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

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Releasable Report

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

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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.

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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.

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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.

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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.

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(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 super-high 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.

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.

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PART 4 - CENTRAL NERVOUS SYSTEM

(U) Research on the effects of radiowaves and microwaves on the central nervous system of humans was relatively widespread. A number of reports are discussed in this section, as well as research results regarding central nervous system effects on animal models and isolated nerves.

(U) Subjects exposed to microwave radiation exhibited a variety of neurasthenic disorders against a background of angiodystonia (abnormal changes in tonicity of the blood vessels). The most common subjective complaints were headache, fatigue, perspiring, dizziness, menstrual disorders, irritability, agitation, tension, drowsiness, sleeplessness, depression, anxiety, forgetfulness, and lack of concentration.

(U) Various neurological disorders were investigated by studying the vestibular and visual analyzer functions in persons exposed to radio waves of varying types for various periods. Elevation of the threshold of excitability was also accompanied by a lengthening of the time required for dark adaptation. The magnitude and intensity of the changes tended to increase with length of exposure. Similar studies showed increases in the threshold of olfactory sensitivity. EEG automatic frequency analysis was performed on 80 persons exposed to one meter wavelength radiation and 80 healthy controls. No differences were found between the exposed group and the controls regardless of length of the exposure, intensity of the field, or frequency. Presumably, all of these exposures were of a nonthermal nature. Conversely, thirty-seven persons occupationally exposed to a superhigh frequency microwave field (10 $\mu W/cm^2$) over periods of two to eight years, were studied; symptoms of asthenic and autonomic vascular disturbances, endocrine shifts, and abnormal EEG's were observed in half of the patients. Their reflexes in response to light and sound were weak, distorted, or nonexistent and their skin galvanic reaction to flashing light was abnormally intense and prolonged. Additional data will be required in order to assess the significance of these human studies.

(U) Long-term experiments conducted on rabbits demonstrated that irradiation with intermittent or continuous low intensity microwave fields elicits qualitatively and quantitatively different changes in the EEG. Intermittent radiation had a more pronounced effect on the recovery time. It has also been observed that long-term exposure of humans to microwave radiation results in extremely flattened EEG patterns.

Exposure of rabbits to low levels of microwave radiation resulted in alteration of brain electrical activity, but caused no detectable macroscopic or microscopic histological changes. Examination of the brains of rabbits sacrificed immediately after exposure to 10 centimeter microwaves at power densities of 20 to 30 mW/cm^2 revealed hyperemia of the meninges, distension of superficial vessels, and small extravasations of blood in deeper brain areas. Some, or all of the observed changes, could have been thermal rather than nonthermal effects, since the power density employed in the experiment was powerful enough to have caused a fairly great temperature rise. The effects noted immediately after exposure were apparently reversible, since no changes in the condition of the brain tissue were found in animals sacrificed on the day following exposure.

(U) Study of the rabbit visual cortex after a one minute exposure of the head to 40 $\mu W/cm^2$ at a wavelength of 12.5 cm revealed changes in the frequency of the background activity of 52 percent of visual cortical neurons. Chronic irradiation (two weeks) of rabbits caused the development of a prevalence of slow, irregular biological currents; this was interpreted as evidence of progressive establishment of an inhibitory state in the cortex of the cerebral hemispheres. Normalization of the electrical shifts required up to two months in some cases. Similar studies with rats indicated apparent decrease in cholinesterase activity in the central nervous system.

(U) Histological examination of the cerebral cortex cells from rats exposed to UHF at 5 to 15 $\mu W/cm^2$ revealed the onset of sclerosis and the formation of vacuoles in some of the cells.

(U) Some excellent studies using biopotential recordings were performed to determine the effect of microwaves on the kinetics of nerve impulse conduction. Frog sciatic nerves were irradiated with 12.5 cm wavelength microwaves for one minute and parallel temperature measurements were made. Calculations showed that the absorption of one calorie of microwave energy per gram of material per minute gave a temperature rise of 1.1 degrees C in the experiment. The effects of microwaves and of direct contact heating (from three to nine degrees) on nerve impulse parameters (the rate of excitation conduction (EC) and the biopotential amplitude (BA)) were measured and compared. For thermal effects alone, one degree increased the values of EC and BA about five percent. Changes in EC were characterized by rapid increases as absorption of microwave energy increased, followed by a fairly sharp drop upon switching off the microwave irradiation and normalization within three minutes. These increases in EC values (higher than values obtained by thermal effects alone) were especially pronounced in a study where the samples were heated three and six degrees. In a series where $\Delta t = 9.1$ degrees, EC was lower, although the temperature did not exceed physiological normal limits. Changes in BA

during microwave irradiation were also characterized by a much faster increase, followed by a sharp drop to below the original level after irradiation and essential recovery in three minutes. In a series where the temperature increased to 31°C, the microwave effect at first was the same as the thermal effect; after thirty seconds the BA value was even lower than for the thermal effect alone, possibly due to overlap of ionic currents at such high temperature. This was followed by a substantial drop after irradiation, and very little recovery in three minutes. The differences in results in this series were attributed to different initial conditions of the preparations.

