biologic effects and health hazards of microwave radiation

PROCEEDINGS OF AN INTERNATIONAL SYMPOSIUM
WARSAW, 15–18 OCTOBER 1973

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Biologic Effects and Health Hazards of Microwave Radiation

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Preface

The International Symposium on the Biologic Effects and Health Hazards of Microwave Radiation was held during the four-day period October 15—18, 1973, at a conference center in Jadwisin, near Warsaw, under the joint sponsorship of the Governments of Poland and the United States of America and of the World Health Organization.

The Government of the Polish People's Republic, through the Scientific Council to the Minister of Health and Social Welfare, designated the Institute of Biostructure of the Warsaw Medical Academy to be the collaborating institution; the Government of the United States of America was represented by the Department of Health, Education, and Welfare, Food and Drug Administration, Bureau of Radiological Health, and the World Health Organization was involved through its Environmental Health Programme.

Special assistance in the arrangements for the Symposium was given by Dr. B. D. Blood, International Health Attaché, United States Mission to the International Organizations in Geneva.

The Symposium was the culmination of a two-year exploratory and planning effort to bring together, for the first time, scientists and scientific program directors from the nations known to have research interests in the effects on health of exposure to microwave radiation. This was believed to be important for several reasons: the expanding use of microwave power for an increasing variety of industrial, military, medical, commercial and household purposes; the capacity of microwave radiation to produce demonstrable biologic effects; and the unresolved differences in reported biologic effects and in the exposure and safety standards derived from them.

The objectives of the meeting were: to exchange current information about the biologic and health effects of microwave radiation and recommend further needed research and approaches, to encourage international cooperation in relevant research, to promote the evaluation of scientific information needed for setting safe exposure standards, to consider ways of achieving international dosimetric standardization, and to publish and disseminate the Proceedings.

It was thought that the purposes of the Symposium would best be served by a relatively small group of participants given ample opportunity for formal and informal discussion. Regrettably this excluded participation by many experts connected with research programs concerned with the microwave range of the electromagnetic spectrum (defined for the symposium as 300—300.000 MHz).

Sixty participants from the following countries and from WHO attended: Canada, Czechoslovakia, Denmark, the Federal Republic of Germany, France, the German Democratic Republic, Japan, Poland, Sweden, the Union of Soviet Socialist Republics, the United Kingdom and the United States of America.

Three specialists from Argentina, Czechoslovakia and Israel who were invited to attend the Symposium had to cancel their scheduled participation.

Representatives of several international organizations also attended the Symposium. The participants were scientists and program directors from various institutions, universities, agencies and laboratories concerned with the physical, biomedical and behavioral sciences.

English and Russian were the official languages of the Symposium and a simultaneous

translation service was provided. The many multilingual participants and members of the staff provided translations from French and other languages.

Thirty-nine scientific papers were presented in six sessions: A. General Effects of Microwave Radiation, B. Influence of Microwave Radiation on the Nervous System and Behavior, C. Effects of Microwave Radiation on the Cellular and Molecular Level, D. Measurements of Microwave Radiation, E. Occupational Exposure and Public Health Aspects of Microwave Radiation, and F. Future Research Needs, Conclusions and Recommendations. Abstracts of the papers, prepared in advance by the authors, were translated in Poland and distributed to the participants in English and Russian versions before the start of the Symposium.

The spirit of the Symposium was one of goodwill, enthusiasm and genuine interest in interchange with scientists of other countries. The setting of the meeting and housing of participants in a suburban conference center greatly contributed to the success of the Symposium. For many participants it was their first opportunity to meet investigators known to them only through the literature. On several occasions, impromptu meetings by groups of participants were arranged in the evening or early morning to discuss topics of interest not on the program. It was notable that plans were initiated during the conference for some collaborative work and exchange of information and instrumentation by participants of different scientific persuasions.

The controversial issues that have characterized the field for the past two to three decades relate to: (1) the mechanisms of interaction of microwave radiation with biologic systems, (2) the levels and circumstances of exposure capable of producing biologic effects, and (3) the nature and significance of biologic effects.

