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# CONTROLLING TECHNIQUE OF AN INDIVIDUAL FILTER SAMPLER

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***Abstract***

*Variants of individual filter samplers and various ways of controlling the speed of the air passing through the filter under different conditions of samplers' application are considered. Prerequisites for improving reliability of the results obtained, as well as conditions of the samplers' optimization and application have been analyzed. Pros and cons of their speed control were pointed out. Emphasis is made as to the importance and adequacy of the respiratory signals or their imitation as a means of controlling the true speed of the air passing through the sampler filter.*

***Keywords:*** *individual sampler, impedance pneumography, respiratory parameters.*

## Introduction

On the one hand, reliable physiological and sanitary evaluation of the working conditions enables these conditions to be optimized and the worker's psycho - physiological loading to be improved. On the other hand, studying dust loading at working places when the samplers are used is based on a number of conventional techniques, using conventional equipment. Specifically, dust loading is studied using a weight method. Individual filter samplers with the constant air suction speed which is controlled within the range of 0.3 ÷ 3.0 l/min, with the air coming from the worker's head space further on through the dust filter, are typically used for this purpose. There are many samplers, for example, produced by the Casella Cel Inc. The dust amount, structure and composition are examined after they are removed. In doing so, direct measuring the respiratory parameters of the worker examined right at his working place is not actually used due to the difficulties of its performing [1-3]. That is why, the relation between the amount and structure of the dust actually inhaled and the dust parameters on the filter is fairly arbitrary, subjective and, as a consequence, not always reliable. In particular, this method does not ensure taking into account the current deviations in the dust amount and degree of its dispersion, especially in case of dust ejection or worker's moving about. Besides, during work, especially if it is not monotonous, the respiratory parameters of the worker under examination repeatedly change - breathing frequency (BF), tidal volume (TV) and lung ventilation per minute LV. There appear, in the process, shifts of different directions in the breathing frequency, tidal volume, lung ventilation per minute, exceeding sometimes several times the initial parameters, as well as changes in the heart rate, due to, among other factors, wearing a respiratory mask. These shifts provide an integral reflection on the worker's psycho physiological loading, the percentage of them amounts to tens, and they are reliably determined

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[4-7]. That is why, the lung ventilation assessment could significantly improve the impartial and reliable estimation of both the amount and fractional composition of the dust deposited in the respiration organs.

## Results and Discussion

The study of dust loading of a human organism under the natural conditions of his professional activity as well as the indirect assessment of individual respiratory organs' protection means can be conventionally classified as variants of the technical means given below.

Determining dust loading of the working place itself without taking into consideration the worker's psycho - physiological parameters. Similar to studying the atmospheric phenomena, the laser beam dying down can be determined for this purpose. Besides, a filter sampler which is close to the working place can also be used. These techniques are most technologically available. The operational relation between the investigation results and the current worker's psycho physiological parameters is not, however, apparent. This impairs the value of the results obtained.

Using an individual filter sampler with the constant air suction speed in the worker's head space, placed and controlled by the researcher within the range of 0.3÷3.0 l/min before the experiments start, taking into account lung ventilation parameters received earlier using any means. This technique is applied owing to the high level of the results reliability as compared to that of the results obtained using the technique mentioned above. Besides, inexpensive individual filter samplers are technologically simple to apply, which is quite apparent. The direct operational relation between the data obtained and the current psycho physiological parameters, especially in case of non-monotonous work, is, however, absent as well, similarly to the above mentioned technique. Thus, the data obtained retain certain subjective feature.

Using an individual filter sampler with a variable though controlled air suction speed within the range of zero up to the value set by the researcher. As a control facility, a functional generator of a variable impulse, e.g. sawtooth or triangular, is typically used. In doing so, with the signal increasing the suction speed of the individual sampler air intake is under control. With the signal decreasing, there is no air suction. The time-amplitude parameters of this signal can be specified, for example, by means of the data set stored in the sampler memory. They can be input online by the researcher, using a keyboard, USB, etc. It is more appropriate to control the suction speed, simulating the current worker's spirogram [1]. The spirogram shape can be soft-synthesized on the basis of some actual characteristics range, e.g. out of 5 ÷ 10 frequency breathing (BF) values, tidal volume (TV), lung ventilation per minute LV the rates and duration of inhalations and exhalations. The opportunities provided by microcontrollers make solving this problem feasible. Accumulating the workers' spirographic data corresponding to the conditions of a particular working process ensures greater reliability of the research results as compared to that provided by the above-mentioned techniques. This technique can be regarded as essential and sufficient for the majority of the experiments, in other words, the best one. Taking into account the effect of changes in the local dust loading, dust ejection, changes in the working conditions or the worker's movements around the plant' territory on the research results is, however, impracticable.

