Passive dosimeters and their comparison with the standard method of determination of contaminants in working atmosphere

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The results of model measurements and the values of basic parameters of diffusion dosimeters which are independent of the rate of air flow in the investigated range 0.1—3 m s^{-1} are presented in this paper. The basic parameters of diffusion dosimeters obtained from model experiments involving the determination of toluene and n-butyl alcohol were used for calculating the basic parameters incident to methyl methacrylate, butyl acrylate, vinyl chloride, and vinyl acetate. In field-work conditions, the reliability and correctness of the withdrawal with passive dosimeters were verified on the basis of comparison with the standard method of sampling chemical contaminants with sampling tube.

Приводятся результаты модельных измерений и значения основных параметров диффузионных дозиметров, не зависящие от скорости тока воздуха в изучаемом интервале от 0,1 до 3 м с$^{-1}$ Основные параметры диффузионных дозиметров, установленные в модельных опытах по определению толуола и н-бутанола были использованы для расчета основных параметров для метилметакрилата, бутилакрилата, винилхлорида и винилацетата. В полевых условиях была проверена надежность и правильность измерений пассивными дозиметрами по сравнению со стандартным методом измерения содержания вредных веществ с помощью отборной трубки.

The most frequent problems of theoretical and experimental interest in papers dealing with passive dosimeters containing preceding diffusion element and solid sorbent are geometry and construction of dosimeter, conditions of measurement, quality of sorbent, and properties of diffusing substance or substance mixture [1—8]. The substance amount captured by dosimeter as described by the Fick's law [2] corresponds to the ideal case of molecular diffusion. The geometrical arrangement of dosimeter (parameter A/l, A — area of dosimeter, l — length of diffusion path) influences the substance amount

which diffuses through diffusion element to the surface of sorbent if the concentration of this substance in air varies [9, 10]. The driving force of diffusion by means of which the sampling is accomplished is the concentration gradient. This gradient comes into existence in close proximity of a passive dosimeter with diffusion element, at the inlet and infinitesimal thin layer by the surface of sorbent. The conditions of molecular diffusion are the postulate that the concentration of substance on the surface of sorbent must approximate to zero, sufficient capacity of sorbent with respect to sorbate, and firm fixation of sorbate on sorbent. The efficiency of substance sampling with respect to the interaction with surface was studied by *Underhill* [11] and the theoretical aspects of substance diffusion towards the surface as well as the reverse diffusion are described by *Moore et al.* [9].

By investigating the operation of our dosimeters [2] under field-work conditions, we found the influence of air flow on the amount of the captured substance in dosimeter. In order to eliminate this influence, we investigated the dependence of dosimeter geometry on the outside rate of air flow. Dosimeters with high value of A/l ($A/l \gg 10$) exhibited a less significant dependence of the deviation from the amount of the captured substance calculated according to the first Fick's law on the outside rate of air flow, which was in good agreement with communications [12—15]. However, high values of A/l (diffusion resistance) result in extension of the sampling time with respect to the analytical method used for the determination of substances in atmosphere, owing to which the risk of the influence of air humidity and prolongation of dosimeter response grows.

The influence of air flow on the results obtained with our dosimeters [2] was eliminated by a modification of dosimeter (Fig. 1) consisting in covering its inlet side with a glass fabric of square mass $110\,g\,m^{-2}$. The dosimeters $\bar{K}$ and $\bar{P}$ thus modified are independent of air flow in the range of the investigated rate of air flow 0.1—$3\,m\,s^{-1}$. The precision and correctness of the data obtained by both types of passive dosimeters were experimentally verified in an exposure chamber and under field-work conditions by comparing them with the data obtained by the standard method involving the sampling of chemical contaminants with sampling tubes.

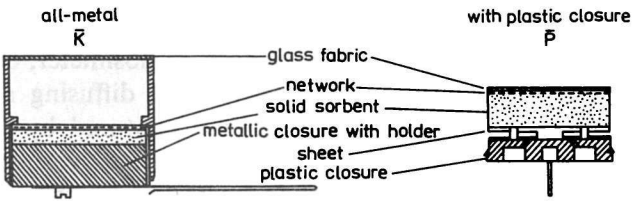

Fig. 1. Passive dosimeters.

