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ANALYSIS OF HEATING CHARACTISTICS OF ANIMALS EXPOSED TO MICROWAVES

Y.RATNA KUMAR, PROF. G.S.N. RAJU

Abstract--- **The whole body for differing animals like rat, dog, Rabbit were exposed at different microwave field intensities. At increasing body temperatures in these animals, cooling reaches a maximum limit, and beyond this undergoes a failure presumably primarily due to a central failure of the respiratory mechanism. Also metabolism is increased under these conditions, partly because of specific temperature dependence, and partly because of an increased respiratory effort. The data presented in tables at the lower rates the three animal species were roughly the same. At higher temperatures, a change is observed with a few of rats and rabbits whereas with the dogs actually retained to the abscissa where body temperature was maintained at the elevated level above the metabolism.**

Index Terms--- **animals, microwave field intensities, cooling**

I. INTRODUCTION

When the animals are exposed to microwave radiation, distinct effects of heating are observed. The microwave radiation, consisting of time varying electromagnetic fields, is generated from a number of sources. For example, they are radar, microwave diathermy and communication transmitters , etc. In general the whole body is affected by radiation. However the lens of the eyes and testis are found to be more sensitive and some studies on them are reported by Clark [1], Schwan [2] and others. This is due to physical location relative to the body surface, their poor ability to dissipate heat, the body can tolerate the moderate increase in temperature. But it has limited ability to lose heat through convection, radiation, evaporation to the surroundings. The lens tolerates relatively high temperatures and the eye is completely a vascular in the lens and vitreous and hence living conduction through humors essentially is the only route of heat loss. On the other hand, the testis is extremely sensitive to the change in temperature. Take-in the views of Clark [3], it is possible to assume that the effect of microwave radiation on biological material is the production of heat. In fact, the heating rate is proportional to the field intensity and independent of time or temperature. Heating rate depends on the dielectric characteristics. When the temperature is increased, the body undergoes physiological changes. The cooling time constant is found out from the cooling curve using a log-linear paper. Most of the studies are focused to determine the field under steady state conditions in order to maintain a specified temperature raise. It is possible to control the field intensity by different methods. When the temperature variation is small with respect to total temperature rise, the cycle time is smaller than the time constant of cooling. Hence, the field intensity is an estimated from time average field. Flanks of rats, rabbits and dogs were exposed to 10cm microwave field in order to study the heating and cooling characteristics, and the whole body heating was observed [4].The increased use of microwave diathermy and of high field strength radar installations makes it desirable to investigate some of the physiological effects of this form of energy. The structures most likely to be damaged, appear to be the body as a whole, the lens of the eye, and the testis. They have already been subjected to some study, and have been mentioned.

A review of studies into the biological effects of microwave indicates that many of the investigations suffer from inadequacies of either technical facilities or energy measurement skills or insufficient control of the biological specimens and the criteria for biological change [5]. Most of the biological data are explained by thermal energy conversion, almost exclusively as enthalpic energy (heating) phenomena. The non-uniform, largely unpredictable distribution of energy absorption may give rise to temperature increases and rates of heating that can result in unique biological effects. The non-uniform pattern of microwave absorption, with differing rates of temperature rise of absorption sites, results in a pattern of heating which cannot be replicated with radiant, convected, or conducted heat.

Low level microwave irradiation alters the heart rate of humans and animals. One such study, 16 rabbits was exposed to dorsal irradiation of the head by 2.4GHz. The power density of $10mw/cm^2$ for 20min.is observed and there is no significant difference between the heart rate during or after irradiation and the heart rate of the same animals during a control condition in which they were not irradiated [6].