(U) These experiments indicate that microwaves may have a specific effect of a nonthermal nature on EC and BA, causing sharp and reversible changes in these functional parameters of nerve impulse. Further experimentation will be needed before extrapolations of similar functional changes to in vivo conditions, or to humans, are attempted. It is expected that Soviet research on these and other CNS responses will continue during the next five years.

PART 5 - DIGESTIVE SYSTEM

(U) A number of alterations in the function of the gastrointestinal system were observed. Reportedly, exposures of subjects working for long periods of time in the presence of low intensity centimeter and decimeter waves resulted in numerous disorders. These included dyspeptic disorders, edema of the gums, bleeding gums, alteration of the gastric acidity, and a reduction of the tonus and evacuator functions of the stomach.

(U) Numerous animal studies have been conducted on the motor function of the gastrointestinal tract and the secretory function of the stomach. Non-thermal intensities were reportedly used. In general, suppression of the stomach's evacuatory function, with signs of adaptation upon repeated exposure, was found. After partial denervation of the stomach, the opposite occurred. It was concluded that the waves have a dual effect - a mediated action through changes in the function of the CNS and a direct effect on the organ or its local innervation. In general, gastric juices increased and little change in acidity was noted. This work tends to support observations of functional changes in humans and indicates that they may actually result from a CNS interaction. Other animal results are discussed below, but do not relate to the human observations.

(U) The effects of high frequency radiowaves on the content of nucleic acids in the digestive organs of rabbits were studied. The total nucleic acid content and the individual levels of DNA and RNA were assayed in the liver, pancreas, stomach, small intestines, and blood. It was found that the content of nucleic acids in the organs was a function of the power and duration of exposure. Low doses were found to considerably stimulate the nucleic acids, while higher doses reduced their content. Significant shifts in DNA content required very high level exposures. In a similar study on frogs exposed to microwaves (2307 MHz), the highest nucleic acid content was found in the pancreas and the lowest in the stomach. Again, low doses increased the total nucleic acid content while higher doses induced insignificant increases or reductions in their content.

(U) The effects of microwaves (2307 MHz) on radiophosphorus resorption in the stomach, duodenum, ileum, and colon were studied in rabbits. Simultaneously, absorbed radiophosphorus distribution in the liver, lungs, kidney, and spleen was investigated. It was found that rates of radioactive phosphorus resorption by sections of the alimentary canal differ. Under microwave exposure, resorptive activity of the stomach is somewhat decreased, while in the small and large intestines, it is increased. Lower intensity exposure accelerated the intestine resorptive function to a greater extent than large doses of lower frequency waves. Radiophosphorus deposition in the viscera is also a function of the dosage.

PART 6 - GLANDS

(U) Investigations of the effects of radiowaves and microwaves on the glandular system have been concentrated mainly on the adrenal, pituitary, and the thyroid. The glandular effects, however, do not appear to be a high priority area when compared to other systems currently under investigation.

(U) The functional status of the adrenal cortex in shipboard specialists subjected to the effects of a UHF field was reviewed. Thirty-eight men were exposed to the field for periods of 24 to 1800 hours and ketosteroids and oxycorticosteroids (which reflect androgenic function) were monitored. The results indicated that androgenic, glucocorticoid, and mineral corticoid functions of the adrenal gland cortex do not deviate from the normal. Microwave exposure also increased thyroid function in these subjects. The increase was attributed to secondary effects of the radiation and was felt to result from disturbances of the sympathetic nervous system in the hypothalmic region. In guinea pigs, the weight of the adrenal glands increased after continuous exposure at low levels for fourteen days, but decreased in animals exposed to interrupted exposures. Modification of lipid metabolism appears to be the mechanism of action. Similar exposure

using chicks resulted in increased ascorbic acid content in the cytoplasm of the adrenal cortex, but other work has produced conflicting results regarding the effects on the adrenal cortex.

(U) A quantitative assay of the gonadotropic hormones and growth hormones in the pituitary body of rats exposed to microwave radiation indicated that for a certain time after exposure, blocking or inactivation of gonadotropin-releasing agents occurs in the hypothalamus. Both neural-hormonal and pituitary gonadotropic hypofunctional effects resulted from whole-body microwave irradiation.

