

DETERMINATION OF MERCURY DOSE RECEIVED BY A PERSON THROUGH RESPIRATION

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Power plants are one of the main anthropogenic sources of mercury emission in the atmosphere. More than 70% of mercury is released in the atmosphere as elemental mercury (Hg^0). Resident time of mercury (Hg^0) in the atmosphere is about one year. It is established that about 80 % of Hg^0 , inhaled by a person, remains in the body and it deposits in various internal organs including the brain. Since mercury is a reason of various mental diseases, particularly, of autism, it is clear that there is interest in different methods of determination of mercury received by a person through inhalation.

A new rapid technique of determination of inhalation dose based on direct measurement of the mercury concentration in the exhaled air by application of the Zeeman mercury spectrometer RA-915+ is proposed. It is experimentally proven that the dose value in short-time exposure to mercury vapors is most faithfully determined by the above method and not by conventional techniques based on the mercury content in blood or urine. The developed technique allows for rapid and reliable determination of received doses of mercury being that are greater than 1 μg .

Introduction

It has been known for many years that the elemental mercury vapor is highly toxic and is very hazardous to human health. Conventional dosimetric techniques based on measuring the mercury content in blood or urine do not allow patients suffering from short-time exposure to Hg vapor to be revealed. We have developed and tested on volunteers a new rapid dosimetric technique based on measuring the mercury content in the exhaled air [1].

Experimental

In our experiments, we used an RA-915+ AAS mercury analyzer (made by *Lumex Ltd.*, Russia) with the high-frequency Zeeman correction for background absorption (interference that attenuates the radiation 100-fold does not bring about false signals). A multipath analytical cell (its optical length being 9.6 m) provides a low mercury detection limit (DL of less than 1 ng/m^3) for air without mercury collection on a sorbent, which makes real-time measuring possible. The above-listed performance features of the analyzer allowed development of very simple and easy-to-interpret procedure for

detection of mercury in the exhaled air. The mercury concentration is measured during 3 to 5 exhales, the total analysis time being less than five minutes, DL for the exhaled air being 2-5 ng/m³, and the repeatability of measurements within 10%.

Results

It has been ascertained by measurements that the absorption of mercury vapor varies from 70 to 80%, independent of the mercury concentration in the inhaled air and strongly dependent on the alcohol content in blood (see Fig. 1). Alcohol not only reduces the absorption of mercury vapor but also promotes its removal (see Fig. 2). These facts were taken into account in our experiments on the study of the mercury vapor effect.

Two volunteers spent three hours in a mercury-contaminated room where the mercury concentration was maintained at 10 µg/m³ for the first 1.5 hour and at 15 µg/m³ for the next 1.5 hour (see Fig. 3). First, the "P" volunteer carried out physical exercise of medium intensity (the lung ventilation being 20 l/min) while the "R" volunteer was at rest and then they changed their state. The mercury content in the air exhaled by the volunteers was measured during the exposure (when changing the state), immediately after the exposure, and also during eight days afterward. These data were used to determine the dependence of the dose received (Dose) on the mercury concentration in the exhaled air (C_{EA}), which appeared to be linear:

$$\text{Dose} = 0.3 \cdot C_{EA} \text{ (see Fig. 4).}$$

We also succeeded in corroboration of the known fact that a decrease in the mercury concentration in the exhaled air as a function of the time passed after the exposure is described by an exponential function with a removal half-period of about 17 hours (see Fig.5). This means that if the time *t* between the termination of the mercury exposure and the C_{EA} measuring is longer than 3-4 hours,

$$\text{Dose} = 0.3 \cdot C_{EA} \cdot \exp(0.04 \cdot t).$$

The effect of the short-time mercury exposure on the organism

Using the CV AAS technique (DL = 0.01 µg/l) we determined the mercury concentration in volunteers' urine in the morning and in the evening five, three, and one day before and one, three and five days after the exposure. It turned out that neither the dose received nor even the fact of the exposure effect itself can be revealed from the results of measuring the mercury concentration in urine.