Differences in approaches and findings, principally between countries in western Europe and North America and those in eastern Europe, have led to considerable variance in microwave exposure criteria and standards. For example, the usual recommended maximum power density level for occupational exposure in the United States is 10 milliwatts per square centimeter, based mainly on the risk of cataract formation from heating effects, in contrast to the standard for full-time work exposure in the Soviet Union of 10 microwatts per square centimeter, based on low intensity non-thermal biologic effects. It was not the intention of this conference to consider discrepancies in standards and compliance, however, but rather to open the way for scientists to present and discuss studies and interpretations that have been the underpinnings of different safety standards and to propose ways of advancing knowledge and understanding in this relatively new field. While differences could not be fully explored, and certainly not resolved, progress was made in clarifying concurrences, delineating areas of disagreement, and identifying needed research, communication and program development.

The session chairmen prepared summaries of their respective sessions and the rapporteurs prepared summaries of the discussion. The session summaries provide specific suggestions for further work in each of the subject areas. The final recommendations reflect the sense of the Symposium and give emphasis to international considerations and broad questions of research and development. In areas where improved international collaboration is needed to advance knowledge and understanding, emphasis was given to the general ways in which this may be accomplished, to the value of an international program in the field, to the critical need for standardization of measurement techniques and dosimetry, to the importance of universal nomenclature and definitions of physical units, and to the usefulness of operational definitions of microwave intensities for comparable approaches to biologic questions. With regard to further research, the need for multidisciplinary studies of interactions and risks was stressed, especially with respect to cumulative and delayed effects, low intensity effects and possible threshold values.

All of the papers presented at the Symposium were submitted by the authors in manuscript form in advance of the meeting. Necessary reduction in length of manuscripts was accomplished with the help of the authors whenever possible. Because prompt publication of the Proceedings was considered important, time did not permit review of proofs by the authors. The Proceedings are published in English only, and all the papers written in Russian were translated into English in Poland.

The Symposium secretariat served as the editorial board for the Proceedings.

The contributions of many individuals and organizations to the planning, conduct and successful outcome of the symposium are gratefully acknowledged. In particular, we note with appreciation the outstanding administrative arrangements for the symposium made by Mr T. Olejniczakowski and his staff; the support and help of the Coordinating Commision for Polish-American Scientific Collaboration and the American Embassy in Warsaw; and the assistance of the administrative and editorial staff of the sponsoring agencies.

Opening Session

K. OSTROWSKI, B. H. DIETERICH, J. C. VILLFORTH

WELCOME TO PARTICIPANTS ADDRESS ON BEHALF OF THE SCIENTIFIC COUNCIL TO THE MINISTER OF HEALTH AND SOCIAL WELFARE, POLISH PEOPLE'S REPUBLIC

K. Ostrowski

Institute of Biostructure, Medical Academy,
Warsaw, Poland

It is my privilege to open the Symposium on Biologic Effects and Health Hazards of Microwave Radiation. This symposium is sponsored by the World Health Organization, the U.S. Department of Health, Education and Welfare, and the Scientific Council to the Minister of Health and Social Welfare of the Polish People's Republic. It is my great pleasure to greet you all on behalf of the last named body. I would like to acknowledge with thanks the financial assistance of the American co-sponsor. Without this generous help it would have been impossible to organize this meeting.

We are in a very fortunate position to have with us the pioneers in the field of research on microwave bioeffects — Dr. Z.V. Gordon from the USSR and Dr. H.P. Schwan from the USA. The organizers of this meeting tried to invite most experienced workers in this field from all over the world, hoping that this meeting will lead to fruitful discussions and allow conclusions to be drawn for further research and perhaps for medical practice.

May I express my most sincere thanks for their help in organizing this meeting to Drs Charlotte Silverman and M.L. Shore from the U.S. Department of Health, Education and Welfare, B. Waldeskog from WHO Headquarters in Geneva and M.J. Suess from the WHO Regional Office for Europe in Copenhagen, as well as to Dr. B. D. Blood, the U.S. International Health Attaché in Geneva, who was not able to attend this meeting.

Special thanks are due to Dr. P. Czerski, one of the leading research workers in the microwave bioeffects field in this country. Most of you know him from scientific contacts, but all of you will remember his activities as the scientific secretary of this Symposium.

As this meeting starts two weeks after the beginning of the new academic year in Poland, may I be allowed to use for the opening of this symposium the time — honored formula, used for centuries at our universities: "ul felix, faustum fortunatumque sit!".