(U) The general conclusion that can be drawn from various (both animal and human) studies of the anterior pituitary and adrenal cortex is that exposure to radiowaves and microwaves of thermal intensities results in suppression of the hormone producing functions but exposure to nonthermal intensities tends to enhance production.

(U) An increase of the thyroid function indices was found in animals undergoing microwave irradiation for four months at a power density of 5 mW/cm^2. In histological sections of the cylindric epithelium covering the thyroid, follicles were seen and electron microscopy revealed reticulum.

PART 7 - METABOLISM

(U) Electromagnetic radiation exposure has been found to produce disturbances in carbohydrate energy and nitrogen metabolism in the brain, liver, and muscles. It appears that under electromagnetic exposure, macroergic compounds become deficient due to disjunction of the oxidative phosphorylation processes and deranged metabolism of carbohydrates. With respect to nitrogen metabolism, radiation causes an intensification of the ammonia formation processes in the absence of correspondingly more vigorous processes for its elimination.

(U) Exposure of rats to various intensities of electromagnetic fields with a frequency of 48 KHz produced an increase of lactic and pyruvic acids and a decrease in glycogen content in brain tissue. The changes depended on the field intensity and exposure duration and one month after cessation of the exposure the titer of lactic acid in the rat brain had not returned to normal.

(U) The role of metabolic disturbances of the heart in development of functional and structural changes under the influence of low frequency impulse electromagnetic fields was studied. Test animals were rats and it was found that exposure decreased ATP and creatinphosphate by

causing disturbances of the oxidative changes of carbohydrates and divergence of conjugation of oxidation and phosphorylation processes. It was concluded that changes in carbohydrate energy and nitrogen metabolism preceded the inception of structural changes in the myocardium.

(U) While these animal studies indicated an upset of some metabolic pathways, the degree of functional impairment was relatively small and probably not a significant factor. No human metabolic variations were noted and meaningful extension of these animal studies to the human is not possible. Research in this area is likely to remain low key and will be conducted mostly on animals.

PART 8 - REPRODUCTION

(U) The effects of electromagnetic radiation on reproductive systems have been the subject of numerous animal studies. Experiments with female white mice revealed changes in the estrus cycle. During the five-month study, the mice were irradiated twice daily for one hour, using a 10 cm wavelength of low intensity (10 mW/cm^2). Although the average number of normal cycles was unchanged, normal cycle duration increased. Prolonged diestrus and metestrus, along with a shortened estrus period, resulted in a decrease in the reproductive function of the ovaries. A weight loss was found to occur starting at about two weeks, reaching a maximum loss after four months.

(U) The fertility of female white mice was also investigated. The animals, irradiated as above, were mated during proestrus or early estrus with nonirradiated males. Conception in fifty-eight control animals was 94 percent, but only 75 percent in irradiated animals. Long-term non-thermal microwave irradiation of male mice evoked diffuse changes in the testes. Subsequent mating of the animals resulted in reduction in the size of litters.

(U) Microwave radiation at 10 and 50 mW/cm^2 intensity was administered for twenty and fifteen minutes respectively at various stages of the twenty day gestation periods. The progeny showed reduced viability, poor development, and anomalies. Changes in rate of postnatal development and disturbances of higher nervous system activity were also observed.

(U) Female white mice were irradiated twice daily for one hour with 10 cm waves of low intensity (10 mW/cm^2) up to the eighteenth day of pregnancy. There were stillbirths, a significant number of weak newborn, and a general retardation of body weight gain and growth. Other researchers found similar effects in litters from females which had been exposed twice daily for one hour to a 10 cm wavelength at an intensity of 10 mW/cm^2 for five months prior to mating.

(U) Genetic effects of electromagnetic radiation were observed in other studies. Male rats, irradiated with microwaves at 50-55 mW/cm^2, were mated with nonirradiated females. Litters displayed reduced viability and abnormal development, reduced rate of development and nervous disorders.

(U) Although researchers noted a certain degree of specificity in the pathological changes induced by microwave irradiation of mice, they concluded that the pathological processes occurring in male or female animals resulted from different mechanisms of action.

(U) Both sexes of the fruit fly, Drosophila melanogaster, were exposed to microwaves to study the effects of radiation-induced mutation. Group A, exposed for five seconds to 38 MHz, showed an increased frequency of mutation when bred five to nine days after irradiation. The results were not statistically conclusive, however. Group B, exposed for ten minutes to 2375 MHz, showed no effect on frequency of mutations.

(U) A strain of Staphylococcus aureus, known to be resistant to penicillin, was exposed to an electromagnetic field. A mutant was found to be sensitive to penicillin, probably due to a change in lipid content.

(U) In summary, a large amount of research has been done on the reproductive effects of EMR. However, effects on human reproduction, especially on male fertility, have not been demonstrated.

