) To summarize the effects of electromagnetic radiation exposure on the blood, the following general changes emerge although conflicting reports are also present:

(1) General decrease in hemoglobin content.
(2) Generally reduced coagulation times.
(3) Decrease in leucocyte count.

These findings are based largely on animal experimentation. While detrimental in themselves, the extent of these changes would not be expected to be great enough to materially affect an individual's performance or general health, especially under stress conditions, where other factors such as physiological protective responses would be far more important.

PART 2 - CARDIOVASCULAR SYSTEM

(U) Heavy emphasis has been placed on investigations involving electromagnetic radiation on the cardiovascular system. Effects on hemodynamics include blood pressure variations and cardiac arrhythmias. Also included are reports of a slowdown of intraventricular and intra-atrial conduction, diffuse cardiac muscular changes, and ventricular extrasystole. As with other effects, animal studies are frequently reported and human reports are typically retrospective in nature. Many of the variations noted on the cardiovascular system result from central nervous system effects.

(U) Several reports concerning human cardiovascular effects from superhigh frequency exposure were reviewed. Functional changes were noted, including a slight increase in the asynchronous contraction phase, a tension period, as well as other data indicative of moderate dystrophic changes of the myocardium accompanied by a disruption of its contractive capacity.

(U) Comparison of a group of engineers and administrative officials who were exposed to microwaves for a period of years and an unexposed control group revealed a significantly higher incidence of coronary disease, hypertension, and disturbances of lipid metabolism among the exposed individuals. Hereditary predisposition to heart disease was approximately the same in both groups, but overt disorders developed much more frequently in the previously exposed group. It was concluded that microwaves may act as a nonspecific factor which, under certain conditions, interferes with adaptation to unfavorable influences. Exposure may, therefore, promote an earlier onset of cardiovascular disease in susceptible individuals.

(U) Hemodynamic indices for thirty men in the 25-40 year age range who had been exposed to UHF exposures for from two to ten years were studied. These men showed a tendency to bradycardia, moderate decrease in the stroke and minute volumes, and a slowing of the rate of blood ejection from the left ventricle. Arterial pressure was essentially normal, but a compensatory constriction of the precapillary bed was noted in response to the decrease in cardiac ejection. There was also an increase in the tone of the large arteries. EKG changes indicated an intensification of vagotonic influences on the heart; possible fluctuations in the potassium-sodium balance were also postulated. In a similar study, it was concluded that hemodynamic changes resulted from disturbances occurring in the structural and functional state of the regulating system.

(U) Morphological changes in experimental mice exposed to short and ultrashort wavelengths were observed. Two series of experiments were conducted using 14.9 MHz and 69.7 MHz waves. In the first series, twelve animals were subjected to single lethal doses of the electromagnetic radiation. Very pronounced vascular dystrophic changes were found throughout the organism. In the second series, 37 mice were given daily 60-minute exposures to nonthermal intensities for five months. Morphological studies of these animals showed slight vascular disorders and compensatory proliferative processes in the internal organs as well as dystrophic changes in brain cells.

(U) In a group of patients suffering from "radio wave disease," cerebral hemodynamic changes were observed. These included reduced intensity of the pulse blood volume and an increase in tonicity of the intra- and extracranial vessels. The changes did not, however, appear to be functional in nature.

Personnel exposed to microwave radiation below thermal levels experience more neurological, cardiovascular, and hemodynamic disturbances than do their unexposed counterparts. Some of the cardiac and circulatory effects attributed to exposure include bradycardia, hypotension, and changes in EKG indices (sinus arrhythmia, extrasystole changes in intraventricular and intra-atrial conduction, diminished amplitude of EKG deflections, etc.).

(U) The cardiovascular effects have always been of primary interest, therefore, it is likely that research in this area will continue. It is not apparent if cardiovascular effects were first observed in animals or in patients suffering from the so-called "radiowave disease." It is probable that further research will more accurately establish hemodynamic variations in both animals and humans. Greater emphasis will be placed on animal studies which will allow for more precise dose-response quantitations.

DST-1810S-074-76
March 1976

PART 3 - CELLS

(U) Histological techniques have been used extensively for evaluating the effects of electromagnetic radiation on cellular systems. Such studies have included in vivo investigations of the cellular effects resulting from whole body irradiation and in vitro studies employing cell cultures.

(U) The most popular cells for study appear to be those of rat or mouse liver. Nonthermal effects on subcellular structures include the formation of binuclear cells and irregular thickening of the nuclear membrane. Invagination of cytoplasm into the nucleus has also been observed, frequently accompanied by breaks in the nuclear membrane. Marked changes in the endoplasmic reticulum and the mitochondria have also been noted. The available data, although still insufficient and inconclusive, seem to indicate that the magnitude of these effects is frequency dependent.

(U) The liver cells of rats exposed for three hours to a 1.625 MHz field showed damage to the protein synthesizing structures. Distinct changes were seen in the nucleoli or ribosome synthesizing apparatus. The ultrastructure of mouse liver cells was investigated after exposure to the same frequency. The mitochondria became swollen and underwent lysis. Some giant mitochondria also appeared. The cellular reactions observed were largely the same as those observed after the action of many other environmental factors.

(U) Phagocytic function has reportedly been increased by exposure to an electromagnetic radiation field and induction of colicin synthesis has been observed in E. coli irradiated with a nonthermal intensity.

(U) In many cases, electromagnetic radiation effects occur at the cellular level, therefore tissue culture techniques provide a well controlled and accurate method for study of those effects. Ultrahigh frequency exposure of cultures of rat fibroblasts, monkey kidney cells, and human embryo fibroblasts led to degeneration of the culture in four to six days. The earliest degeneration occurred in primary cell cultures. Studies are now under way on cell permeability, cell interfaces, cell stimulation, and the electrical characteristics of nerve cells. Other Bloc research will include study of microwave effects on mitosis, cell differentiation, and subcellular deoxidation potentials. The data obtained from these studies of cellular and subcellular responses to electromagnetic stimulation will be highly significant, since they may lead to the eventual understanding of basic mechanisms underlying biological changes which occur during and after microwave radiation.