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THE USE OF PERSONAL SAMPLING METHODS AS AN AID IN THE ASSESSMENT OF THE TOXICOLOGICAL RISK AT THE WORKING PLACE*

by

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SUMMARY

Where small concentrated pollution sources are involved the concentration of the pollutant depends strongly on the specific location. Therefore, when work is carried out near such a source - a condition which is often found in practice - the determination of the pollutant concentration should be made with a personal sampler in the breathing zone of the exposed person. If this is not done considerable errors in judgement of the toxicological hazard which is involved can be made. Another application of personal sampling devices is in the determination of the exposure of highly mobile personnel such as maintenance men.

In this paper, an explanation of the typical field of application of personal sampling equipment has been given, followed by a brief comparison between the general properties of personal sampling and conventional sampling devices and then by a survey of personal sampling devices which are at present used. Measures taken when results of concentration determinations exceed allowable limits are illustrated using a pollution control diagram. Finally a brief outline is given of developments which will be of increasing importance in the near future.

THE USE OF PERSONAL SAMPLING METHODS AS AN AID IN THE ASSES~~MANT~~sment OF THE TOXICOLOGICAL RISK AT THE WORKING PLACE

INTRODUCTION

Life processes can only be maintained by using energy. The generation of this energy takes place in the smallest building blocks of living organisms, namely the cells. The complex reactions which provide the energy in the human body cell can basically be described as the oxidation of food components with oxygen taken up from the surrounding air. Blood is the transportation medium. It carries food components and oxygen to the cells and removes waste products from them. The exchange of gases - oxygen from the surrounding air to the blood and carbondioxyde from the blood to the surrounding air - occurs in an exchange device - the lungs - which consist of 300 - 500 million vesicles called alveoli, with a total surface area of 80 - 130 m^2 (see Figure 1). The thickness of the membrane which separates blood from the air is approximately 10^{-4} mm.