PART 9 - VISUAL SYSTEMS

(U) The role of microwaves in cataract formation and visual damage has been studied extensively in the past and is reasonably well understood. Primary attention in many studies has been directed at the biological effects of superhigh frequency electromagnetic radiation on the crystalline lens of the eye. Biomicroscopic techniques have been used to study cataract development in persons regularly exposed to microwave fields. A four-year study involving 600 workers and 300 controls revealed no significant difference between the two groups. Cataracts were discovered in only one percent of those persons exposed to such radiation; most of these cases resulted from safety violations. Cataracts which occurred were characterized in their early stages by turbidity of the lens and changes in form and color.

(U) In another study, thirty-five workers regularly exposed to microwave fields and having pronounced congenital lenticular cataracts were examined over a one to three year period; the results of their examinations were compared to those of twelve persons with similar cataracts who had no history of exposure to radiation. No progression was noted in any of the exposed individuals; changes were slow and probably attributable solely to natural aging of the lens.

(U) Combined wavelengths over the range of the millimetric spectrum were used in an animal study involving nine rabbits exposed for 35-70 minutes. Although the radiation used was of considerable intensity (120-495 mW/cm^2), no damage occurred in the deeper media of the eye, in particular the lens, during the 2 to 2½ months observation period. However, erosion of the epithelium of the cornea did occur along with damage to the conjunctiva and its vessels. Multiple tiny hemorrhages in the mucosa and submucous tissue were also evident.

(U) The Soviets have reported the occurence of "acute attacks" (sic) of glaucoma (1304 cases) which were correlated with geomagnetic disturbances. Moreover, recurring "acute attacks" came primarily on days when the mean value of the horizontal component of the geomagnetic field varied significantly. The significance of this report is questionable, but it indicates that the Soviets are examining all aspects of magnetic and electromagnetic radiation which might cause changes in vision.

(U) Although a growing body of evidence suggests that the microwave power density required to produce cataracts is incompatible with life, the Soviets will continue to investigate the visual effects of EMR but their effort will be reduced from its previous level.

PART 10 - INTERNAL SOUND PERCEPTION

(U) Perception of modulated microwave signals which seem to be originating intracranially as characteristic sounds is a phenomenon which was first reported in the US open literature more than thirteen years ago. To produce sounds, peak power densities of up to 80 mW/cm^2 may be required, but the average power density usually is 5 $\mu W/cm^2$. The Soviets have studied this phenomenon in order to determine the underlying physiological mechanism(s) and to define the optimum irradiation parameters needed to evoke the response. They found that when the fundamental frequency of the electromagnetic stimulus was raised from 2050 to 2500 MHz, the reaction threshold rose significantly, but at a frequency of 3000 MHz there was no reaction in the auditory centers. The average intensity of electromagnetic radiation required to evoke the response was less than 10 mW/cm^2; it was concluded that the fundamental signal frequency rather than the amount of energy constituted the primary stimulus and that the observed phenomenon was sensory in nature.

(U) The Soviets will continue to investigate the nature of internal sound perception. Their research will include studies on perceptual distortion and other psychophysiological effects. The results of these investigations could have military applications if the Soviets develop methods for disrupting or disturbing human behavior.

SECTION III

MISCELLANEOUS OBSERVATIONS

(U) Most of the reported biological effects from radiowaves and microwaves result from exposure to the higher frequency ranges. Many of the observed physiological changes probably occur as a result of thermal effects arising from the vibration of ions and dipoles of water molecules in tissues; the vibrations are set into motion more efficiently by the shorter wavelength (high frequency) waves. For example, a radiowave of ten centimeters wavelength converts about fifty percent of its energy into heat in this manner, whereas a three-centimeter wave converts nearly ninety-eight percent of its energy into heat. A study of the biological activity of low frequency (seven KHz) impulse electromagnetic radiation of different intensities and durations was done on rats. It was found that the pathological changes were a function of dose; susceptibility to radiation was governed by metabolic processes and morphology and the organs and systems could be classified as to sensitivity in the following order: testicles, liver, kidneys, heart, and central nervous system. Another study indicated that relatively low frequency electromagnetic fields generated sonic and ultrasonic oscillations in living organisms which in turn produced elastic deformations. If the frequency of the source field corresponded to the oscillation frequency of the cells (the resonance frequency most likely), the cells deteriorated as a result of the mechanical resonance.