Experimental

Model experiments involving the exposure of dosimeters in a chamber

The required concentration of individual contaminants in the chamber was achieved by dosing the calculated amount of the freshly distilled substance into the chamber the atmosphere of which was stirred by a fan placed on the bottom. The exposure chamber of 0.7 m^3 volume was made of rubber-fabric and glass plates with different tightly closing manipulation and control holes and a built-in temporally adjustable automatic stirring of atmosphere. The regulation of air flow in the chamber during the exposure of dosimeters lasting for 1 or even 4 h was accomplished by a small fan with adjustable revolutions. The rate of air flow at the inlet of dosimeters was continuously controlled by a thermoanemometer (Wallac, GFR) while the concentration of contaminants in the chamber was continuously recorded by an infrared analyzer of gases and vapours (MIRAN IA FOXOBORO, USA) and discontinuously recorded by a gas chromatograph (Hewlett—Packard 5830A, USA). During the exposure of dosimeters the atmosphere was also checked by means of sampling tubes through which 3—10 dm^3 of air were sucked by using individual withdrawing pumps (Sipin S-15, A. J. Sipin Co., USA).

The content of gaseous contaminants in the volume dosed into the gas chromatograph was determined on the basis of direct calibration of chromatograph with the solutions of contaminants in carbon disulfide or an extraction agent.

The content of substances taken with sampling tubes was determined according to known methods [16—18]. The differences between the concentration determined by the method of direct dosing and the concentration continuously measured by MIRAN IA as well as the average values temporally weighed for a certain time of exposure did not exceed 5 %.

The dosimeters were tested in the temperature range 294 K—308 K, the relative humidity of gaseous mixture being 45—65 %. The mass concentration of contaminants varied in the range 10—200 mg m^{-3} for vinyl chloride (VC), vinyl acetate (VAC), methyl methacrylate (MMC), butyl acrylate (BAC), and n-butyl alcohol (n-B) and in the range 100—500 mg m^{-3} for toluene. The time of exposure was equal to 1—4 h.

Testing of dosimeters under field-work conditions

The dosimeters were tested in working atmosphere under field-work conditions by the simultaneous use of personal sampling (system sampling tube—personal sampling pump) and stationary sampling (system sampling tube—pump).

The volume flow for personal sampling was 20—40 cm^3 min^{-1} while it was 200—500 cm^3 min^{-1} for stationary sampling. After sampling the activated carbon was taken from the passive dosimeters or sampling tubes, poured into a ground glass tube with 2 cm^3 of extraction agent cooled to the temperature of a mixture of ice and NaCl. The extraction was terminated under intermittent stirring after 60 min. After extraction 1 cm^3

of the solution was mixed with 1 cm^3 of the solution of internal standard and the resulting solution was subjected to gas chromatographic analysis.

Results and discussion

According to the first Fick's law valid for ideal case, the parameter $D(A/l)$ which is constant for a given substance and type of dosimeter is directly proportional to the amount of diffusing substance n_t and inversely proportional to the time of diffusion t and concentration of diffusing substance c_t at the inlet into dosimeter [2].

The dependence of the parameter $D(A/l)$ on the rate of air flow in the exposure chamber was investigated in model experiments for dosimeters of the type (K, P) [2] and dosimeters with the modified inlet side ($\bar{K}$, $\bar{P}$) [19]. Toluene and n-butyl alcohol the diffusion coefficients of which are known were used for these experiments. D(toluene) = 0.0849 $cm^2\,s^{-1}$, D(n-butyl alcohol) = 0.0861 $cm^2\,s^{-1}$ [20].

The precision and correctness of the parameter $D(A/l)$ the dimension of which is equal to the volume air flow in the diffusion element of dosimeter depend on the precision and correctness of determination of the amount of substance captured on the surface of sorbent in dosimeter n_t, average concentration of substance c_t in the exposure chamber, and time of exposure of dosimeter t.

The precision and correctness of determination of c_t is given by the analytical method used for a certain substance. The methods used by us [16, 17] and the method of toluene determination [18] are precise and correct methods according to statistical valuation [21] because the value of relative standard deviation is 2.3—4.1 %.

Table 1 documents a good agreement of the values of ϱ_t obtained in model experiments by the method using a sampling tube with the values obtained by direct dosage into a gas chromatograph and with the values determined with an infrared analyzer of gases and vapours MIRAN IA.

