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Biomedical Applications of Simulated Environments

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ABSTRACT

Environmental physiology assumes great significance in our national context in view of the diverse climatic conditions prevailing in different regions. Troops have to operate in diverse environmental conditions guarding the frontiers. Hence, the research in this area has been focused on the usage of field studies in the natural environments or simulated environments in the laboratory. Besides, the application of the simulation chambers in the research on the physiological effects of diverse environments, these studies may have applications in the control and management of certain clinical disorders. Some simulation chambers and specialised set-ups have been designed and developed at the Defence Institute of Physiology and Allied Sciences to carry out simulation studies. This paper describes these developments and the potentials of these biomedical applications of simulated environments.

1. INTRODUCTION

The research application of simulation environments has a long history. Environmental biologists including physiologists have been using these for various research endeavours related to the biological effects of environments such as high altitude, cold, desert, aerospace and underwater[1-5]. Studies on environmental physiology assume great significance in the national context in view of the diverse climatic conditions prevailing in different parts of India. The alpine climate over the Himalayas, the arid conditions over Rajasthan desert, hot-humid conditions over coastal peninsula and per humid conditions over the eastern region[6] present challenge to the human adaptability. The best way to understand the biological effects of such environments is to carry out experiments in the natural environmental conditions. But due to constraints in the logistic support required for these studies involving sensitive instrumentation, it becomes a necessity to carry out such experiments in the simulated environments in the laboratory.

Human decompression chamber for hypoxia, human climatic chamber for cold or heat, hyperbaric chambers for underwater environment, explosive decompression for aviation and space laboratories for simulating zero gravity space environments are conventionally used for simulation studies. Besides the research applications, these environmental chambers may have some therapeutic applications in the control and management of certain clinical disorders. For example, four weeks of exposure in a decompression chamber to a simulated altitude of 1800–2000 m helps in the treatment of chronic obstructive pulmonary diseases like asthma and bronchitis[7].

1.1 Human Decompression Chamber

Hypoxia (low oxygen pressure) and cold are the major stressors at high altitude (HA). Human decompression chamber (HDC) can simulate these two stressors at controlled level. The chamber is suited for evaluating the acute responses to hypoxia and cold; however long term exposure for several days poses several logistic problems. Psychological factors which usually play a significant role in modulating the hypoxic effects on physiology and behaviour cannot be adequately simulated in chamber studies.

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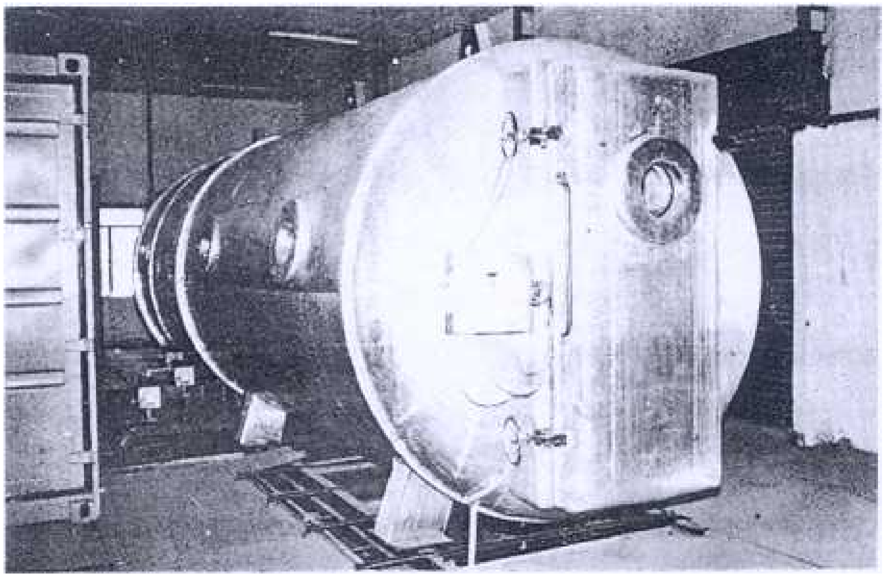


(a)

(b)

Figure 1 Human decompression chamber, (a) external view, and (b) interior view.