(U) Clinical studies were done on thirty subjects, aged 25 to 40 years, exposed to industrial ultrahigh frequency centimeter waves at power densities of 10 to 500 mW/cm^2 for periods of time ranging from 4 to 13 years. Subjective complaints included generalized weakness, afternoon and evening apathy, fatigue, headache, sleep disorders, and nonradiating precordial pain suggestive of asthenia or neurasthenia with autonomic dystonia. Electroencephalography revealed periods of absence of alpha wave activity alternating with low R waves, increased frequency of potentials, dysrhythmia, periodic low peak potentials, and reactions to afferent stimuli. Peripheral blood studies revealed lymphocytosis or monocytosis in eight subjects; increased alpha and gamma globulins were found in 18 subjects. Erythrocyte potassium was within the lower limits of normal, while urine potassium was within the upper limits of normal. Adrenal cortex function was evaluated by urine levels of 17-ketosteroids, which were elevated to 22 to 40 mg in 11 subjects; average levels were 20.5 mg. Urine levels of epinephrine and norepinephrine were elevated in some subjects. Thyroid function was evaluated by rate of radioiodine uptake. Average uptake within two hours was 11.3 percent, and in four hours 16.9 percent. The 24 hour uptake did not differ from normal values. Electrocardiography revealed changes in the heart conduction system in six subjects; the $T_{v1}>_{v6}$ syndrome was found in ten

subjects and a U wave was registered in lead V_3 in eight subjects. Hemodynamic and myocardial function parameters were studied by tachooscillography and polysphygmography. Arterial pressure was usually within normal limits, although it was of a labile nature. Bradycardia was present in 14 subjects and decreased minute volume was observed in eight; increased peripheral resistance was found "in a significant number" of subjects. Autonomic-vascular changes and emotional lability and reactivity were attributed to CNS changes and increased pituitary-adrenal gland function. It was also noted that such shifts in neuroendocrine function could lead to circulatory disorders manifested by changes in the hemodynamic indices and electrical activity of the heart.

(U) A second study was done on two groups of workers occupationally exposed in the radio industry. The first group consisted of 100 subjects who had worked for several years under conditions of periodic exposure to microwaves of considerable intensity (up to several mW/cm^2). The second group consisted of 115 subjects who had begun work after the introduction of protective measures and had been exposed to microwave intensity levels approximately the same as those to which the first group was exposed. A control group of 100 subjects not exposed to the action of microwaves was also continuously examined. The study showed adverse effects, primarily on the nervous and cardiovascular systems, in both exposed groups. These effects were more pronounced in the first group. They were manifested by more frequent complaints of asthenic syndrome and vegetative vascular dysfunction.

(U) A lack of standards for measuring power levels represents a problem which probably accounts for conflicting reports regarding the effects of a given frequency and intensity. Other problems with dosimetry and experimental technique also exist. Such differences make comparison of results from one investigator to another, as well as from one country to another, extremely difficult.

(U) Only a few studies involving electromagnetic interaction with the immunological system have been reported. In one, rabbits were employed to study the body immunological reactivity under long-term irradiation. The rabbits were immunized with typhoid antigen and divided into two groups. One group was exposed to waves of 50 and 10 mW/cm^2 intensity for four hours a day over a four-month period. Analysis of the data obtained indicated that chronic exposure to the effects of low intensity high frequency radiowaves can influence the immunoreactive state of the body as evidenced by differences in phagocytic activity of neutrophils, blood serum complement level, and specific antibody titers.

(U) Soviet investigators have conducted studies on the effects of microwave frequencies in combination with ionizing radiation, magnetic fields, drugs, and nonionizing electromagnetic radiation of other wavelengths. Generally, synergistic effects have been observed. Continued work in this area is expected, and possibly new safety standards for these combined effects will be developed.

(U) In summary, this section shows the rather broad front on which Soviet researchers are investigating the biological effects of EMR. It is apparent that their interest covers all body systems which could reasonably be expected to display responses to such radiation. As with Western researchers, they have concentrated their efforts on the higher frequency spectrum which would be expected to produce more thermal responses. However, they also continue to be interested in nonthermal effects, which, by Western standards, they have yet to conclusively demonstrate.

SECTION IV

DISCUSSION OF RESEARCH METHODOLOGIES

The Soviet interest in the nonthermal effects of microwave radiation is evident both from the standards established and the many low intensity irradiation experiments conducted by their researchers.

The results of the research have encouraged the Soviets to investigate methods for exploiting microwaves and radiowaves to produce controllable psychophysiological effects. Laboratory facilities for investigating the combined effects of several microwave frequencies have been established at various institutes. Other research involves examining the pathological effects of UHF radiation from 300 to 3,000 MHz on man. This work supports the view, contested by some non-Soviet authors, that there are nonthermal modes of action. While no specific research results are reported, it appears that on the basis of results obtained the Soviets will not alter their standards. Part of this effort apparently involves development of prophylactic procedures against nonthermal UHF radiation as well as development of therapeutic techniques for those exposed. Beneficial effects of exercise and nutrition in increasing body resistance to radiation have been postulated. Physiotherapy, vitamins, and stimulants are recommended for the treatment of this type of radiation sickness.