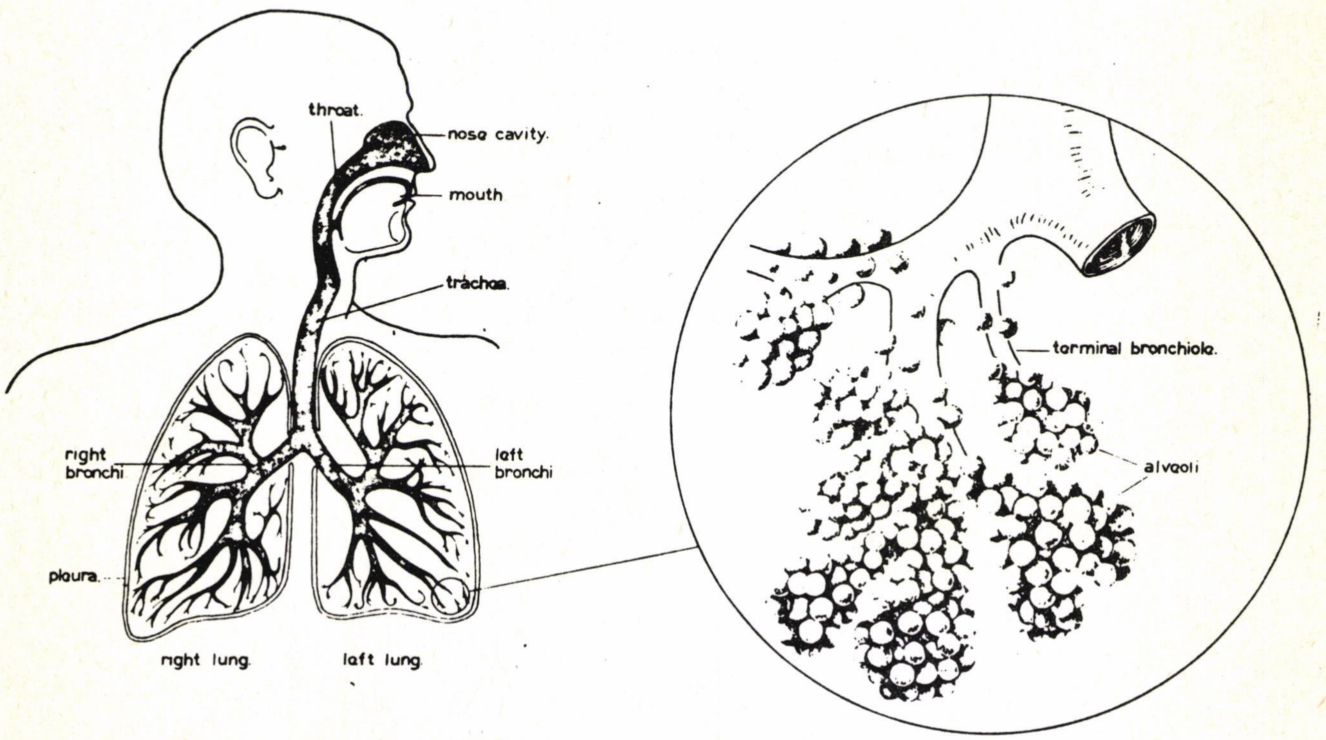

FIG.1: SCHEMATIC DIAGRAM OF LUNGS AND AIRWAYS.

Perhaps this gives some idea of how the delicate this exchange device is and it should not be forgotten that its correct functioning is a necessity for good health.

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The lungs are protected by a complicated filter which consists of nose/mouth, trachea and bronchi. This filter absorbs gases and retains particles (Figure 2).

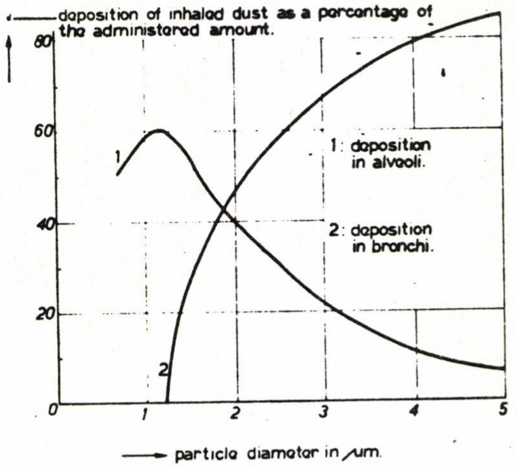

FIG 2 : DEPOSITION PERCENTAGE OF DUST PARTICLES IN ALVEOLI (1) AND BRONCHI (2) IN RELATION TO PARTICLE DIAMETER.

Dependent on the amount of work which has to be performed, the amount of air taken in by a healthy adult can vary from between 5 l at rest to 45 l per minute during very heavy work. For very short periods, amounts of 170 l per minute have been recorded.

From these figures it should be clear that in principle considerable amounts of toxic substances contained in air can enter the body.

In fact the breathing mechanism is considered to be the major entrance route to the body for toxic substances taken up during work. Therefore in almost all industrialised countries, rules for the maximum allowable concentrations of toxic substances in the air at work have been made [1,2,3,4]. They are based on the time-weighted average concentrations for an eight hour working day - forty hour working week - to which people can be exposed without suffering adverse health effects as far as is known at present. By using an average concentration as a basis, higher concentrations are permitted provided that they are compensated by lower values. It is clear that this rule is limited in application. As a rule of thumb peak concentrations during a relatively short time (15 minutes) should stay below 1,25 - 3 times the maximum allowable concentration [5]. It should be mentioned that for some substances no departion over the maximum allowable concentration is allowed.

With the knowledge of what is the maximum concentration allowed for particular substances and some rules on how to handle mixtures of toxic substances, theoretically it should not be too difficult to ensure good

-working-

working conditions when based on proper air monitoring. However, in this paper we look at some of the difficulties which are encountered in practice.

SAMPLING

Two steps can be distinguished in the determination of the concentration of pollutants:

1. the taking of one or more sample(s) which should be representative of the situation;
2. the determination of the amount of pollutant which is present in the samples.

Both operations can be performed discontinuously or continuously.

In this report, the focus is on the sampling operation, which consists of the collection of a known volume air from a chosen area at a chosen interval in time. Examples of sampling devices are shown schematically in Figure 3.

