

1. Introduction

Electromagnetic pollution has become a relevant problem for the actual environmental policy, especially for the tight connection with human health [1, 2]. NIR (Non Ionizing Radiation) interaction with environment and man is one of the most interesting research field for the world scientific community [3, 4]. This paper describes a part of a multidisciplinary research on the possible effects of RF (Radiofrequencies) electromagnetic fields on man. Man is always exposed to RF electromagnetic fields, which are in the 30-300 MHz range and regard radio and television communications. The investigation was carried out by an experimental facility which was built for exposing thymic cell cultures to RF electromagnetic fields. Thymic cell cultures were chosen because their alterations are generally index of cancerogenesis. The experimental facility was made by a climatic room, a control unit and a RF generating system. The control unit allow to control temperature, humidity and CO₂ concentration in the climatic room respectively at 37°C, 74% and 5% (life condition for cell cultures). The climatic room is constituted by three boxes: an actuator box where temperature and humidity actuators are installed; a control box where parameter sensors and the CO₂ actuator are installed; a measurement box which contains the cultures and the RF generating system. The climatic room walls are made by polystyrene which is transparent to electromagnetic fields in order to avoid anomalies in the field distribution. The RF generating system is made by a 144 MHz transmitter connected to a condenser by a coaxial cable. A 144 MHz frequency was chosen for the exposition tests because it is a typical frequency for radio amateur communications and it is intermediate between broadcasting radio and TV frequencies. Besides, other thymic culture plates were inserted into sinterized nickel boxes in the measurement box. The sinterized nickel boxes acts as an electromagnetic shield. Thus, these are the not-exposed cultures. Exposition tests were carried out for three and six hours; the electromagnetic field intensity into the cell cultures was simulated by a numerical code. The exposed and not-exposed cultures were analysed after the tests. This paper focused to the analysis of the thermophysical properties of the cultures (density, viscosity, specific heat). The analysis was carried out in order to verify if the exposition induced alterations of such properties. Besides, other branches of this research verified possible variations in the biomedical properties of the cultures. Results showed that the exposition at 144 MHz electromagnetic fields does not modify the thermophysical properties of the thymic cultures in the tested conditions.

2. The experimental facility

The experimental facility is constituted by a climatic room, the RF generating system and a control unit. The control unit allows to control temperature, humidity and CO₂ concentration to standard life condition for the cell cultures (temperature = 37°C, humidity = 74%, CO₂ concentration = 5%). Thus, the control unit is characterized by three inputs and three outputs (see picture in Figure 1). Three sensors (temperature, humidity and CO₂ concentration) are connected to the control unit inputs; three actuators (electric resistors for temperature control, a vapour generator for humidity control, a pipe connected to a CO₂ bottle for CO₂ concentration control) are connected to the control unit outputs. The climatic room was designed to avoid anomalies in the electromagnetic field concentration. Thus, it was built in plastic material (polystyrene), which is transparent to 144 MHz electromagnetic fields. The climatic room is constituted by three boxes (see Figures 2 and 3):

- control box: it contains the actuator for CO₂ control and the sensors for temperature, humidity and CO₂ measurements. The sensors are a psychrometer (temperature and humidity measurements) and a CO₂ data acquisition card (see Figure 4).
- actuator box: it contains the electrical resistors for temperature control and a vapour generator for humidity control;
- measurement box: it contains only the not exposed cell cultures (which are shielded by a sinterized nickel box), the exposed cultures and the RF generating system; in this way, the cultures are not subjected to the electromagnetic radiations due to sensors and actuators placed in the control and in the actuator boxes.

The three boxes are connected each other by plastic pipes. Fans allows to keep uniform the air conditions. The RF generating system is constituted by a 144 MHz transmitter connected to a condenser by a coaxial cable. The condenser plates dimension are 10 cm × 10 cm × 1 mm. The condenser plates are separated by air. The distance between the condenser plates is 2 cm (see Figure 5).



Figure 1: control unit

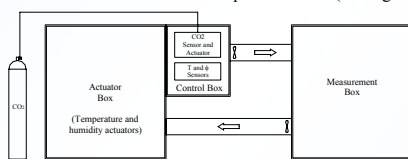


Figure 2: climatic room scheme

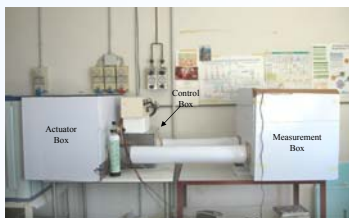


Figure 3: picture of climatic room.

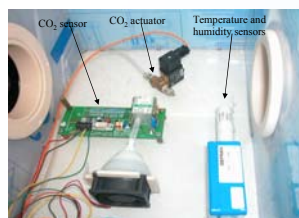


Figure 4: control box

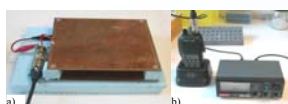


Figure 5: a) the condenser; b) the RF transmitter

3. The experimental tests

In vitro experiments were carried out on thymic cells obtained by C3H rat thymus. The rats were 3-4 weeks aged of both the male and female sexes. They were obtained in single cells suspension after centrifugation (1200 rpm for 10 minutes), washing and resuspension in a RPMI1640 culture medium containing 5% concentration fetal bovine serum. Live cells were counted by a blood cytometer and diluted at a 2x10⁶ cells/ml concentration in cultures two-well plates. Two kinds of cultures were placed into the climatic room where standard climatic conditions are kept uniform and stable:

- exposed cells: their two-well plates are installed between the RF condenser plates (see Figure 6);
- not-exposed cells: their two-well plates are inserted into a sinterized nickel box characterized by high electromagnetic insulation (see Figure 7).