A specially designed apparatus that restricted the body movement of rats, but permitted simultaneous exposure and monitoring of performances was unemployed. Measures of incident and absorbed energy were made in an effort to determine levels that disrupt that the operant behavior. Patterns of thermalized energy of rat carcasses exposed to 918MHz CW radiation in the near zone have been determined using a computerized thermograph [7].The deleterious effect upon animals exposed to intense microwave radiation was made and definite damage to the eye and to the testicle was found. The effects of microwave exposure on neuroendocrine systems are being investigated with renewed interest. More precise and better controlled experiments are being conducted to confirm previously reported biological effects (8, 9). However, the complexity of the functional organization of neuroendocrine systems has made isolation of the site or sites of action of microwaves very difficult. The Hypothal Amichypophysial-Thyroid axis is the neuroendocrine system primarily responsible for control of metabolic rate. Figure 3.1 shows the components of this system, the hormonal products which each produces and the direct and feedback pathways which provide its organization and control. Prausnitz et al carried out to determine pathological and longevity effects caused by chronic microwave irradiation of mice. They observed changes in the body weight at 0.100W/cm radiation for 59 weeks for daily 4.5 minutes [10].

In order to study the physiological mechanisms of temperature sensation, the forehead area of seven subjects was too controlled heating while the skin temperature was radiometrically Measured and recorded. Warmth threshold was accompanied by a rate of rise of skin temperature of 0.001^0C/second; cool threshold accompanied by a rate of fall of skin temperature of 0.005^o to 0.006^0C/second. Reports of temperature sensation continued to be given when no changes in skin temperature could be measured. Small, rapid fluctuations in skin temperature exceed measurements. The former difficulty has been covering the rates of rise and fall just given, evoked no reports of sensational. The same sequence of sensation reports resulted from preliminary heating up or cooling down the skin, and then return to it spontaneously to its normal temperature level. All such changes producing a threshold warmth sensation caused a temperature rise of about 0.02°C at a depth of 150-200 microns below the skin surface. Exposure of the skin to free-field, 3-cm microwave radiation produced initial changes in skin temperature compatible with primary heating of the tissues by the absorbed energy [109]. In the current international guidelines and standards for human exposure to Micro Waves (MWs), the basic restriction is determined by the whole-body average Specific Absorption Rate (SAR). The basis for the guidelines is the adverse effect such as work stoppages in animals for whole-body average SARs above a certain level. We performed experiments on rabbits exposed to 2.45-GHz MWs. A total of 24 measurements was conducted for power densities from approximately 100 to $1000W/m^2$. The whole-body average SAR required for MW-induced behavioral sign in rabbits was estimated at approximately 1.3W/kg for 2.45-GHz MWs [11]. In an attempt to determine whether environmental control would be a feasible and effective tool with which to further investigate microwave bio-effects, we have performed a pilot study. Some researchers believe that the biological effects of microwave radiation are primarily thermal in nature. Others believe that microwave energy deposition in the specimen can cause effects that are non-thermal. To help resolve this controversy, we have devised an environmental chamber that augments the experimental animal's heat transfer mechanisms so that the subject can withstand the thermal insult encountered in high-intensity microwave fields. [12]. Several investigators in microwave bio-effects research have exposed biological preparations to intense microwave fields, while at the same time cooling the sample with flowing water. The sample is modeled as a uniform sphere, cylinder, or slab subject to uniform heating, which is located in an unbounded coolant flow. The heat transfer is determined by the Biot and Reynolds numbers (which reflect the geometry, fluid flow, and material thermal properties of the system) the temperature rise is governed by the heat conduction equation coupled with external convection. At low coolant flow rates, the maximum temperature rise can be biologically significant, even for relatively small objects (of millimeter radius) exposed to moderate levels of microwave energy (with a SAR of ca. 100mW/g). The results are valid also where the coolant is a gas or a liquid different from water, the only restriction being on the Reynolds number of the flow [13].

II. ANALYSIS OF MICROWAVE HEATING CHARACTISTICS

Let C be the heat capacity of the body heated by an internal source, S. It is expressed in Cal/degree.