The blood was sampled from the volunteers' veins before and after the exposure. The mercury concentration in the blood was measured by the CV AAS technique upon microwave digestion of the blood samples (DL = 0.5 µg/l). The mercury concentration in the blood did not change after the exposure.

The blood samples were studied by the Erythrotest method based on the examination of erythrocytes in peripheral blood by a scanning electron microscope (see Fig. 6). Statistical analysis of the distribution of erythrocyte forms was made on 200 cells per sample.

Table 1. lists the percent content of the basic erythrocyte forms in volunteers' blood before and after their exposure to mercury vapor. As can be seen from the tabulated data, a weak trend to a decrease in normocytes and stomatocytes is observed for both the volunteers due to an increase in various degenerating and degenerative forms. A fraction of microcytes substantially increased in the volunteers' blood after their exposure to mercury. According to our data, the disturbance of the rheological properties of blood accompanied by microcytose is the primary consequence of the mercury intoxication.

Table 1. Percent contents of the basic erythrocyte forms in volunteers' blood before and after their exposure to mercury vapor.

No.	Erythrocyte shapes	Norm	Volunteer "P"		Volunteer "R"	
			Before	After	Before	After
1	Normocytes and stomatocytes	> 90	70	65	64	62
2	Degenerating, degenerative shapes	< 10	30	35	36	38
3	Microcytes	< 11	10	23	12	20

Conclusion

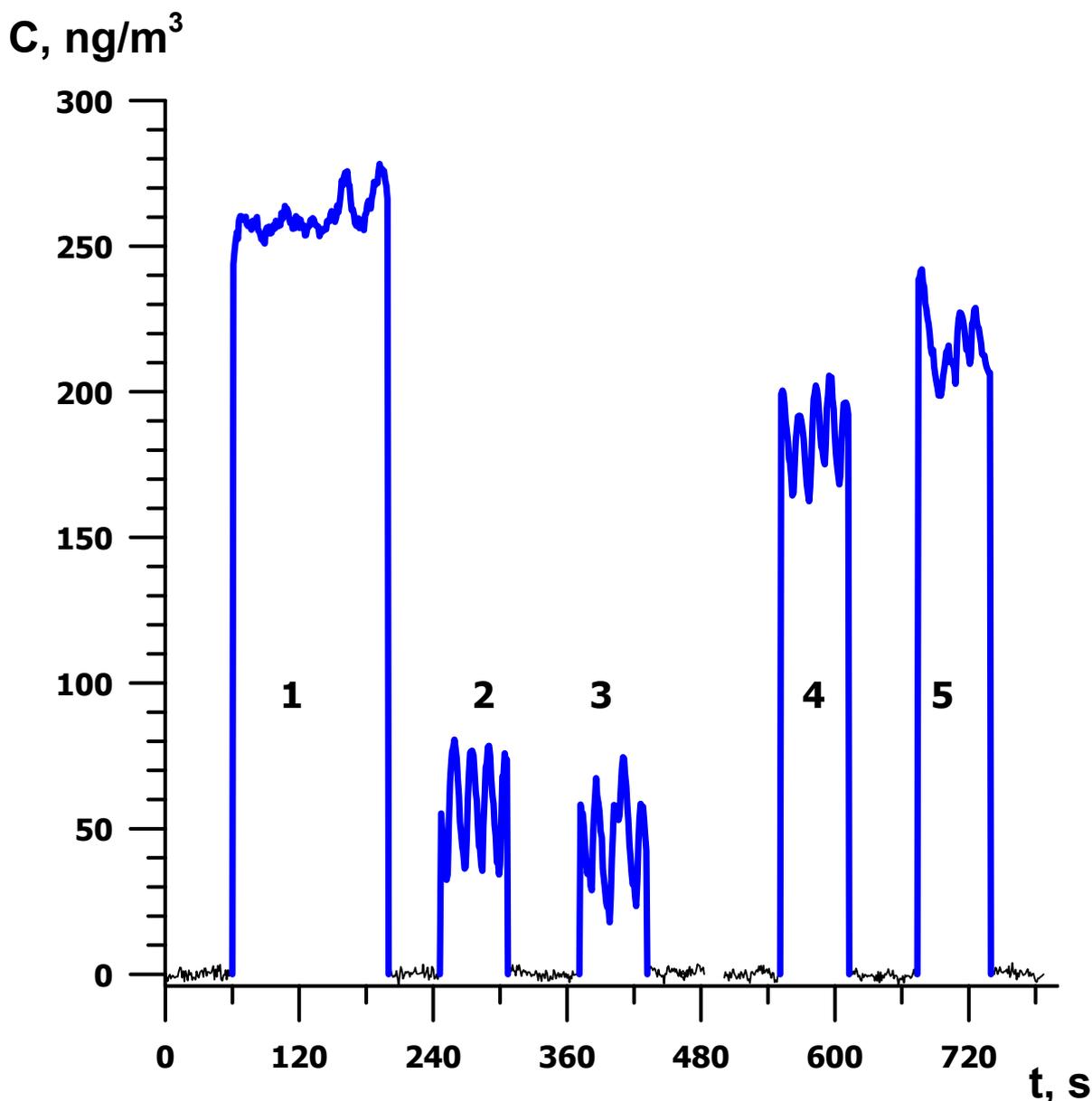
We have developed and tested on volunteers a new rapid dosimeter technique based on measuring the mercury content in the exhaled air. This technique allows detection of even small doses (DL ~ 1 µg), which are typical for short-time exposure to mercury vapor of individuals who are not professionally involved in mercury-related industries. Furthermore, it has been demonstrated that the short-time exposure to mercury causes deterioration of rheological properties of blood accompanied by the erythrocyte microcytose.