WHO CONCERN AND ACTIVITIES RELATED TO HEALTH IMPLICATIONS OF MICROWAVE RADIATION

B. H. Dieterich

Division of Environmental Health, World Health Organization, Geneva

It gives me great pleasure to welcome you to this International Symposium on Biologic Effects and Health Hazards of Microwave Radiation which is jointly sponsored by the Scientific Council to the Minister of Health and Social Welfare of the Polish People's Republic, the Department of Health, Education, and Welfare, USA and the World Health Organization. I should like to convey to you the greetings of Dr. Mahler, the Director-General of WHO, and of Dr. Kaprio, the Director of WHO's Regional Office for Europe.

Before coming to the specific subject of this Symposium, I should like to emphasize the importance which WHO is giving to protecting human health from adverse influences resulting from conditions in the environment. Human environment has become lately of concern to governments and people all over the world, and great efforts are being made to understand more clearly, and if possible quantify, the relationship between the environment and man. Large programmes have been initiated in many countries and large amounts of money are being invested in controlling environmental pollution and in protecting and promoting human health by means of environmental control.

As WHO has noted in its Fifth General Programme of Work for the period 1973—77, man has always had to face the problems of his physical environment but — at the beginning of the century — these problems underwent rapid changes. As the progress of science and technology has provided man with the possibilities of more rational approaches and more effective tools to conquer nature, he has attempted to create certain control mechanisms in order to adapt himself to the changing situation. In the contemporary world he has been faced with greater challenges than ever before. Old environmental hazards still prevail in many parts of the world hampering basic health progress in the developing countries in both their rural and urban areas. New problems, however, have emerged that need increasing attention by WHO The air in urban and industrialized areas is being heavily polluted by automobiles, aeroplanes, power generators, heating equipment, and refuse incinerators. The microclimates produced are being further impaired by thermal inversion and photochemical changes induced by solar energy. Rivers are being polluted not only by an increasing variety and amount of inorganic, synthetic, organic and radioactive compounds in industrial wastes, but also by chemicals used in agriculture and by domestic detergents. Oceans have not been spared either and the poisoning of aquatic life together with the export of seafood have created health problems even in the parts of the globe far away from the site of pollution.

Adverse environmental influences include also physical and social stresses associated in some countries with rapidly increasing urbanization and industrialization, such as crowding, slums, noise, behavioral disorders and accidents. Man at work has been faced with occupational hazards in industrial plants, as well as in small-scale rural industries, particularly in those countries which have not yet been able to develop adequate occupational health services suitably equipped and staffed with health personnel. Therefore environmental problems nowadays must be attacked on a much broader front.

Within this framework, this Symposium has been organized to bring together available knowledge on the biological effects and health hazards of microwave radiation. For

the last five years WHO has been concerned about the health implications of the growing use of devices producing non-ionizing radiation, and particularly microwave radiation. In view of the potential magnitude and significance of environmental pollution from microwaves there appears to be a need for national and international public health programmes concerned with the evaluation and control of human exposure to microwave radiation — programmes that will reflect the rapid technical development of devices emitting such radiation. There is a pressing need for internationally agreed criteria and standards of exposure on which to base any control programme. Many questions still remain to be answered before such an agreement can be reached. These include more research on the effects of microwave radiation on human health and the development of techniques and instrumentation for the determination of the exposure and dosimetric parameters to achieve quantitative research. The review and evaluation of existing knowledge made by this Symposium will aid WHO in suggesting priorities and reviewing the long-term programme on microwave radiation. Also, it is expected that identification of the researchers and organizations involved in the study of microwave radiation and the promotion of contacts between them during this Symposium will improve the necessary exchange of information on research in this field.

We are, therefore, looking at this Symposium as a step forward in this joint effort undertaken by the scientists in various countries and WHO to bring together scientific achievements in different parts of the world and to establish on this basis recommendations to respective governments which should ultimately lead to the control of potential hazards from radiation.

I hope that this Symposium will make in important contribution in the field of science and will promote further cooperation between the participants and WHO.

I wish you success in the task ahead of you.

U. S. PUBLIC HEALTH SERVICE CONCERN AND ACTIVITIES RELATED TO HEALTH IMPLICATIONS OF MICROWAVE RADIATION

J. C. Villforth

Bureau of Radiological Health, Food and Drug Administration, U.S. Department of Health, Education, and Welfare

The population is being exposed to a rapidly increasing number of devices which emit potentially hazardous radio frequency (RF) and microwave radiation. The availability of these devices in consumer, medical und industrial applications is increasing. The biological effects of low-level microwave exposure are not well documented or understood. The state-of-the-art in manufacturing processes to develop new and improved RF and microwave devices has far exceeded the developmental aspects of radiation detection instruments necessary to measure these frequencies of radiation and the biological research efforts to determine the potential somatic or genetic risks from these devices.