The mass concentration $\varrho_t/(mg\,m^{-3})$ was calculated for MIRAN IA as average concentration in the whole time interval of sampling by continuous investigation of the concentration change in the exposure chamber. The values of ϱ_t obtained by the use of sampling tube were calculated from three measurements as average concentrations in the investigated time interval. This calculation was performed with ten measurements if the method of direct dosage was used.

On the basis of the presented results, we may state that the average concentrations of substances obtained from a given set of measurements by the method

Table 1

Measured and calculated average concentrations of substances in exposure chamber

Substance	Average mass concentration in atmosphere ϱ_t/(mg m^{-3})			t/s	Relative error/%	
	MIRAN	Sampling tube	Gas chromatograph		Sampling tube	Gas chromatograph
Toluene	126.5	126.8	126.1	3600	0.2	0.3
	495	485	498.5	3600	0.2	3.5
	250	245.8	251.5	3600	1.7	0.4
n-B	352	344.5	358.5	7200	2.1	1.8
	121	118.5	120.1	3600	2.1	0.7
	94	91	92.8	3600	3.2	1.3
MMC	120	115.3	121.7	3600	3.9	1.4
	69.8	66.9	70.5	3600	4.2	1.0
	25.8	24.9	25.5	7200	3.5	1.2
BAC	138	137.6	139.5	3600	0.3	1.1
	103	104.5	105	3600	1.4	1.9
	38.5	31.9	32.4	7200	4.8	3.3
VC	125	119.7	120.9	3600	4.2	3.3
	98	99.9	96.1	3600	1.9	1.9
	35	33.8	36.2	7200	3.6	3.4
VAC	168	165.9	164.3	3600	1.3	2.2
	55	53.7	56.9	3600	2.4	3.5
	27	26.1	26.7	7200	3.3	1.1

of sampling tube or by direct dosage are in good agreement with average concentrations determined by the use of MIRAN. The relative errors of the determinations by the method of sampling tubes or direct dosage with respect to the values determined with MIRAN vary within the range 0.2—4.8 %.

For calculating the value of $D(A/l) = n_t/c_t \cdot t$ we used the average concentration c_t determined by the infrared analyzer MIRAN IA and the amount of captured substance n_t calculated as average value of exposure of six dosimeters $\bar{\mathrm{K}}$, $\bar{\mathrm{P}}$ [19] and six dosimeters K, P [2] after gas chromatographic analysis.

The values of $D(A/l)$ calculated from experimental values of n_t, c_t, and t are plotted on the axis y in Fig. 2. It follows from this figure that the function of dosimeters K, P [2] is significantly dependent on the rate of air flow. The modification of dosimeters brought about elimination of the dependence of dosimeters $\bar{\mathrm{K}}$ and $\bar{\mathrm{P}}$ [19] on the rate of air flow in the investigated range 0.1 —3 m s^{-1}. The modified types of dosimeters were tested in the exposure cham-

ber in the medium of toluene and n-butyl alcohol for concentrations 100—500 mg m^{-3} and rates of air flow 0.1—3 m s^{-1} by using six dosimeters of the type $\bar{K}$ or $\bar{P}$ or else three pairs of dosimeters $\bar{K}$ and $\bar{P}$. The concentration in the exposure chamber was investigated again by an analyzer MIRAN IA and sampling tubes. The parameters of dosimeters $D(A/l)$ were calculated from experimental values while the geometrical constants (A/l) of modified dosimeters were calculated for some substances with known diffusion coefficients.

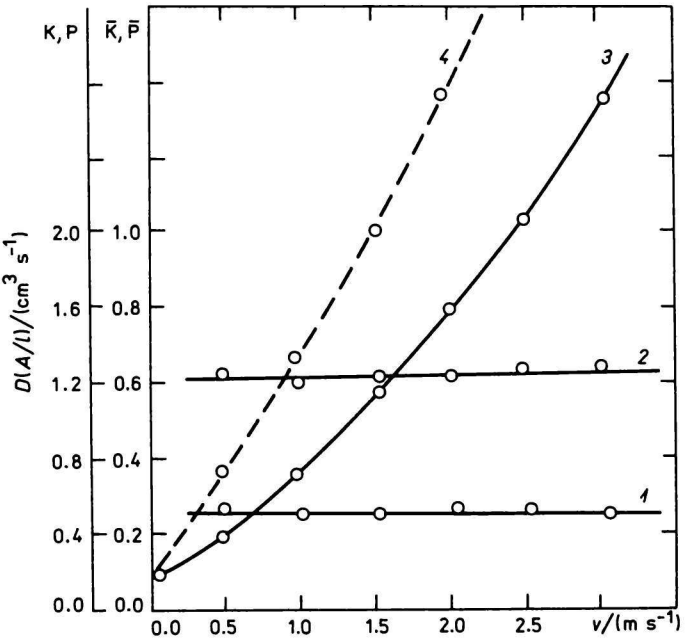

Fig. 2. Parameter $D(A/l)$ for toluene as a function of air flow v.
1., 2. Modified dosimeters $\bar{K}$ and $\bar{P}$; *3., 4.* original types of dosimeters K and P.