Let be the loss/sec-m^2, per degree and 'a' be the surface area of the body. Then the calories gained in dt is given by

$$CdT_{(t)} = Sdt = \square a(T_{(t)} - T_e)dt \quad (3.1)$$

Hence $dT_{(t)}$ = Temperature change in a time dt, T_e is the external temperature

Differentiating by dt both sides, we have

$$\frac{dT_{(t)}}{dt}=\frac{S}{C}-\frac{\delta a}{C}\left(T_{(t)}-T_e\right) \quad (3.2)$$

If S/C = D'p, $\frac{\delta a}{C}=g$ where D is dissipation coefficient. It is independent of temperature, $T_{(t)}$ and time, t.

Then equation, (3.2) Becomes

$$\frac{dT_{(t)}}{dt}=D'P-g\left(T_{(t)}-T_e\right) \quad (3.3)$$

$T_{(t)}$ is Temperature at any time t

T_s is Steady-state temperature

The temperature rise at any time t

$$\Delta T_{(t)}=T_{(t)}-T_e \quad (3.4)$$

And at steady state

$$\Delta T_s=T_s-T_e \quad (3.5)$$

Then equation (3.3) can be written as

$$\frac{d\Delta T_{(t)}}{dt}=g\left(DP-\Delta T_{(t)}\right) \quad (3.6)$$

Where $D=\frac{D'}{g}$

The integral of equation (3.6) becomes

$$\Delta T_{(t)}=DP\left(1-e^{-gt}\right)+\Delta T(0)e^{-gt} \quad (3.7)$$

$\frac{d\Delta T_{(t)}}{dt}=0$, gives

$$\Delta T_s = DP \quad (3.8)$$

Then equation (3.7) becomes

$$\Delta T_{(t)}=\Delta T_s\left(1-e^{-gt}\right)+\Delta T(0)e^{-gt} \quad (3.9)$$

If the heating of the body is stopped p becomes 0, then from the instant of heating is stopped, ΔT (t) obeys

$$\Delta T_{(t)}=\Delta T(0)e^{-gt} \quad (3.10)$$

The slope estimated from a graph drawn in semi-log plot, using an above relation gives –g

Now $\tau=\frac{1}{g}$ = time required for the temperature rise to fall to $\frac{1}{e}$ of this initial value.

Considering the situation in which ΔT (0) = 0, then the equation (3.9) becomes

$$\frac{\Delta T_{(t)}}{\Delta T_s}=1-e^{-t/\tau}=\frac{\Delta T_{(t)}}{DP} \quad (3.11)$$

Assume that a system at an Electric field intensity P is heated, its temperature rise follows equation (3.11). Then at any t, the corresponding rise in temperature is ΔT (t). The Electric field intensity with the rise in temperature is $P' \leq P$. P' is dependent of t and P.

From equation (3.8), P' is given by

$$\Delta T_{(t)}= DP' \quad (3.12)$$

So, introducing the equation (3.12) into equation (3.11) yields

$$\frac{P'}{P}=1-e^{-t/\tau} \quad (3.13)$$

III. RESULTS

The data of Field intensities with different temperatures for samples of Rat, Rabbit and Dog at 10cm microwave field are presented. It was found that in these three structures, heating rate is essentially proportional to microwave field intensity, especially in the case of the eyes and testis.

The data for samples of the rat's body which gives the information related to body temperature rise in℃ with microwave field intensity p($^{mw}/_{cm^2}$)is presented in table (3.1). The data for samples of Rabbit's body is presented in table (3.2), Dogs body is presented intake (3.3).

Comparison between microwave field intensities of rat, rabbit and dogs is presented in table (3.4).