Recently, US and other Western scientists have been quite concerned with the vast difference between the two standards. So far, there has been no serious attempt to reconcile or explain these dissimilarities. However, two interesting possibilities presented below may partially explain the lack of agreement:

a. Soviet researchers are using batch exposure techniques. They expose a number of animals in compartmented cages to the same radiation dose. Western experience with batch exposure has shown that such a practice tends to exaggerate or perturb the field. This exaggeration is due to reflected energy and the phenomenon of standing waves. What the exaggeration means in terms of comparison to the exposure of a single animal is that one is likely to be dealing with higher power levels than he realizes. This may, to some extent, explain the different findings at supposedly identical dosage levels.

b. Much of the difference between US and Soviet thermal and nonthermal positions may exist because of a definition problem. The Soviet definition of "thermal" means a measurable increase in body temperature measured rectally.

"Nonthermal" means that no increase in rectal temperature is measurable. Therefore, it appears that if a change or an effect is noted without an increase in rectal temperature it is a nonthermal effect explainable as an energy coupling. This definition does not take into account localized temperature increases which may not be reflected in rectal temperatures.

It has been reported that some European Communist countries have established two standards - one for military and one for the civilian sector. Although the civilian standards are lower, some researchers feel that they are not low enough. Reports also indicate that a number of female workers in industry may have aborted as a result of exposure to microwave radiation ostensibly within the safety standards.

The extent to which microwaves and other nonionizing radiation causes chromosome aberrations is somewhat of a controversial subject as is the question of the reversibility of any possible injury. It has been suggested that studies on the surface properties and perméability of cell membranes could supply some answers to these questions.

SECTION V

SAFETY PRECAUTIONS AND STANDARDS

(U) Safety precautions and standards have been established in both the US and USSR to protect not only persons who are occupationally exposed but also to protect the health of persons living or working near powerful generating or transmitting facilities. Significant differences in these standards exist and appear to be primarily due to different viewpoints on nonthermal effects in the two countries. Both nations' standards take into account the potentially lethal thermal effects resulting from high-intensity exposure, but the biological effects of nonthermal irradiation are not well defined or documented. In addition, some research has indicated the possibility of a cumulative effect on humans, but this is also very poorly defined.

Soviet research has produced guidelines which were used to establish a value of 10 $\mu W/cm^2$ per working day as the maximum admissible value for microwave irradiation. Higher exposures, at values of 0.01 to 0.1 mW/cm^2, are permissible for up to two hours per day or 1 mW/cm^2 for 15 to 20 minutes per day. Protective glasses are required in the latter case. The Czechoslovakian standards for frequencies above 300 MHz allow a maximum of 0.025 mW/cm^2 in the continuous wave mode for eight hour exposures. The standard for pulsed operation for the same exposure period is 0.01 mW/cm^2. In June 1973, Poland revised its exposure safety standards for nonionizing radiation in the frequency range of 0.3 to 300 GHz. The new standard permits unlimited exposure of humans to field intensities of 0.01 mW/cm^2. Eight hours per day exposure is permitted for intensities up to 0.2 mW/cm^2 for fixed fields and 1.0 mW/cm^2 for rotating fields. Exposures of up to 10 mW/cm^2 are permitted for limited periods of time without safety equipment. Exposures greater than 10 mW/cm^2 are prohibited without approved safety equipment. Prior to June 1973, the maximum radiation exposure level for all nonionizing radiation was 0.01 mW/cm^2 for up to eight hours per day, which is the same as the safety standard for the USSR. The 0.1 mW/cm^2 limit remains in effect for 0.1 MHz to 300 MHz, but revised standards for this frequency range are under consideration. The East German maximum permissible exposure to microwaves is 10 mW/cm^2, but neither the exact frequency range or duration for this exposure is specified. By comparison, the United States Standards Institute recommends 10 mW/cm^2 as averaged over any 1/10 hour period. The US Army and Air Force use the following equation to determine permissible exposure time (T_p).

$$T_p = \frac{6000}{W2}$$

where T_p = permissible exposure time in minutes during any one hour period and
W = the power density in the area in mW/cm^2.

Potential problem areas for exposure to excessive electromagnetic radiation which were found in the Communist literature included a wood processing plant, coastal radiotransmitting centers, radio equipment on ships, and flight communications equipment in the crew cabins of aircraft. Open feeder lines were identified as major sources of exposure.