Determining dust loading of the working place itself taking into consideration the worker's psycho physiological parameters, first and foremost, his cardio respiratory parameters [2-4]. In doing so, the dust amount and degree of its dispersion are most reliably evaluated taking into account the changes in the psycho physiological loading. It's necessary to note that wearing a dust-proof mask adds to the psycho physiological loading which changes the structure of cardio respiratory parameters and their deviations greatly. It is known that wearing a mask on one’s face leads to decreasing breathing frequency, with the tidal volume increasing by tens per cent, lung ventilation and heart rate increasing by several per cent even in the course of some minutes of the examination as compared to the direct Douglas mask control method [4]. Cardio respiratory data can be allowed for with high degree of reliability, controlling the suction speed of the individual filter sampler by means of a breathing parameters sensor. In this case, the air stream in the individual sampler duplicates the current breathing curve. The stream is uniquely dependent upon the breathing frequency (BF), tidal volume (TV), lung ventilation per minute LV, the rates and duration of inhalations and exhalations. This ensures the objective assessment of dust loading near the worker’s face as well as the dust amount and its structure. It will be possibly enough to control the individual sampler when inhaling only. The research aimed at investigating in the exhalation stage will be of interest at a later time. This approach enables the amount and fractional composition of the dust deposited in the respiration organs to be assessed. The study of dust loading at the working place, simultaneously taking into account the worker’s cardio respiratory parameters is the most reliable, technologically appropriate and promising technique.

A spirometric sensor is used, first, as a sensor of direct measurements, e.g. the turbine, secondly, as a sensor of indirect measurements, e.g. the chest thorax parameters sensor. The former is accurate but increases the worker’s psycho physiological loading both due to some resistance in breathing, and due to the necessity to attach it to the worker’s face. The latter is less accurate but ensures free breathing, and provides obtaining some physiological parameters, e.g. heart rate. That is why, in conducting comprehensive investigation it is more preferable. Measuring the chest thorax perimeter, for example, using an elastic belt is not stable and has a high correlation $r \approx 0,6$ c of the lung respiration. In perspective, a sensor will be used in the form of the impedance pneumography [4], the spirogram and the impedance pneumogram are correlated: $r = 0,95 \div 0,99$ [5]. Impedance pneumography is a maskless method of measuring the variations in transthoracic electrical impedance $\Delta Z$ by means of the Ohm law, associated with changes in the aeration of the lungs and the volume of the chest thorax. The 4 – electrode impedance pneumography is different in measuring the lung ventilation per minute, using the Douglas control method - $\Delta V / V \leq 20\%$, even in case of continuous telemetric investigations under natural conditions [6]. The advantage of the maskless control of the sampler is the absence of both the psycho physiological loading and resistance to breathing. Then, there is the most important fact that, in the course, the structure of respiration is not distorted. It has been pointed out that under laboratory conditions, applying even a less disturbance-proof two-electrode impedance pneumography for controlling an individual sampler provides a two-fold increase in the accuracy of the dust loading measurements [2]. It is strongly recommended to use an individual sampler possessing a 4 – electrode impedance pneumography [4, 6, 7].

Comparing the four above-mentioned variants enables to outline the fields of their application. The first one is economical but subjective and can be used by those whose qualification is not high or who have no special medical sanitary education. This variant is advisable when there are no strict requirements as to the accuracy and reliability of determining the dust loading at working places as well as when the workers’ psycho - physiological parameters are not necessarily to be taken into account. This technique can be used in the course of continuous periodical testing the dynamics of the working places’ dust loading.

Besides, it can also be used if there no dust ejections and when the levels of the working places' dust loading are stable for a long time.

The second variant is fairly widely used. It is economical, technologically feasible and can be realized by the medical personnel of medium professional skills. The choice of the individual sampler speed set and controlled within the 0.3 ÷ 3.0 l/min range, as well as making the experiments, using an individual sampler attached to the worker require the researcher to have a medical sanitary certificate and certain organizational activities to be performed. To evaluate the results of the investigations, the available data bank comprising a priori collected physiological parameters, first of all those of lung ventilation, and sanitary standards of dust loading for this particular type of professional activity are used. Investigations can be made on both regular and selective basis. The availability of a wide range of individual samplers, for example, CEL712, Microdust Pro, Apex Pumps of the Casella Cel Inc. provides the necessary hardware for ensuring the investigations. The trouble with this technique is the subjective nature of the choice to be made, insufficient reliability of the relation between parameters of the dust deposited on the filter and those of lung ventilation. Besides, it is impossible to reliably allow for the results of the dust ejections or the worker's movements around the plant. The third variant ensures improving the accuracy and reliability of experimental results as compared to the previous one. The individual sampler stores in its memory a data bank with a priory collected spirometric, pneumographic or simulation parameters. They enable controlling the speed of the air passing through the filter in the manner similar to the inhaling phase. This variant represents the evolution of the previous one of the individual sampler. The experiments, in the course, remain essentially unchanged in terms of technological, organizational and economical aspects. The drawbacks are similar to those of the previous variant but to a lesser extent. In particular, the choice of the individual sampler speed retains its subjective nature. In this case, it is possible for the results of experiments to differ in comparison to the previous variants. It can entail changing the sanitary parameters, e.g. marginal concentrations, as well as the organizational activities aimed at changing the operational and working conditions. The third and the fourth variants of the sampler control are shown in Fig.1 and the main oscillograms are shown in Fig. 2.