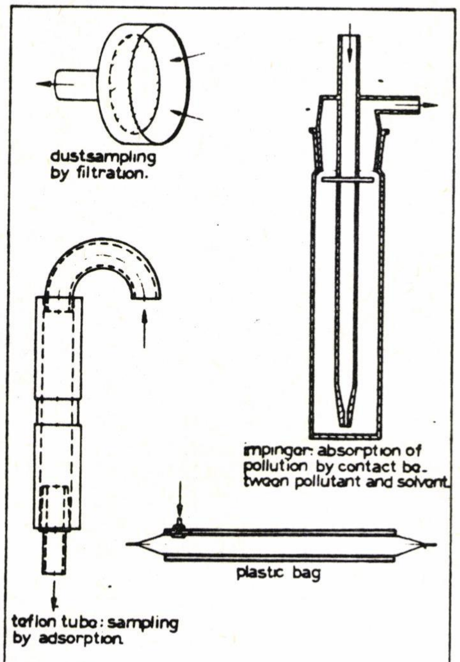

FIG 3: SCHEMATIC DRAWINGS OF A FEW SAMPLING DEVICES.

Sometimes considerable "enriching" effects can be obtained during sampling e.g. adsorption of pollutants on active carbon. The reverse operation, i.e. removing the pollutant from the carbon is performed at an elevated temperature with the aid of a small gas current which can result in an enrichment factor of 1,000. Since high enrichment factors lead to complications

-during-

during subsequent analysis, sampling and analysis have to be tuned to each other. From this it can be seen that though sampling and analysis are different and in general easily distinguishable steps, their interdependence is very strong and every indoor air pollution measuring problem has to be designed taking its own peculiarities into account.

This subject will not be further pursued but we shall restrict ourselves to considerations related to the fact that the concentrations of pollutants vary in general from place to place and in time.

These effects are strongly manifest when studying the exposure of workers in professions such as finishing, paint spraying, welding, fettling, etc. In these professions the action of the person under consideration creates a pollution source locally and in the immediate neighbourhood of this person. Under these circumstances the concentration decreases very rapidly with distance and the result of concentration determinations depends very much on the sampling location (Figure 4).

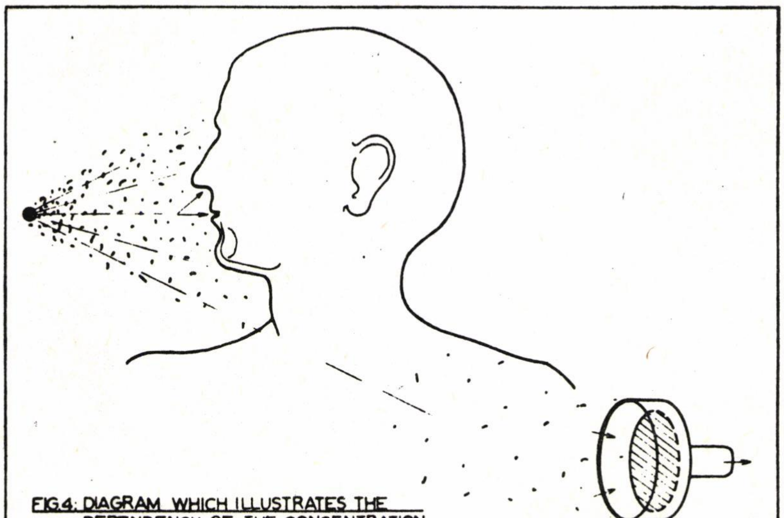

FIG.4: DIAGRAM WHICH ILLUSTRATES THE DEPENDENCY OF THE CONCENTRATION ON THE SAMPLING LOCATION IN SPACE.

In these cases, determination of concentrations in the breating zone with personal samplers might result in establishing concentrations which are 10 x higher than concentrations determined with conventional sampling devices.

The location of the sampling device is not the only point to be considered. Another important parameter is sampling time, which is influenced by a number of factors:

1. Enough material has to be collected to perform a quantitative determination.

   Note: For the determination of the concentration of respirable dust, this means a sampling time of approximately 8 hrs with a personal sampler and approx. 1 hour with conventional devices.