[1] - Pogarev S. E., Ryzhov V., Mashyanov N., Sholupov S. and Zharskaya V. Direct measurement of the mercury content of exhaled air: a new approach for determination of the mercury dose received// Analytical and Bioanalytical Chemistry, 2002, v374, N 6, 1039-1044

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Fig.1. Inhalation absorption of mercury vapor



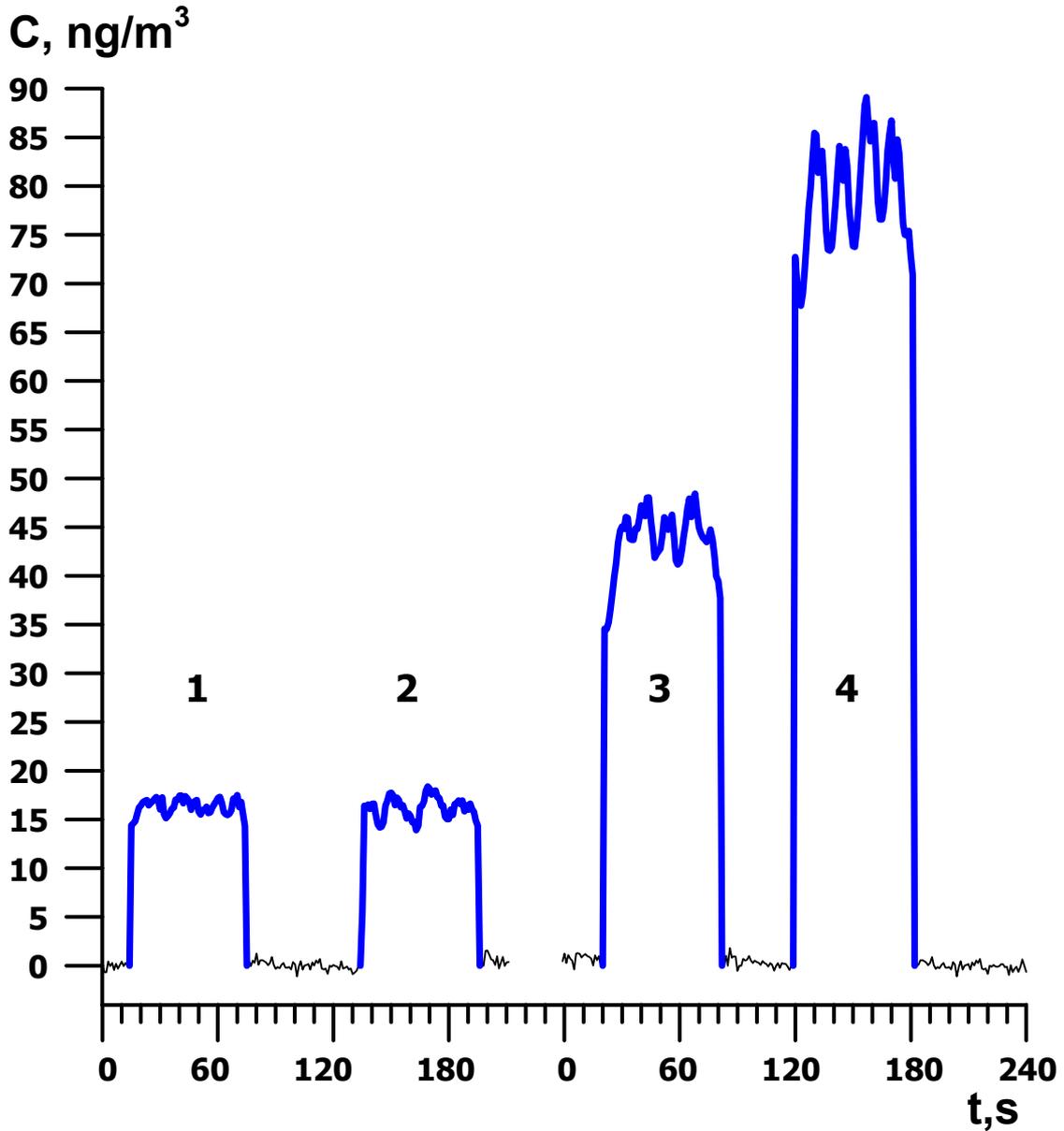
1 – concentration of mercury vapor in the indoor air
($C = 260 \text{ ng/m}^3$);

2, 3 – mercury in the exhaled air (EA) by volunteers

“P” ($C_{EA} = 55 \text{ ng/m}^3$) and “R” ($C_{EA} = 50 \text{ ng/m}^3$), Absorption $\approx 80\%$;

4,5 - mercury in the EA by volunteers “P” ($C_{EA} = 80 \text{ ng/m}^3$) and “R” ($C_{EA} = 210 \text{ ng/m}^3$) after drinking alcohol, Absorption $\approx 30\%$.

Fig. 2. Alcohol effect on the mercury content in the exhaled air (EA)



1,2 – mercury content in the EA by volunteers “P” and “R” ($C_{EA}=16 \text{ ng/m}^3$) before drinking alcohol;
3,4 – mercury content in the EA by volunteers “P” ($C_{EA}=44 \text{ ng/m}^3$) and “R” ($C_{EA}=79 \text{ ng/m}^3$) after drinking alcohol.

Fig. 3. Mercury content in the indoor air and the mercury dose received by volunteers “R” and “P” during the exposure experiment