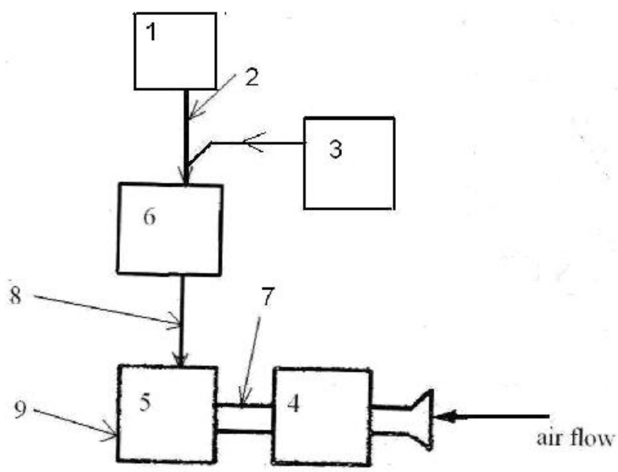


**Fig 1.** The sample control: 1 – impedance pneumograph; 2 - impedance pneumogram; 3 - imitator of the pneumogram; 4 – filter; 5 – individual sampler; 6 –inspiration allocation apparatus; 7 – air flow of the sampler; 8 - inspiration signal; 9 – electric power of the sampler

The forth variant represents the evolution of the third one. It ensures the fundamental improvement of the experimental results' reliability and accuracy, compared to the effect of the previous variants. Only this variant provides the true value of the dust loading during a working shift irrespective of the variations in the work intensity, dust ejections, worker's movements around the plant, etc. Besides, the availability of physiological parameters characterizing lung ventilation ensures reliable evaluation of the fractional dust composition, taking into account the time, inhaling rate and the tidal volume. These approach and technique are essentially more complex than the previous ones; they require more highly qualified researchers, including in the field of medical investigations. The application of this technique is limited as compared to the application of the above-mentioned variants.

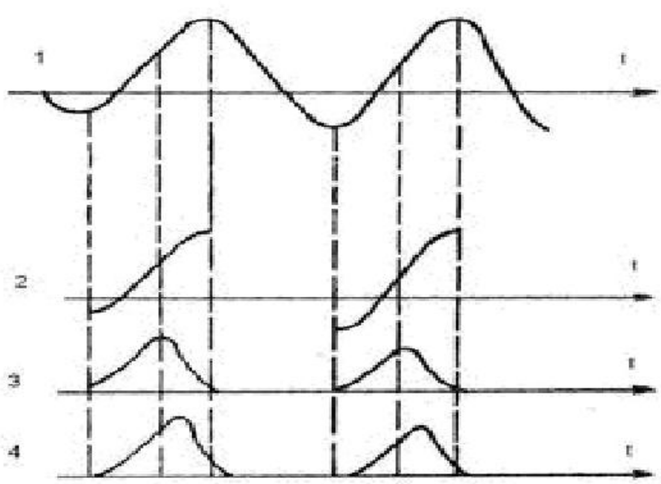


**Fig. 2.** The signals of respiration system: 1 - pneumogram, 2- inspiration, 3 – electric power of the sampler, 4 – air flow of the sampler

But in order to develop norms, standards and to perform highly accurate scientific investigations in the field of occupational pathology, as well as to test the individual means of respiratory protection, it is this investigation technique that is most efficient. It enables impartially justifying the future requirements to be imposed on developing and rating multifunctional individual samplers compatible with the complexes for measuring the cardio respiratory parameters, e.g. telemetric cardio-monitors.

## Conclusion

The analysis of variants of individual filter samplers, the fields of their application, their advantages and drawbacks has demonstrated the efficient use of the controlled individual samplers of the second and third variant in the majority of cases. The basic drawback of these techniques is the subjective nature of the choice to be made as to controlling the speed of the air passing through the filter.

Control of the individual sampler in accordance with the worker's lung ventilation will be used more seldom as it makes the investigation significantly more complicated. This controlling technique, however, provides the true studies of the effect of dust loading on the human organism in the working zone and enables implementing deep comprehensive physiological sanitary and rating investigations.

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