-Gas-

Gas sampling devices are set in such a way taht in general the sample has to be taken in ½ - 1 hour.

2. Time should be long enough to give a good approximation of the exposure.
   Note: As a generalisation, it can be said that up to now the sampling devices treated function discontinuously. They are satisfactory if average exposure concentrations have to be determined, but are somewhat cumbersome to use if peak concentrations have to be determined.
3. Sampling time has to be as short as possible, so as to cover as large an area as possible with limited equipment and manpower resources.
   Note: Generally a one hour sampling period - provided that enough material can be collected - is a fair compromise.

SURVEY OF PERSONAL SAMPLING DEVICES

In general, samplers consists of a pump, a power source and a number of interchangeable devices which collect a certain amount of air, or trap the pollutant present in the air. It is important that the air current provided by the pump during the sampling operation is kept constant. Constant air flow is sometimes guaranteed by automatic control devices, but usually the air flow is simply checked from time to time with a flowmeter. Personal equipment differs from conventional equipment in the smaller size, while pumps in general are battery powered (50 - 100 Whr).

Where gaseous pollutants have to be determined, the absorption of the pollutants by appropriate liquids, though sometimes used,has disadvantages. Personal sampling methods in general are restricted to two types. Firstly by bags-approximately 2.000 cm^3-made of plastic with a low adsorption tendency to the substances which have to be determined e.g. Tedlar (polyvinylfluoride), Mylar, Saran, can be used for many organic vapours; and secondly by the adsorption by e.g. active coal, silica gel, molecular sieves packed in glass or Teflon tubes, followed by desorption by elutriation with e.g. dimethylformamide or at elevated temperature by a gas stream.

Figure 5 shows a personal sampling device for the determination of respirable dust which has an equivalent aerodynamic diameter, at unit density, smaller than 10 µm.

-Figure 5-

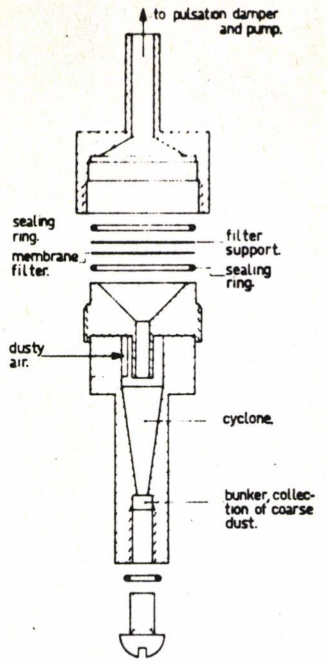

FIG. 5: PERSONAL AIR SAMPLER.

The following table gives a comparison between personal samplers and conventional sampling devices.

Table. Comparison between personal sampling and conventional sampling devices

Property	Personal sampler approx. data	Score	Conventional sampler	Score
1. Weight	1 kg	+	up to more than 40 kg	-
2. Ruggedness		+		+
3. Sampling volume	30 cm^3/sec	±	300-30,000 cm^3/sec	±
4. Sampling speed	cm/sec	±	m/sec	±
5. Dust sampling	(respirable dust only	−	(total dust and respirable dust	+
6. Gas sampling		0		0
7. Relative accuracy	15 %		5 %	
8. Sampling time	approx. 8 hrs		in principle unlimited	

\+ favourable; − unfavourable; 0 no preference.

NOTES

1. Personal samplers with a weight up to 1 kg are readily accepted. With increasing weight the acceptance decreases, e.g. 4 kg seems to be too heavy. The weight of conventional devices is also decreasing.
2. There is probably not a necessary relation between size and ruggedness.

3. This are approximate figures. At very low concentrations the small sampling volume of the personal sampler might be a disadvantage. However this tendency is balanced by the development of analytical equipment with a higher sensitivity. High volumes might influence the concentration in a closed environment.
4. The low sampling speed is a disadvantage when the total dust concentration has to be determined.
5. See point 4.
6. Gas sampling devices can be set in such a way that the sampling volumes and speeds stated in the table are not a limiting factor.
7. In general, higher accuracies of the determination can be obtained with conventional devices.
8. The limiting factor is the amount of energy which can be stored in the batteries.