(U) Protective devices described for use in working near unacceptable intensity fields include protective (metal-coated) eye glasses and clothing and shielding of the source with special absorbers or sheet metal or wire mask shields. A small semiconductor indicator instrument used to warn workers of dangerous conditions from electromagnetic fields has been developed. It rings an alarm when the field intensity exceeds the allowable level. An indicator paper for visual determination of the intensity of an electromagnetic field has also been developed. The indicator is prepared by impregnating a filter paper with a thermosensitive chemical compound.

(U) In an animal study, it was reported that oral administration of caffeine in doses of 20 mg per kg lowered the duration of resistance against hyperthermia caused by microwave irradiation. Caffeine did not influence the temperature at which the animals died, but it shortened the time to death. The reason for the lowered resistance of rats to microwaves was attributed to caffeine's exciting effect on the CNS which caused increased metabolic activity and consumption of oxygen. Although caffeine might exert similar effects on the human CNS, any lowering of resistance to hyperthermia would be insignificant; trained personnel working with properly operating, adequately serviced microwave equipment would probably almost never be exposed, even accidentally, to the tremendous radiation intensity required to induce heating of the human body. Nevertheless, monitoring of Soviet research on the action of drugs in combination with microwave radiation should continue, since such studies may eventually result in the detection of nonthermal safety hazards resulting from the mutually potentiating effects of radiation fields and pharmacological compounds.

Should subsequent research result in adoption of the Soviet standard by other countries, industries whose practices are based on less stringent safety regulations could be required to make costly modifications in order to protect workers. Recognition of the .01 mW/cm^2 standard could also limit the applications of new electronic technology by making the commercial exploitation of some products unattractive because of increased costs imposed by the need for additional safeguards.

SECTION VI

TRENDS, CONCLUSIONS, AND FORECAST

(U) A significant amount of research continues to be performed in the Eurasian Communist countries to establish the effects of radiowaves and microwaves on biological systems. It is often difficult to evaluate the reported results, however, because details of the exposure in terms of frequency, duration, and intensity are quite variable, and sometimes poorly reported. This, coupled with problems of measurement encountered in such studies, creates a rather confusing body of data from which to draw objective and absolute conclusions regarding the significance of the research. The Eurasian Communist investigators tend to place greater importance on the potential nonthermal effects than do their counterparts in the West, but information regarding the precise nature of the exposure under consideration is often difficult to establish. A move toward improved statistical analysis of data and standardization of dosimetry can be expected as Eastern Bloc researchers react to criticism of their work by Western scientists.

(U) The types of responses reportedly exhibited by the various biological organs, processes, or functions are in line with what has been reported by Western investigators. Again, most of the responses which are reported can be linked with the thermal action of the radiation. Studies which report on nonthermal effects deal largely with subjective responses, relying on reports of headache, sleepiness, loss of appetite, etc. The presence of nonthermal effects, in addition to thermal effects at higher intensities, has also been postulated by Eurasian Communist investigators, but no detailed investigative support for this possibility was noted. Accordingly, it is difficult to establish whether or not a trend toward this type of research will begin. It is safe to say that research on nonthermal effects at thermal intensities will be exceedingly difficult since another dimension to an already formidable problem will have been added.

No Eurasian Communist research activity has been identified which can be clearly or directly related to any military offensive weapons program. However, Soviet scientists are fully aware of the biological effects of low-level microwave radiation which might have offensive weapons application. Their internal sound perception research has great potential for development into a system for disorienting or disrupting the behavior patterns of military or diplomatic personnel; it could be used equally well as an interrogation tool. The Soviets have also studied the psychophysiological and metabolic changes and the alterations of brain function resulting from exposure to mixed frequencies of electromagnetic radiation. One physiological effect which has been demonstrated is heart seizure. This has been accomplished experimentally in frogs by synchronizing a pulsed ultrahigh

frequency microwave signal of low average-power density with the depolarization of the myocardium and beaming the signal at the thoracic area. A frequency probably could be found which would provide sufficient penetration of the chest wall of humans to accomplish the same effect. Another possibility is alteration of the permeability of the blood-brain barrier. This could allow neurotoxins in the blood to cross. As a result, an individual could develop severe neuropathological symptoms and either die or become seriously impaired neurologically.

The above study is recommended reading material for those consumers who have an interest in the application of microwave energy to weapons. A discussion of weapons is not within the scope of this study.

SECTION VII

INFORMATION GAPS

(U) Little information regarding the effects of relatively low frequency radiowaves was available. These frequencies produce few thermal effects, but although Eurasian Communist research frequently investigates nonthermal effects, few reports of studies at these low frequencies could be found.

(U) A limited amount of information regarding the effects of environmental conditions on susceptibility to damage from radiowave exposure was reviewed. In fact, the few articles available on these factors present conflicting results. In addition, a few reports on the effects of the very complex fields encountered in the near field situation (i.e., very close to the source) were found.