Table 3.1 Microwave field intensity values with body temperature rise for samples of rat's whole bodies.

samples	Body temperature rise(°C)	Microwave field intensity P (mw/cm²)
1	37	0
	39	42
	42	52
2	37	0
	38	12
	39	49
	40	63
	41	71
3	37	0
	39	42
	40	60
	41	75
	42	85
	43	70
	44	60
4	37	0
	39	42
	40	45
	41	50
	42	65
5	37	0
	40	55
	41	81
	42	100

Table 3.2 Microwave field intensity values with body temperature rise for samples of rabbits' whole bodies.

samples	Body temperature rise(°C)	Microwave field intensity P (mw/cm²)
1	38	0
	40	41
	41	50
	42	95
2	38	0
	39	8
	42	25
3	38	0
	40	25
4	38	0
	39	15
	39	15
	40	20
	40	25
5	38	0
	39	15
	39	15
	40	20
	40	25
6	38	0
	42	41
	43	45
7	39	0
	39	10

Table 3.3 Microwave field intensity values with body temperature rise for samples of dog's whole bodies.

samples	Body temperature rise(°C)	Microwave field intensity P (mw/cm²)
1	38	0
	41	41
	42	40
	42	10
	42	0
2	38	0
	39	10.5
3	39	7
	40	20
	41	20
	42	10
4	39	0
	40	30
5	39	0
	40	40
6	39	0
	42	23
	43	0
7	39	0
	41	45
	42	35
	43	40
8	39	0
	42	50
	43	0

Table 3.4 Comparison between microwave field intensities of rat, rabbit and dog

samples	Body temperature rise(°C)	Microwave field intensity P (mw/cm²)
Rat	37	0
	38	12
	40	45
	42	52
Rabbit	39	0
	40	15
	41	22
Dog	39	0
	41	20
	42	15
	42	0

IV. CONCLUSIONS

The whole body for differing animals like rat, dog, rabbit were exposed at different microwave field intensities. At increasing body temperatures in these animals, cooling reaches a maximum limit, and beyond this undergoes a failure presumably primarily due to a central failure of the respiratory mechanism. Also metabolism is increased under these conditions, partly because of specific temperature dependence, and partly because of an increased respiratory effort. The data presented in tables at the lower rates the three animal species were roughly the same. At higher temperatures, a change is observed with a few of rats and rabbits whereas with the dogs actually retained to the abscissa where body temperature was maintained at the elevated level above the metabolism.

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I. AUTHORS DATA

Dr. Y. Ratna Kumar did his B. Pharmacy in JNTUH and M. Tech (Biomedical Engg.) in Andhra University. At present, he is Assistant Professor (c) in the Centre for BioMedical Engineering, Dept. of Electronics and Communication Engineering, AU College of Engineering (A), Visakhapatnam, and a Ph.D. under the guidance of Prof. G.S.N. Raju. He is a life member of the PCI, SEMCE (I), BMSI, and ISB.

Dr. G.S.N. Raju received his B.E., M.E. With distinction and first rank from Andhra University, Visakhapatnam and Ph.D. from IIT, Kharagpur. He is Professor of Electronics and Communication Engineering in Andhra University College of Engineering, Visakhapatnam, India. He is in teaching and research for the last 30 years, Andhra University, Visakhapatnam. He guided 16 Ph.D.s in the fields of Antennas, Electromagnetics, EMI/EMC and Microwave, Radar Communications, Electronic circuits. Prof. Raju has published about 260 technical papers in National/ International Journals/Conference Journals and transactions. He is the recipient of “The State Best Teacher Award” from the Government of Andhra Pradesh in 1999, “The Best Researcher Award” in 1994, Prof.Aiya Memorial “National IETE Award” for his best Research guidance in 2008 and “Dr. Sarvepalli Radha Krishnan Award for the Best Academician of the year 2007”. He was a visiting Professor in the University of Paderborn and also in the University Karlsruhe, Germany in 1994. At present he holds the positions of V.C, Andhra University, Visakhapatnam, Chief Editor of National Journal of Electromagnetic Compatibility, India. Prof. Raju has published five textbooks “Antennas and Wave Propagation”, “Electromagnetic Field Theory and Transmission Lines”, “Electronics Devices and Circuits”, “Microwave Engineering”, Radar Engineering and Navigational Aids”.Prof. Raju has been the best faculty performer in Andhra University with the performance index of 99.37%.