EVALUATION OF RESULTS

Most pollution problems are described by the diagram shown in Figure 6.

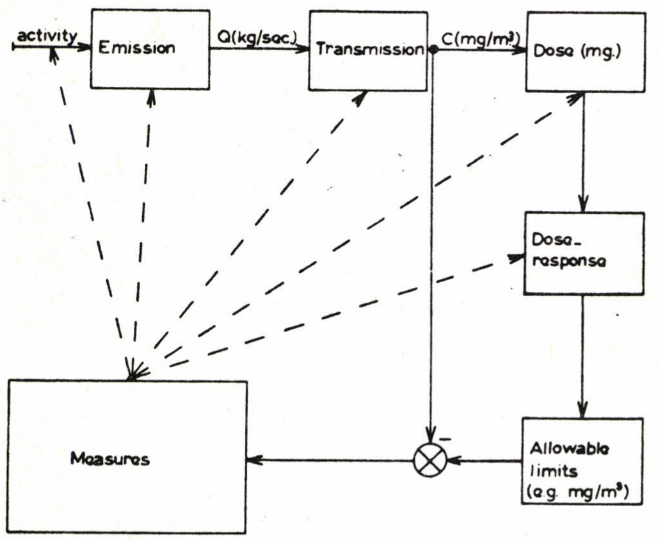

FIG.6: POLLUTION CONTROL DIAGRAM.
the symbols used are related to an air pollution control problem

If allowable limits are exceeded by concentration determinations, a number of measures can be taken, for instance:

1. A change of posture might influence the concentration in the respiration zone considerable.

2. It might be necessary to change the process.
3. If work has to be performed near an emission source, decreasing the concentration near the men by increasing the general ventilation is often very inefficient. However, the transmission might be influenced by a local exhaust near the emission source - e.g. a low volume, high velocity exhaust.
4. The amount of toxic substances taken up can bekept within acceptable limits by using protective devices (masks). This is an unattractive alternative, but sometimes is unavoidable.
5. The dose - response relationship might be influenced by medical slection of the right personnel.

In practice, combinations of these measures are generally taken.

NEW DEVELOPMENTS

Personal sampling methods are being developed in two directions:

a. Portable instruments which indicate momentary concentrations. They are specially useful if pollution sources have to be traced. They save the time of laboratory personnel and equipment. These instruments combine sampling and analytical operations and are therefore much more expensive than simple sampling devices. They are more delicate and need regular maintenance and calibration.

b. Biological sampling. The whole concept of the maximum allowable concentration is geared to average situations and can only be used as a guideline. To illustrate this one has only to consider the amount of toxic substance D (mg) taken up from the inhaled air which approximately can be represented by

$$D \approx \int_{t_b}^{t_e} 0.001\, \dot{V}\, (c_i - c_0)\, d\, t$$

$\dot{V}$ = amount of air inhaled in l/min;

c_i = concentration of toxic substance(s) in the surrounding air as a function of time;

C_0 = concentration of toxic substance(s) in the exhaled air as a function of time;

t = time in minutes;

t_b is beginning, t_e is end of exposure.

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Since $\dot{V}$ can greatly vary e.g. as a function of work load, the amount which is taken up during exposure can vary considerably. This is one of the reasons why investigations are going on to try to correlate the composition of the exhaled air, urine, blood or other body fluids with amounts taken up by the body. Apart from alcohol and a few industrial toxins such as lead, there are still many problems which have to be solved before this interesting approach will find general application.

To summarise, it can be stated that to keep the risks from exposure to potentially dangerous substances within limits, increasing vigilance will be necessary. Personal monitoring for which personal sampling is a necessary step will therefore increasingly be used in the coming years.

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[5] Issue 1974 of Threshold Limit Values (Ref. 1), Appendix D, pp. 52 - 53.

* References [1,2,3] are reissued every year with changes and corrections.

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