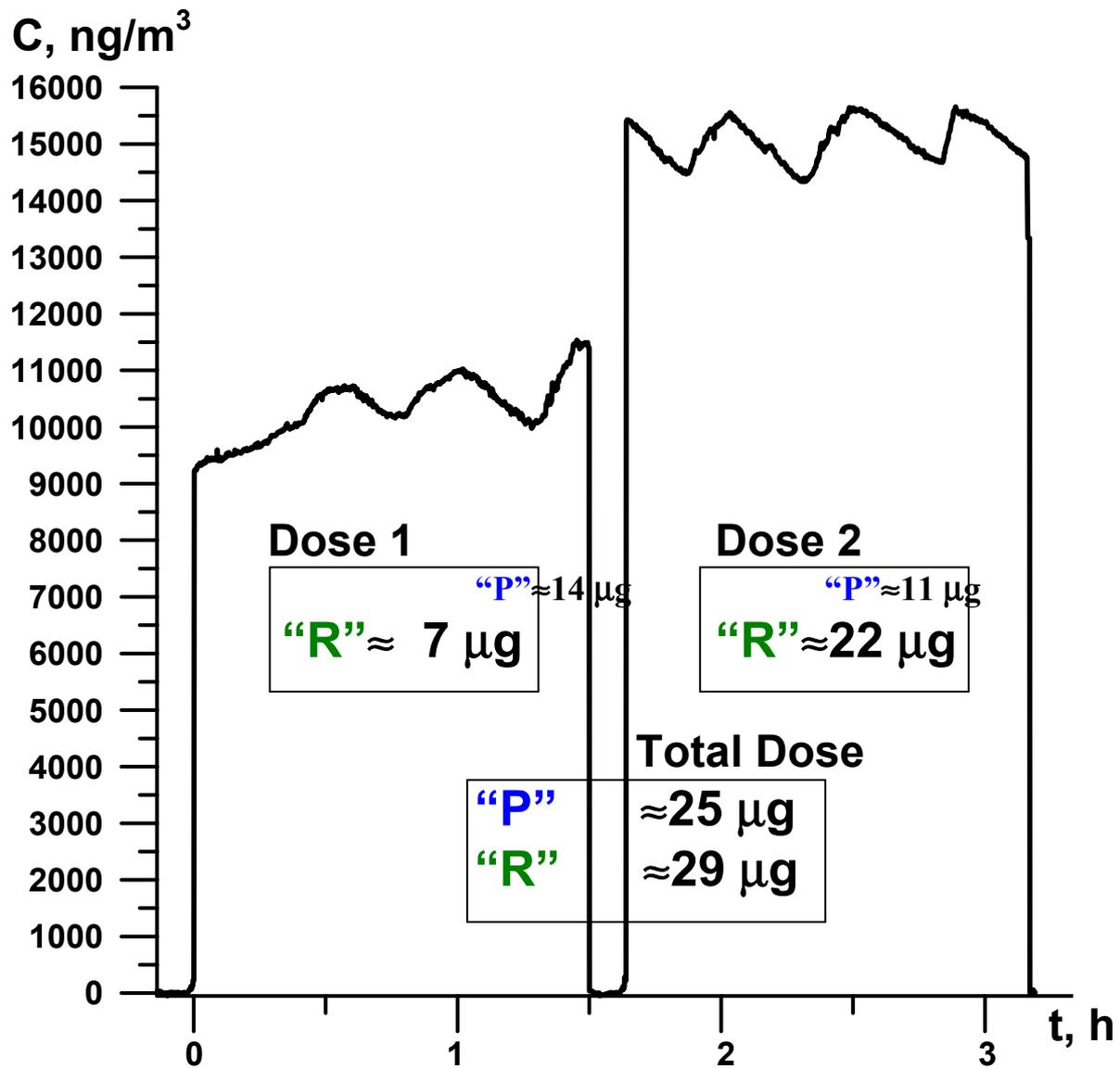