HDC available at Defence Institute of Physiology and Allied Sciences (DIPAS) can simulate altitudes upto 9,144 m (30,000 ft) with cold stress upto -20 °C. This has provision for stepwise rate of ascent in a predetermined level and for monitoring physiological functions (Fig. 1). While altitudes above 3000 m may result in physiological manifestations of altitude stress, simulated altitudes between 1800-2000 m were found to be beneficial in the treatment of respiratory diseases like asthma and bronchitis[7]. The prognosis of the disease showed a positive correlation with the improvement in the hypothalamic thermoregulation efficiency. Our studies on higher altitude of 3500 m, on the other hand, revealed a slight deterioration in thermoregulation efficiency[8]. In view of the differential responses to moderate high altitude, it is essential to derive the optimal heights at which desirable therapeutic effects for chronic obstructive pulmonary diseases. HDC may also have therapeutic application in certain other psychosomatic disorders through exposure to moderate HA below 2500 m.

1.2 Portable Oxygen Regenerator

High altitude pulmonary oedema (HAPO) is one of the major clinical problems at HA. The hyperbaric chamber is useful as adjunct to other medical treatments. Defence Bioengineering & Electromedical Laboratory (DEBEL) also has developed a one-man hyperbaric chamber which will find a lot of applications in remote field areas as an immediate first aid to curb the progression of the pathophysiology and ameliorate the clinical problems. Recently DIPAS devised a much simpler portable closed circuit breathing assembly (Fig. 2) which uses potassium superoxide as oxygen regenerator (air regenerating compound). This compound simultaneously produces oxygen and absorbs

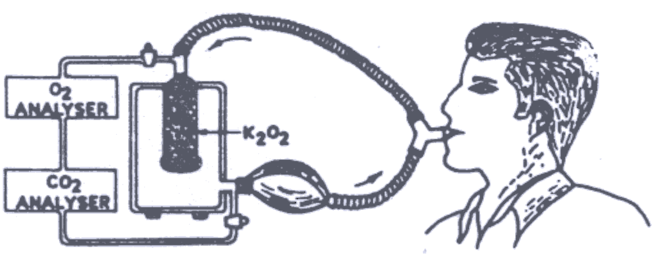


Figure 2. Portable oxygen regenerator set-up.

carbon dioxide which is essential for breathing for a living system. The oxygen releasing capacity of potassium superoxide is 233 cc/gm at normal temperature and pressure. Another speciality of this compound is that it requires moisture to produce oxygen and to absorb carbon dioxide as per the following chemical reactions:

$$2K_2O_2 + 2H_2O = O_2 + 4KOH$$

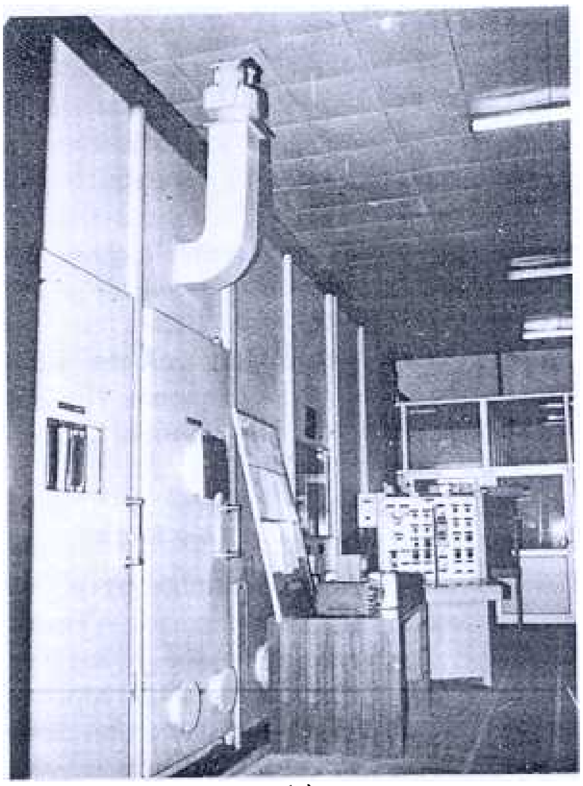
It is an exothermic reaction and hence the heat produced can also be used to keep the patient warm and thereby help to combat the vagaries of cold stress. Soldiers becoming victims of HAPO in extreme field conditions at high altitude areas where medical treatment and oxygen supply are not available, this compound can be very effectively used with the portable closed circuit breathing assembly for a few hours till the patient is transferred to the nearest hospital. Thus the progress of the disease and deterioration of the patient's condition can be arrested for a few hours. This can act as a life saviour. Efforts are on to make the system more compact and effective.