Table 2 contains the geometrical constants of dosimeters for toluene and n-butyl alcohol, diffusion parameters $D_K = D(A/l)$ and time of response of dosimeter t_K [2] for temperatures 294 K—308 K, relative air humidity 35—55 %, pressures 101.3—101.5 kPa, and rate of air flow 0.1—3 m s^{-1}

The experimental value of geometry of $K_{\bar{K}}$ and $K_{\bar{P}}$ may be used under the above-mentioned conditions for determining the average concentration of those substances the diffusion coefficient of which is known.

Table 3 contains the values of diffusion constant of dosimeter $D(A/l) = D_K$ for a modified all-metal dosimeter ($D_{K\bar{K}}$) and a dosimeter with plastic closure

Table 2

Constants of dosimeters

Substance	Geometrical constant				Diffusion parameter $D_K = D(A/l)$				Time of response of dosimeter	
	cm				$cm^3 s^{-1}$				s	
	$\{K_R\}$	$\{s\}$	$\{K_P\}$	$\{s\}$	$\{D_{KR}\}$	$\{s\}$	$\{D_{KP}\}$	$\{s\}$	$\{t_{KR}\}$	$\{t_{KP}\}$
Toluene	2.9	0.09	7.8	0.06	0.246	0.008	0.662	0.006	8.7	0.6
n-B	2.9	0.10	7.8	0.09	0.250	0.009	0.672	0.005	8.6	0.6

Table 3

Values of diffusion constants of dosimeters

Substance	Diffusion constant of dosimeters			
	$D_{KR} = D(A/l)_R$	s	$D_{KP} = D(A/l)_P$	s
	$cm^3 s^{-1}$	$cm^3 s^{-1}$	$cm^3 s^{-1}$	$cm^3 s^{-1}$
Toluene	0.246	0.012	0.662	0.010
n-B	0.250	0.011	0.672	0.009
MMC	0.251	0.011	0.676	0.011
BAC	0.224	0.029	0.620	0.054
VC	0.289	0.026	0.777	0.038
VAC	0.230	0.012	0.619	0.018

(D_{KP}) with respect to toluene, n-butyl alcohol, MMC, BAC, VC, and VAC which were experimentally determined under the above conditions. The values of the parameters $D(A/l)$ calculated from experimental values were used for comparing the diffusion dosimeters of the type $\bar{K}$, $\bar{P}$ and K, P with the samplings by means of standard sampling tubes. The time of exposure for which the dosimeters were subjected to concentration in working atmosphere was equal to the time necessary for taking the contaminants in sampling tubes. The results of model as well as field-work measurements are given in Tables 4—7.

The analysis of results has shown that the set of concentrations determined by 1 h samplings with sampling tubes and dosimeters is characterized by the equations of straight line $y = (a - bx)$, correlation coefficients (r), standard deviations of the slope (s_b) and intercept on the axis y (s_a), and interval of reliability for the intercept on the axis x and y ($L(b)_1$, $L(b)_2$, $L(a)_1$, and $L(a)_2$).

Table 4

Comparison of concentrations of vinyl chloride

	Mass concentration of vinyl chloride/(mg m^{-3})		
	Sampling tube	Dosimeter	
	x	$y_1(\bar{K})$	$y_2(\bar{P})$
1	121.5	128.1	123.9
2	118.7	127.1	130.8
3	118.9	121.9	127.2
4	97.5	96.9	94.1
5	32.5	37.1	34.2
6	36.4	37.0	37.2
7	32.1	36.1	32.8
8	10.0	9.3	9.2
9	12.1	10.9	13.5
10	16.2	18.1	17.2

$y_1 = 0.3196 + 1.0393x$
$r = 0.9986$
$s_a = 2.8178$
$s_b = 0.0195$

$L(a)_1 = -5.1071$; $L(a)_2 = 5.7464$
$L(b)_1 = 0.9670$; $L(b)_2 = 1.1115$

Zone of reliability/(mg m^{-3})