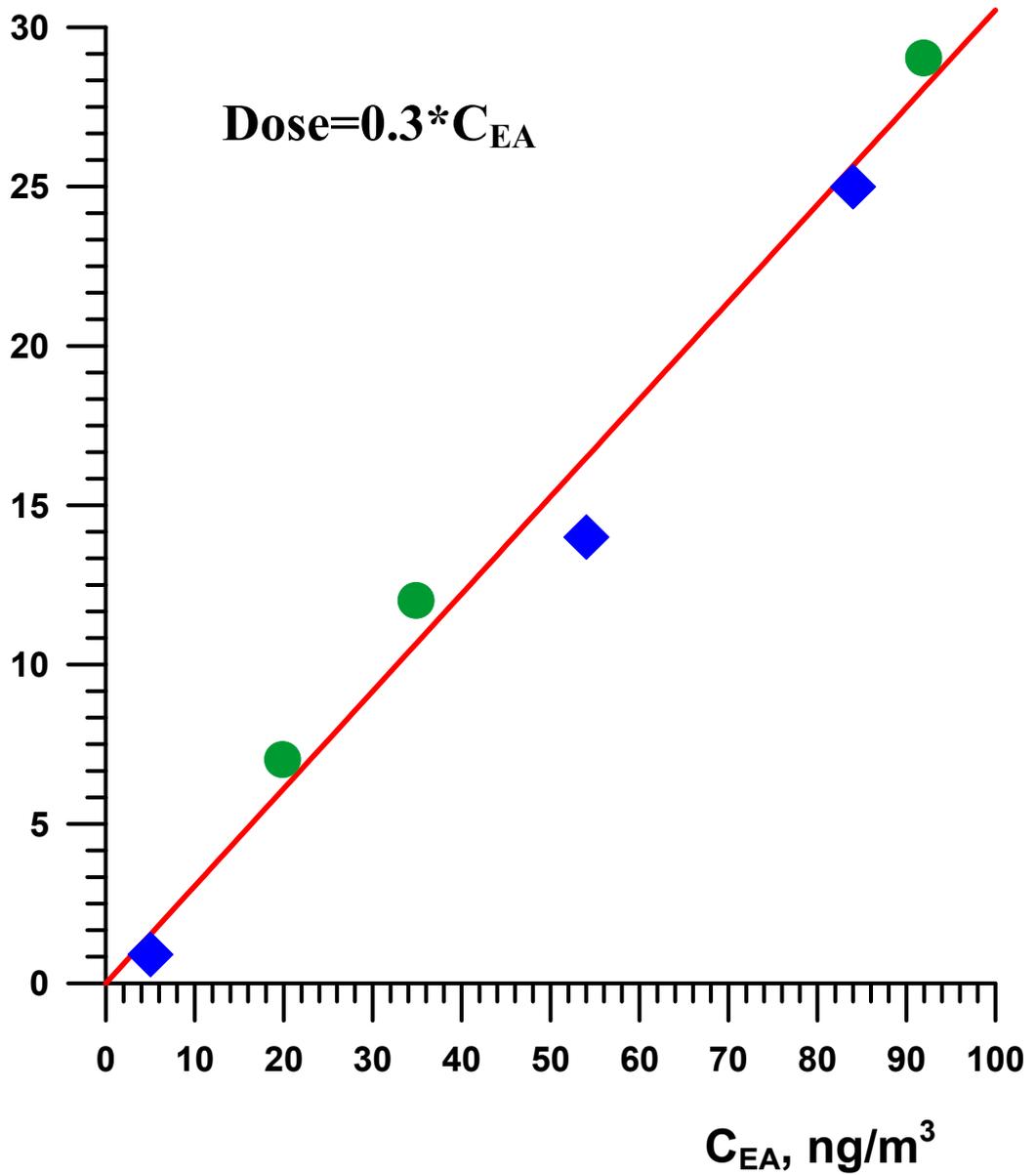