1.3 Human Climatic Chamber : Cold Stress

Cold acclimation in cold chamber by periodical intermittent exposure has been reported in both men and animals[9,10] The physiological changes are brought about in thermoregulation and metabolic adjustments in the form of facilitation of non-shivering thermogenesis. These are known to help in maintaining the body core temperature under cold exposure thereby preventing hypothermia, as well as protection against cold injuries[11]. This can be achieved by a daily four-hours exposure in a cold chamber maintained at 10 °C with minimal clothing for a period of 3 weeks. Even 10 °C cold without protective clothing is intense enough to bring about physiological acclimatization[2]. Cold chamber at DIPAS (Fig. 3) can simulate cold stress of the order of -20 °C which can be regulated to an accuracy of ± 0.5 °C.

1.4. Hot Chamber

The troops operate in heat stress situation which may be of hot dry conditions prevailing in Rajasthan desert area or of hot humid conditions in coastal peninsula. The major clinical problems of heat stress include : heat stroke, heat syncope, heat pyrexia, and dehydration[12]. The primary aetio-pathological factor is failure of thermoregulatory system[13]. The transmigration from temperate regions to tropical arid regions during peak summer may accentuate the strain on thermoregulatory mechanism. Earlier studies[3] at DIPAS have shown the possibility of inducing heat acclimatization by intermittent heat exposure of 3-4 hr at 45 °C dry bulb and 30 per cent relative humidity for a period of 8 days. The hot chamber can be used to minimise the heat casualties in summer months.



(a)

(b)

Figure 3. Human climatic chamber, (a) external view, and (b) interior view with bicycle ergometer.

1.5 Hyperbaric Chamber

Underwater simulation is carried out by the use of a hyperbaric chamber for physiological studies related to diving, mining, etc. This chamber has therapeutic applications in the control and management of clinical disorders like dysbarism in divers, HAPO at high altitude and also the hyperbaric hyperoxic therapy for peripheral vascular disorders like intermittent claudication and frostbite[14]. The increase in the quantity of dissolved oxygen helps to recuperate the ischaemic tissues affected by vasoconstriction.

1.6 Microwave Chamber

Microwaves are used in long distance communication, radars and even in some domestic appliances like ovens. The personnel working near these installations are exposed to microwaves of different power density. Microwave chamber has been commissioned at DIPAS in collaboration with Indian Institute of Technology, Kanpur (Fig. 4) for undertaking studies on the biological effects of microwaves. While assessing the adverse effects of microwaves, if any, on reproductive system, behaviour, vision and nervous system, efforts are on to see if certain wave bands at lower power density can be beneficial particularly to potentiate the immune system.

1.7 Hypercapnic Exposure Set-up

Recent studies at DIPAS have illustrated the possible application of carbogen mixture (5 per cent carbon dioxide and 95 per cent oxygen) in reducing the noise-induced hearing loss as well as in facilitation of its recovery[15]. The simple set-up illustrated in Fig. 5 can be used prior to and after the exposure to noise in certain occupational environments. Five per cent carbon dioxide is a potent vasodilator which obliviates the noise-induced vasoconstriction while 95 per cent oxygen meets the additional metabolic requirements of hair cells due to noise stimulation.