(U) The effects of relatively low level exposure to radiowaves (such as might be encountered by persons living in the vicinity of high powered radio stations) are not well documented. One report suggests a statistical evaluation of the health of persons living in such areas as compared to persons living in areas with a more normal electromagnetic level. This would be a very difficult study to undertake if statistically significant data were to be obtained.

(U) No official safety standards have been identified for Albania, Bulgaria, Hungary, Yugoslavia, and the Asian Communist countries.

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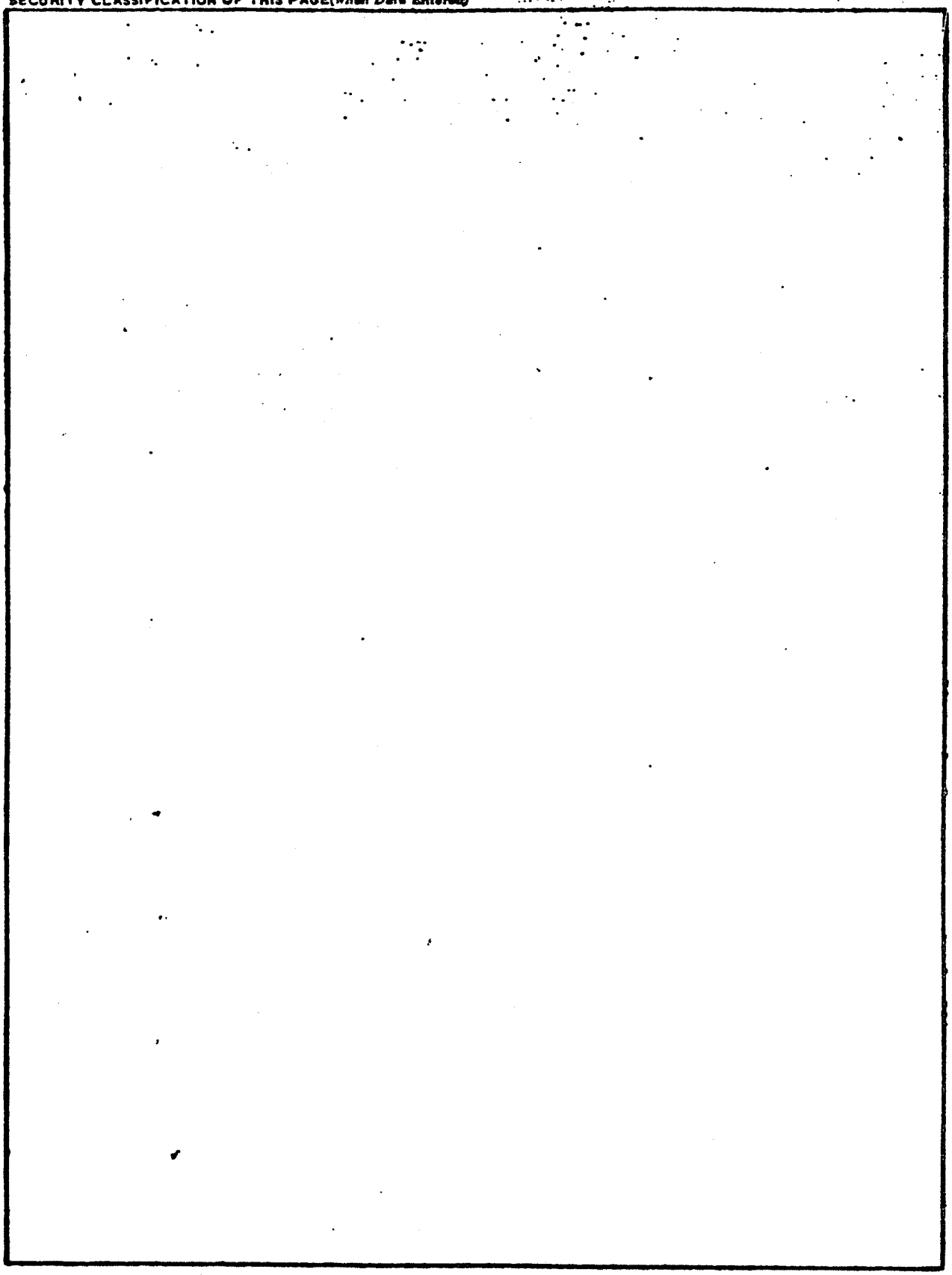
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(U) This study was undertaken to provide a review and evaluation of the current Eurasian Communist country state-of-the-art in the area of the effects of radiowaves and microwaves. It generally covers the 1968-1975 period. The major topics include discussions of the effects on humans and animals. The study provides information on the general trends of research with special attention to possible military applications. Where appropriate, information on safety standards and research personalities and facilities is provided.

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