Fig. 4. The received dose vs. the mercury content in the exhaled air

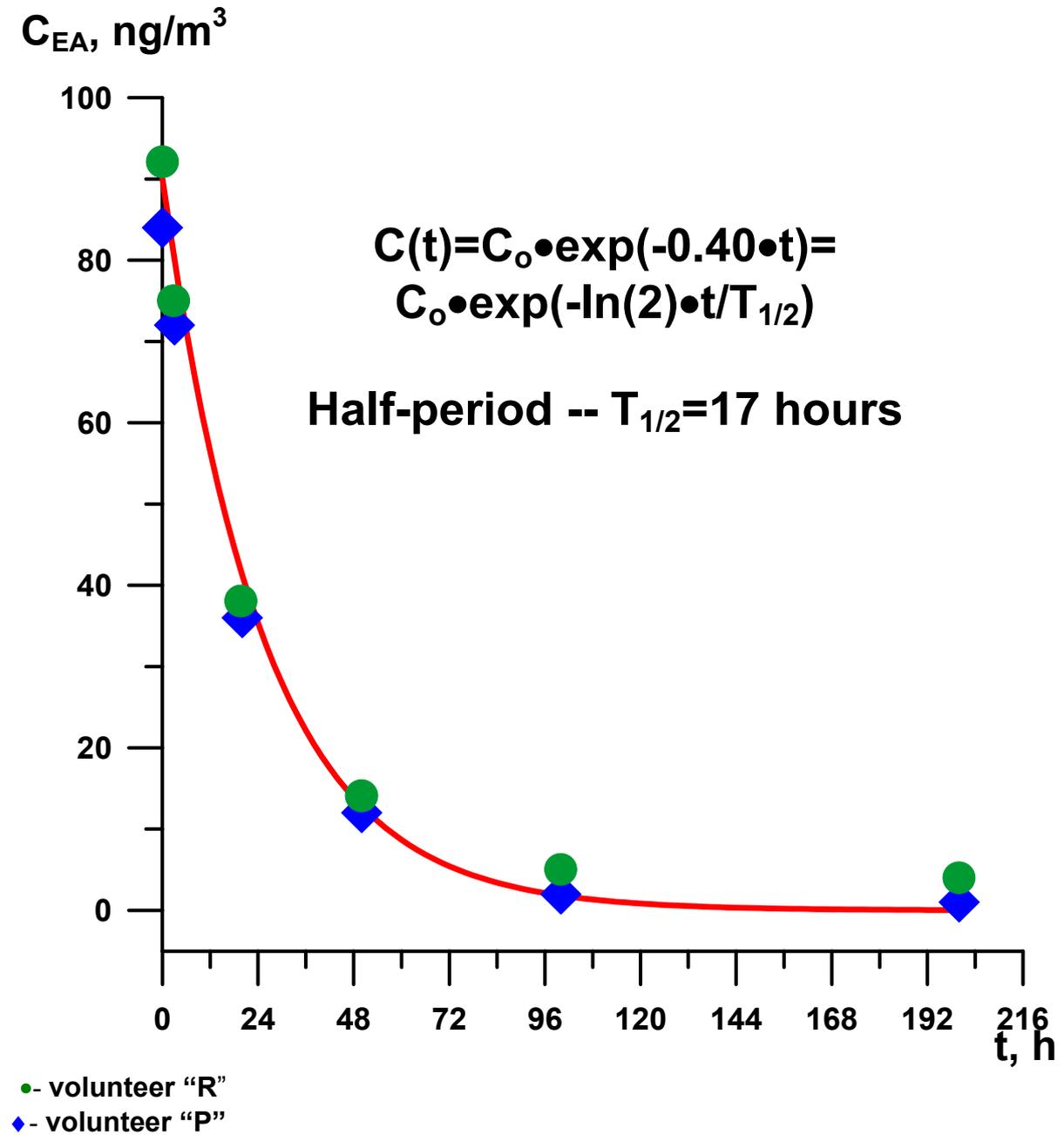
Dose, μg

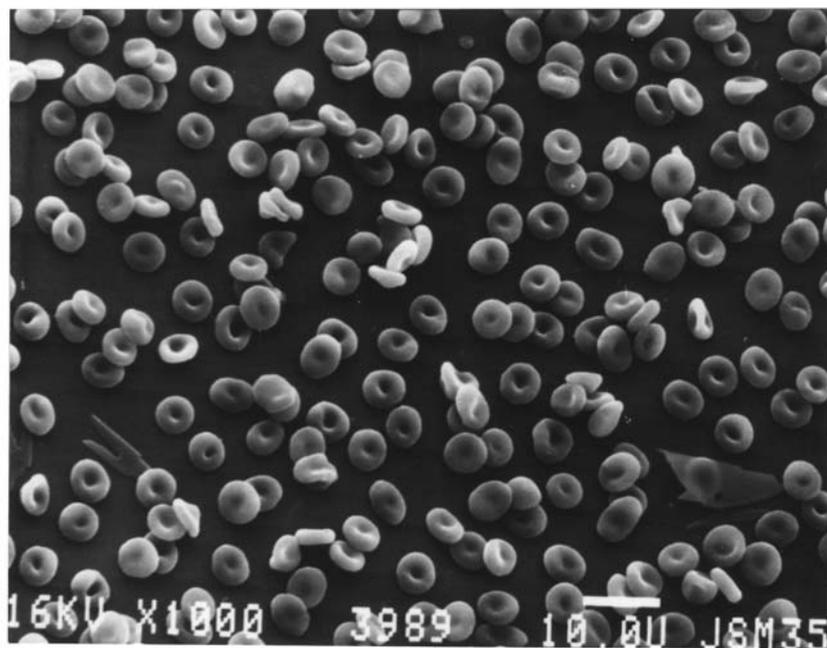
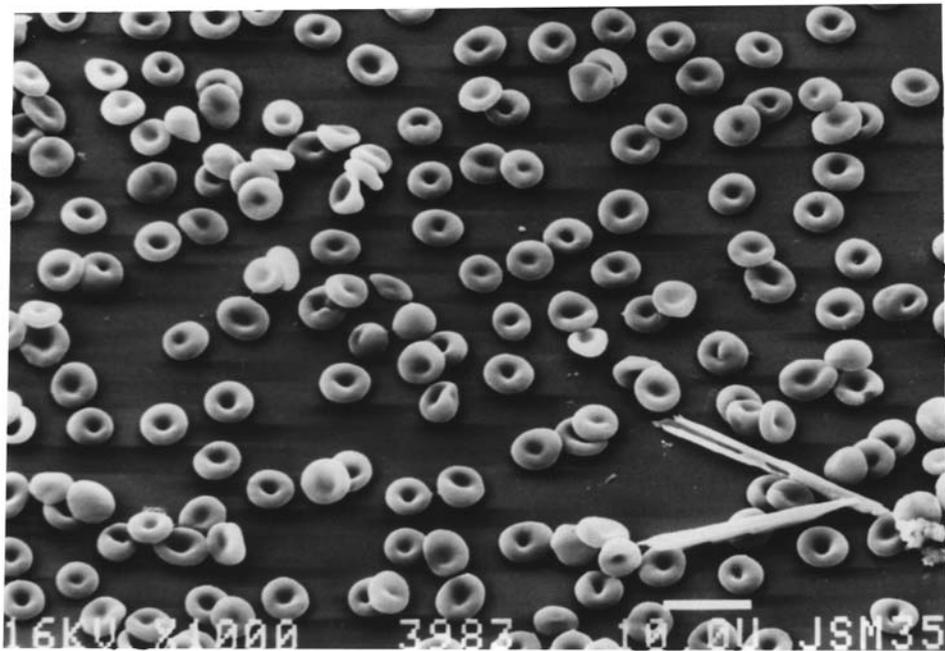


- - volunteer "R"
- ◆ - volunteer "P"

Measurements were performed immediately after the exposure to mercury vapor.

Fig. 5. Mercury content in the exhaled air as a function of the time after exposure to mercury vapor





1)

2)

Fig. 6. The photos (enlargement 4000) of blood erythrocytes before (1) and after (2) exposure (dose – 25 μ g), for volunteer “P”

After mercury exposure portion of unripe normocytes significantly increased for both volunteers (see Table)