As a result of these and other concerns, the Radiation Control for Health and Safety Act was passed in 1968, and the primary responsibility for administering this Act was delegated to the Bureau of Radiological Health in the U. S. Public Health Service. The Act requires the Bureau to conduct research into the health effects from electronic products radiation (including microwaves) and to establish and enforce standards of

performance for electronic products that will assure that the public health and safety are protected.

The concerns for protection from microwave radiation have also been manifest in the functions of two other federal agencies in the USA. The Environmental Protection Agency, established in 1971, is concerned with the effects of the general population exposed to environmental hazards, including microwaves from such sources as radar sites and communication systems. Although the EPA does not have specific authority to establish regulatory standards for these sources, it has general authority to develop guides and recommendations.

The third federal agency is the Occupational Safety and Health Administration of the U. S. Department of Labor. This Administration is charged with the protection of the workers from occupational insults, including microwaves. They have under consideration occupational exposure limits for the working environment. This organization is not, presently, conducting research in the biological effects of radiation.

Although it is the intent of this Symposium to keep within the area of biological effects and health hazards of microwaves, I feel it would be of interest to mention some of the activities of the Bureau of Radiological Health related to microwave radiation.

Within the broad microwave frequency band the most immediate public health problem in the United States was that associated with microwave ovens; therefore, a high priority was given to the assessment of the potential hazard of this microwave emitter which was designed to be used in the domestic and institutional preparation of food. Initially there were no commercially available instruments which could be utilized to quantitate the energy in the specific frequencies used by microwave cooking ovens. Efforts to remedy this deficiency were carried out in our laboratories as well as under contract with other Federal agencies and commercial establishments. Existing engineering as well as biological laboratories of the Bureau had to be remodeled to permit work on this new problem. The Bureau began instrumentation development for microwave research, concentrating on 2450 MHz — the frequency most commonly used in ovens. Instrumentation was essential for both radiation characterization and biological research activities. An anechoic chamber was designed and constructed to provide for near and far field 2450 MHz exposures. Instruments were designed, fabricated and tested to monitor radiation in the chamber. Special field survey instruments were also constructed. Most of the bioeffects work conducted by the Bureau has been restricted to this frequency for which instrumentation is now available.

Simultaneously with developmental work on measurement and dosimetry capabilities, the Bureau commenced a laboratory investigation to assess the performance parameters of microwave cooking ovens and to determine the engineering variabilities which affected radiation emissions. Product evaluation in the laboratory was paralleled by field investigations and manufacturing plant visits.

The Bureau's biological and engineering specialists established the need for a standard, defined the permissible leakage levels associated with it and made the essential determination of feasibility. All existing knowledge was evaluated to provide a sound scientific basis for the microwave standard. This basis was successfully defended against the scientific arguments which were developed primarily by the affected industry. The Bureau published the microwave oven performance standard in the Federal Register on October 6, 1970. The standard became effective in October of 1971. The scientific basis for the microwave oven performance standard has been recognized as a significant achievement in support of the general product safety activities of the United States; however, the emission limit of 1 mW/cm^2 measured at 5 cm from the surface of a new oven is for a single product (cooking oven) which operate at two specific frequencies

(915 and 2415 MHz) and should not be confused with occupational exposure standards used in the USA and other countries.

The Bureau is concentrating on its enforcement activities in support of the microwave oven standard. These activities include continued efforts in the laboratory compliance and endurance testing programs as well as continuous review and evaluation of manufacturers' certification and testing programs. This latter function will consist of both administrative evaluation of submitted reports as well as site inspections of testing and quality control programs at the point of manufacture.

The second part of the program is the complementary biological research in the RF microwave area. The following biological research areas are being pursued:

Epidemiologic studies. Evidence pointing towards a correlation between fathers working at radar installations and the incidence of mongolism in their progeny has been examined.

The study is not complete, but preliminary indications are that the original correlation may not be supported. An epidemiologic study is under consideration to determine if cataracts or other lens opacities are associated with the therapeutic application of microwave diathermy in medical and dental practice.

