A METHOD OF MEASURING THE SURFACE TENSION AND SURFACE POTENTIAL OF LUNG SURFACTANTS

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An apparatus for measuring the surface tension and surface potential of lung surfactants is described. These values can be recorded in relation to changes in the surface concentration of surfactant.

Surface-active substances (surfactants), found on the surface of the lung alveoli, play an important role in the mechanism of respiration [8]. Disturbances of the surfactant system, moreover, are associated with various disorders of the lungs: atelectasis, pulmonary edema, and hyaline membrane syndrome of the newborn [14]. Neergaard [11] showed for the first time that the forces of surface tension are the chief factor creating the elastic resistance of the lungs. Pattle [12], who studied the stability of air bubbles in lung extracts, concluded that the surface of the alveoli of the lung is covered by a monolayer of surface-active substances which lower the surface tension practically to zero. Clements [10] confirmed the existence of powerful surfactants in the lungs of mammals. These substances lower the surface tension as the surface contracts. The compression–relaxation curves under these conditions do not coincide and a wide hysteresis loop is formed. The size of this loop reflects the surface activity of the substances [13]. Using a mathematical model of an alveolus Clements et al. [9] showed that its unusual stability is connected with the distinctive behavior of the surface forces. Surface-active substances in the alveoli of the lung have also been described in the Soviet literature [1-7].

In the study of the connection between surfactants and changes in the mechanics of respiration most attention has been paid to the chief property of surfactants – lowering the surface tension. However, considerable technical difficulties arise during the investigation of this property. These difficulties are connected both with the method of extraction of surfactants from the lungs and with the method of measurement of their surface-active properties.

To study the surface activity of surfactants, Soviet investigators have used Pattle's method of determining the stability of bubbles [1, 2] or Rebinder's method of determining surface tension [1, 2]. The first method is only an indirect view of the surface activity of the substances whereas the second is unsuitable for substances whose absorption on the boundary surface between air and liquid is protracted. A method enabling visual determination of surface tension depending on the area occupied by surfactants is described in only one paper [5], although it is this function which gives the fullest characteristics of surfactants.

In this paper an account is given of the apparatus used by the author to record the surface tension and surface potential – an important electrical characteristic of the monolayer – continuously.

The apparatus (Fig. 1) consists of three components: a Teflon cell with mechanical part, a strain gauge, and a vibro-electrode. The cell has a tight-fitting moving Teflon barrier. The barrier performs to-and-fro movements by means of an electric motor and worm mechanism. The position of the barrier is estimated from the resistance of a multiple-turn rheostat. The potential from the rheostat is led to the X-plate of an oscilloscope.

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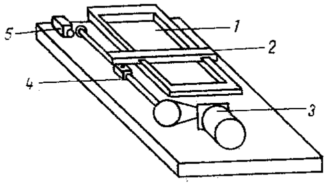

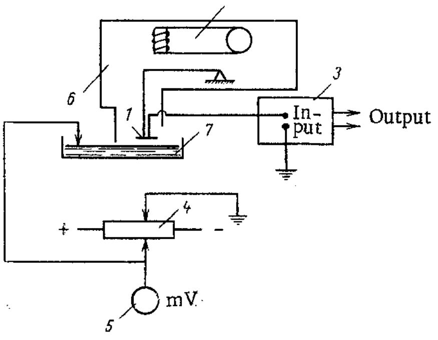

Fig. 1 Fig. 2

Fig. 1. Apparatus for measuring surface tension and surface potential of lung surfactants: 1) Teflon cell; 2) moving barrier; 3) electric motor; 4) worm drive; 5) variable resistor.

Fig. 2. Scheme of the vibro-electrode: 1) vibrating plate of capacitor; 3) electrovibrator; 3) cathode follower unit; 4) rheostat; 5) millivoltmeter; 6) screen; 7) cell containing fluid.

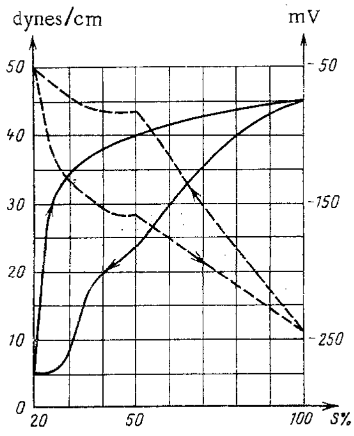

Fig. 3. Surface tension and surface potential as functions of area. Continuous line – surface tension; broken line – surface potential.

A solution of the surfactant is poured into the cell. After a certain time has elapsed the surface-active molecules are adsorbed on the surface. The area occupied by the surface-active molecules is altered by movement of the barrier. The area is varied from 100 to 20%. The surface tension is measured by Wilhelmy's method: a glass coverslip touches the surface of the fluid (not shown in Fig. 1).

Since the angle of wetting between the glass and the liquid is close to zero the surface tension is determined directly from the attracting force acting on the coverslip. This force is measured by a strain gauge consisting of a type 6MKh1S mechanical-electrical transducer tube. Before the experiment begins the signal is calibrated with a known load. The error of measurement due to meniscus formation does not exceed 5%. This value can be taken as the accuracy of measurement.

The surface potential is determined by means of a vibrating electrode (Fig. 2). The plate of a capacitor is brought to a distance of 1 mm from the surface of the liquid. It is made to vibrate by means of an electrovibrator. The signal from the plate is led to the input of a cathode follower. The signal is calibrated with a rheostat and millivoltmeter. Measures to abolish interference are necessary when working with this apparatus: the electrovibrator and the apparatus as a whole must be screened. The noise level is affected by the mutual arrangement of the various parts of the apparatus.

The results are recorded on a double-beam S1-17 cathode-ray oscilloscope with camera attachment. The results of an investigation of surfactants obtained from dog's lungs are given as an example (Fig. 3). The lungs were filled with 0.9% NaCl solution which was then aspirated from the trachea.

As Fig. 3 shows, the surface tension and surface potential fall sharply with a decrease in area. The curves of these values as functions of area are not linear but form hysteresis loops.

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