2. CONCLUSION

The simulation facilities for different environmental conditions such as hypoxia, hypercapnea, hyperbaric, thermal and microwave chambers available at DIPAS not only help to assess the physiological, biochemical and psychological responses to various environments but also illustrate their potentials for therapeutic

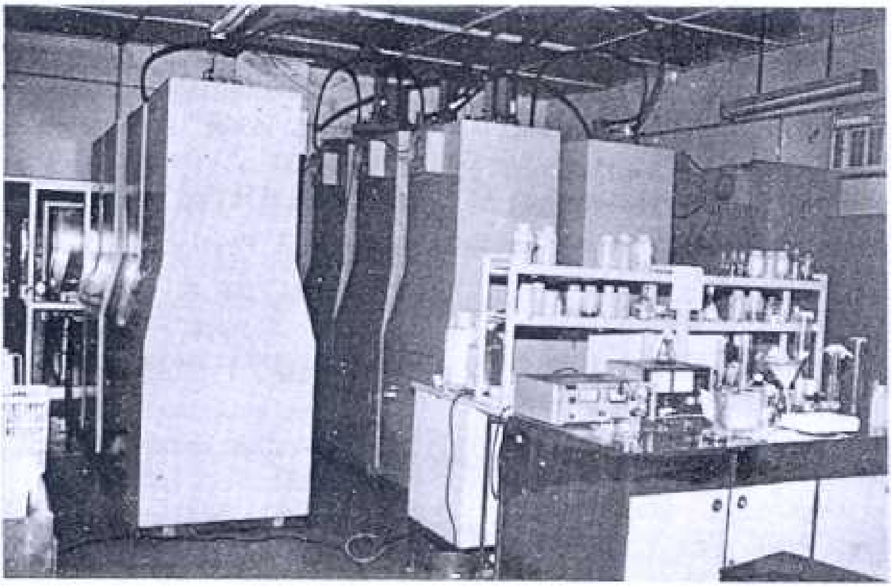


Figure 4. An outer view of the microwave chamber for animals.

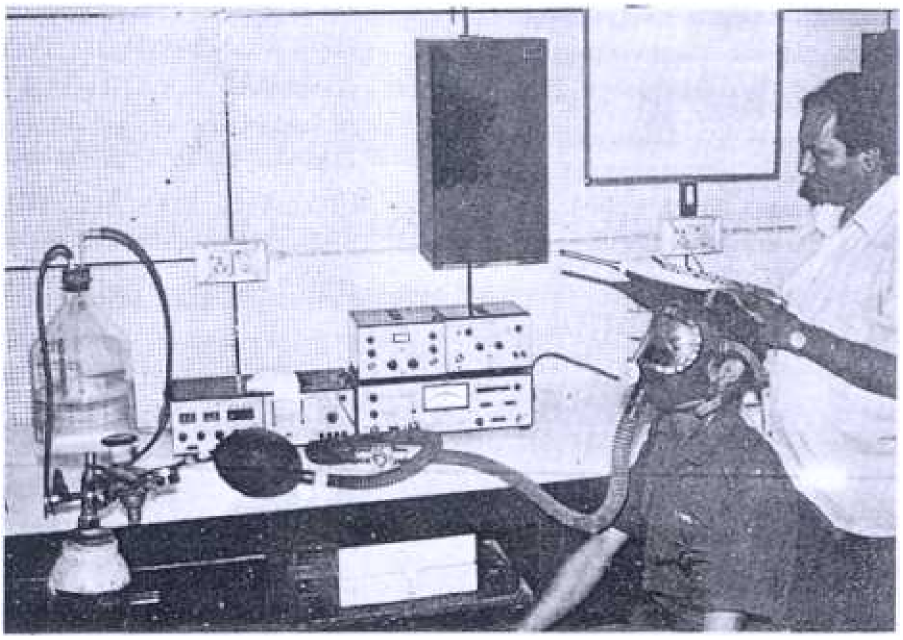


Figure 5. Hypercapnic exposure set-up.

applications. Further studies will be required for understanding the mechanisms underlying such therapeutic effects to make these acceptable to the medical world

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