Pathologic studies. Investigations are under way on both the direct and secondary ocular effects of microwave exposure. Rabbits and a genetically-determined cataractogenic strain of mice are being used as test animals. The mouse strain is being utilized in studies of effects of chronic, low-level exposures.

Research in microwave teratogenesis is under way with positive results at high doses. Research with the fetus has also revealed some marked and persistent effects on the bone marrow. Therefore, hematological observations are also being made. Studies of rodent testes are aimed to provide comparisons between effects of different sources of heat, including microwaves, infrared and conducted heat. Suggestive evidence has also been obtained to indicate persistent testicular effects in mice which received chronic low-level exposure averaging about 6 mW/cm^2.

Metabolic studies. Research is directed toward the biochemistry of the central nervous system, and of fetal development. Microwave induced changes being examined include total protein and myelin content of brain. Some specific molecular species changes, such as changes in absorption spectra of irradiated albumin in both *in vitro* and fetal blood systems, require additional study.

Neurophysiologic studies. Baseline observations of normal behavior in tasks involving learning, memory, alertness and arousal continue, and dose-response curves relating absorbed microwave power and performance will be compiled. Data obtained up to now suggest that some of the microwave effects have their origins in neurochemical processes. Techniques to measure neurochemical transmitters are being developed.

Genetic studies. More informative procedures for survival assays have been identified so that the killing efficiency of microwave irradiation of cells in culture can be determined. Techniques have been developed to examine lethality from the absorption of energy by water in comparison with possible effects that may have been masked by absorption. In addition studies have been initiated to measure the effects of microwave irradiation on genetically determined temperature-sensitive enzyme systems. These enzymes may be useful in further studies of effects of protracted exposures.

Dosimetric studies. Laboratory experience with animal irradiation has led to the development of a controlled environment semi-automated waveguide irradiation apparatus for which integral dose rates and absorbed doses can be determined for each exposed biological specimen. Currently being developed is a laboratory for determining

the distribution of absorbed dose in biological specimens and in anatomically realistic phantoms of animals.

The technical problems encountered by the Bureau in its investigations of microwave ovens, specifically the lack of nearfield measurement devices for 915 and 2450 MHz, is indicative of the general hardware problem associated with all non-ionizing radiation investigations. The manufacturing industry utilization of recent technical developments to produce electronic products for consumer, medical, industrial, and educational applications, has not been matched at all times by a concern for radiation safety. The net result of this situation is that the Bureau, in many cases, is forced into a research and development activity in order to produce the necessary product evaluation information from which dosimetry systems can be developed in order to assess the present or potential deleterious biological effects from exposures to these radiations.

Although the Bureau has promulgated a performance standard for microwave ovens, a great deal of research is required to assess the differences of opinion related to low-level exposures to microwaves. We have only scratched the surface in developing a biological effects program with respect to microwaves, and it should be noted that even this minimal effort is only being directed at the frequency (2450 MHz) which is utilized for microwave cooking ovens and for which instrumentation is available.

Contents

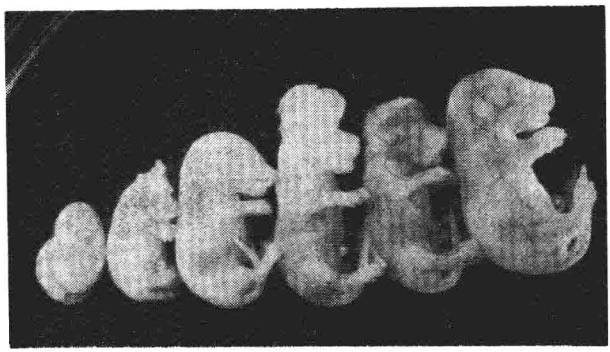

Fig. 5. Variety of anomalies obtained from various litters which had been exposed to microwave radiation. From left to right: Dead fetus still attached to placenta. Dead fetus with almost anencephaly. Apparently normal but stunted fetus. Normal sized fetus but with pronounced exencephaly. Ice-pack type exencephaly, with circulatory stasis. Apparently normal fetus with circulatory stasis.