A calibration campaign was carried out before each test in order to verify that standard climatic conditions are maintained in the measurement room. Stable standard conditions are obtained after two hours from the climatic room start-up. Air velocity and illuminance were also measured into the measurement room: their average values are respectively 0,05 m/s and 17 lux. Two kinds of exposition tests were carried out:

- Three hours exposition to 144 MHz electromagnetic fields;
- Six hours exposition to 144 MHz electromagnetic fields.

Ten tests were carried out for each condition.

Simulations were carried out by a numerical code in order to identify the intensity of the electromagnetic fields to which the cultures were exposed. 500 mW is the electromagnetic power which feeds the condenser by the 144 MHz RF transmitter. Simulation results shows that the cell cultures are averagely exposed to a 0.6 W/m³ power density.



Figure 6: cultures to be exposed in the condenser plates



Figure 7: not exposed cultures in the sinterized nickel box

4. Measurement results

Not exposed and exposed cultures were inserted after the tests into a commercial climatic room (Mazzali Climatest C 330 G5) where standard life conditions are maintained. Thermophysical properties were measured for not exposed and exposed cultures.

Viscosity was measured by an Ubbelohde viscosimeter (calibration constant C_s = 0.03347·10⁻⁶ m²/s²). Measurement were carried out into the Mazzali climatic room at 37°C and high humidity (74%) conditions (see Figure 8).

Average measured cinematic viscosities are the followings:

- not exposed cultures: $\nu = 0,846 \cdot 10^{-6} \text{ m}^2/\text{s}$ (standard deviation = $0,033 \cdot 10^{-6} \text{ m}^2/\text{s}$);
- 3-hours exposed cultures: $\nu = 0,908 \cdot 10^{-6} \text{ m}^2/\text{s}$ (standard deviation = $0,009 \cdot 10^{-6} \text{ m}^2/\text{s}$);
- 6-hours exposed cultures: $\nu = 0,901 \cdot 10^{-6} \text{ m}^2/\text{s}$ (standard deviation = $0,023 \cdot 10^{-6} \text{ m}^2/\text{s}$).

Thus, the difference is less than measurement errors. Viscosity is not affected by the exposition at 144 MHz electromagnetic fields in the tested conditions.

Density measurements were carried out by a precision weighing scale and a graduated container where the exposed and not-exposed cultures are inserted after the exposition tests. Measurements were carried out in the Mazzali climatic room at 37°C and high humidity (74%) conditions. Average measured densities are the followings:

- not exposed cultures: $\rho = 1,009,50 \text{ kg/m}^3$ (standard deviation = $3,50 \text{ kg/m}^3$);
- 3-hours exposed cultures: $\rho = 999,00 \text{ kg/m}^3$ (standard deviation = $4,15 \text{ kg/m}^3$);
- 6-hours exposed cultures: $\rho = 996,67 \text{ kg/m}^3$ (standard deviation = $3,32 \text{ kg/m}^3$);

Thus, also density is not affected by the exposition to 144 MHz electromagnetic fields.

Specific heat was measured by a calorimeter Setaram model C 80 Calvet (see culture inserting procedure in Figure 9). Measurements were carried out in the [35°C, 40°C] temperature range which is the maximum range for which cells may live without anomalies. Table 1 reports average results for exposed and not exposed cultures.

Also specific heat is not affected by electromagnetic fields exposition.



Figure 8: picture of viscosity measurements



Figure 9: picture of culture inserting into the calorimeter

Table 1: measured specific heat of not exposed and exposed cultures

T (°C)	Not exposed Cp (kJ/(kg °K))	3-hours exposed Cp (kJ/(kg °K))	6-hours exposed Cp (kJ/(kg °K))
35,0	3,9484	3,9915	3,9794
35,5	3,9777	3,9924	3,9811
36,0	3,9836	4,0171	3,9945
36,5	3,9840	3,9915	3,9949
37,0	3,9940	3,9991	4,0003
37,5	4,0158	4,0254	4,0175
38,0	4,0204	4,0267	4,0258
38,5	4,0288	4,0338	4,0271
39,0	4,0526	4,0434	4,0476
39,5	4,0840	4,0844	4,0727
40,0	4,0957	4,1129	4,0970

5. Conclusions

Thermophysical properties of thymic cell cultures were investigated. The study focused to analyse the possible effects of 144 MHz electromagnetic fields on human health. Thus, an experimental facility was built: exposed and not exposed thymic cell cultures were characterized in terms of viscosity, density and specific heat. Results showed that the thermophysical properties of thymic cell cultures are not modified by 144 MHz electromagnetic fields in the used test conditions and configuration. Besides, biomedical analyses developed by the Clinical and Medical Department of the University of Perugia showed that also biomedical pathways (such as Ras, p53, BCL-2) and cellular processes such as apoptosis and proliferation are not modified by the exposition.

6. References

- National Council on Radiation Protection and Measurements, *Biological Effects and Exposure Criteria for Radio Frequency Electromagnetic Fields*, NCRP Report 86, Bethesda, MD, 1986.
- World Health Organization, *Electromagnetic Fields (300 Hz to 300 GHz), Environmental Health Criteria 137*, Geneva, Switzerland, 1993.
- Hocking B, Gordon IR, Grain HL, Hatfield GE, *Cancer incidence and mortality and proximity to TV towers*, Medical Journal of Australia, Vol 165, 2/16 December, pp 601-605, 1996.
- Rosai J, Sobin LH, *Histological typing of tumors of the thymus*. Rosai J Sobin LH eds. WHO International Histological Classification of Tumors, pp 1-65, Springer-Verlag, Berlin, 1999.