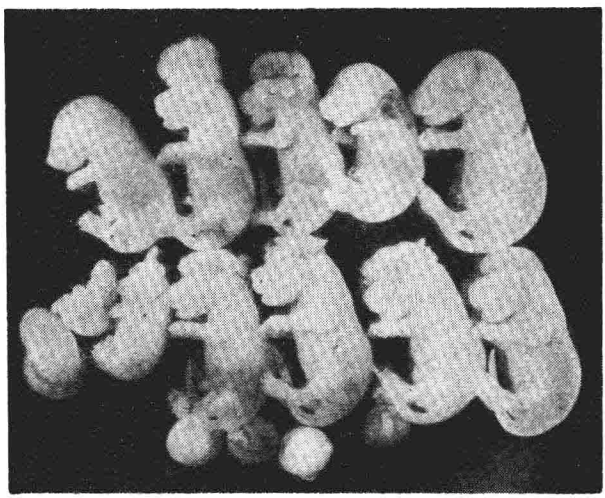

Fig. 6. Anomalies produced by microwave irradiation of CF_1 mice on their eighth day of pregnancy, showing: Resorptions (three examples). Dead fetuses (three examples), lower left. Exencephalies of various degrees (six). Stunting — (two examples); apparently normal topographically. Normal (one example) upper right.

prevent direct comparison of the data in Figure 3 with the radiation absorbed by the pregnant mice. However, we concluded that the doses to pregnant mice were moderately to severely stressful.

Figure 4 shows total observed anomalies among fetuses exposed to microwave radiation. Each point refers to the proportion of anomalous fetuses observed in each dissected litter, and is expressed as a percent of the total number per litter. Resorptions, dead, stunted, and malformed fetuses were scored as anomalous. Examples of these types of anomalous fetuses are shown in Figures 5 and 6. Such effects are distinct from immediate effects of microwave radiation on the fetus. Figure 7 shows two

Fig. 7. Appearance of two mouse fetuses at day 15 of gestation after microwave irradiation of the mother. Fetuses were removed within 5 minutes after cessation of exposure to acute sublethal dose. Note hematomas throughout the body, and particularly in the head region.

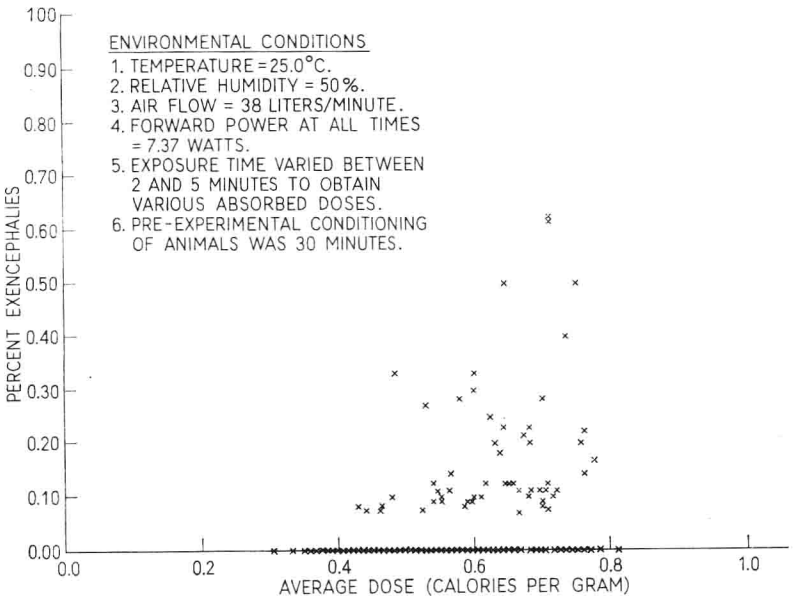

Fig. 8. Incidence of exencephaly in litters exposed to various average doses of microwave radiation. Each point represents the exencephaly in individual litter. Environmental exposure conditions were as indicated on the graph.

fetuses removed at day 15 of gestation, after irradiation at 7.37 watts of forward power (which corresponds to 123 mW/cm²) for less than 5 minutes. The predominant feature is the hematomas, both throughout the body and particularly in the brain region.

Anomalous fetuses were observed through the range of average doses used in the study. Normal litters were also observed almost throughout the same range. However, the number of litters without anomalous fetuses decreased as the average dose increased. The decrease in normal litters suggests the possibility of a dose-effect relationship. However, the available data are too limited and too divergent to establish the relationship conclusively.

Above 4.2 cal/g, exencephalies were observed as shown in Figure 8. Exencephaly