$x = 15$	$x = 30$	$x = 90$
$y_1 = 12.3$	$y_1 = 27.6$	$y_1 = 89.9$
$y_2 = 15.9$	$y_2 = 30.4$	$y_2 = 93.1$
$y_3 = 18.5$	$y_3 = 35.4$	$y_3 = 95.8$

$y_2 = -0.6388 + 1.0513x$
$r = 0.9973$
$s_a = 2.0663$
$s_b = 0.0275$

$L(a)_1 = -8.2993$; $L(a)_2 = 7.0216$
$L(b)_1 = 0.9493$; $L(b)_2 = 1.1533$

Zone of reliability/(mg m^{-3})

$x = 15$	$x = 30$	$x = 90$
$y_1 = 11.9$	$y_1 = 26.9$	$y_1 = 88.4$
$y_2 = 15.1$	$y_2 = 30.9$	$y_2 = 93.9$
$y_3 = 19.1$	$y_3 = 33.6$	$y_3 = 96.6$

The high values of correlation coefficients indicate the linear relationships x — sampling tube, y — dosimeter but do not reveal the reliabilities of determination by these methods with respect to each other. For determining the reliability of the method of sampling with a passive dosimeter with respect to the method of sampling tube we calculated the zone of reliability of the values y_1, y_2, y_3 for the values x.

The statistical processing of results and calculation of parameters were carried out according to [21, 22] with a computer Sinclair ZX-spectrum in the program language BAZIC.

The results given in Tables 4 and 5 were obtained from measurements with sampling tubes and passive dosimeters $\bar{K}$ and $\bar{P}$. These measurements were

Table 5

Comparison of concentrations of vinyl acetate

	Mass concentration of vinyl acetate/(mg m^{-3})		
	Sampling tube	Dosimeter	
	x	$y_1(\bar{K})$	$y_2(\bar{P})$
1	155.8	161.5	159.4
2	159.1	163.1	164.1
3	58.5	53.2	53.9
4	56.1	53.9	51.9
5	26.0	28.2	27.5
6	27.9	27.7	29.1
7	25.5	27.1	29.0
8	12.1	10.9	10.9
9	14.8	13.5	15.9
10	12.5	10.9	13.2

$y_1 = -1.8087 + 1.0361x$
$r = 0.9991$
$s_a = 2.6658$
$s_b = 0.0157$

$L(a)_1 = -6.2801$; $L(a)_2 = 2.6626$
$L(b)_1 = 0.9778$; $L(b)_2 = 1.0944$

Zone of reliability/(mg m^{-3})

$x = 15$	$x = 30$	$x = 90$
$y_1 = 12.2$	$y_1 = 26.8$	$y_1 = 87.7$
$y_2 = 14.7$	$y_2 = 29.3$	$y_2 = 91.4$
$y_3 = 17.6$	$y_3 = 32.7$	$y_3 = 95.2$

$y_2 = -0.6039 + 1.0231x$
$r = 0.9987$
$s_a = 1.3965$
$s_b = 0.0182$

$L(a)_1 = -5.7812$; $L(a)_2 = 4.5734$
$L(b)_1 = 0.9555$; $L(b)_2 = 1.0906$

Zone of reliability/(mg m^{-3})

$x = 15$	$x = 30$	$x = 90$
$y_1 = 13.1$	$y_1 = 28.1$	$y_1 = 87.9$
$y_2 = 14.7$	$y_2 = 30.1$	$y_2 = 90.4$
$y_3 = 17.2$	$y_3 = 33.9$	$y_3 = 92.8$

carried out in the exposure chamber with the 2 h exposure and involved stationary sampling of model concentrations at the temperature of 294 K—296 K, pressure of 101—103 kPa, average value of air flow of 1 m s^{-1}, and relative humidity of 34—48 %.

The results calculated from Tables 6 and 7 were obtained from field-work measurements of the concentrations of butyl acrylate and methyl methacrylate by using personal sampling during their production at the temperature of 293.7 K, rate of air flow of 0.5—1.0 m s^{-1}, pressure of 101.5 kPa, and relative humidity of 52 % at maximum. The presented values which were obtained under equal conditions of sampling indicate different behaviour of dosimeters K, P and $\bar{K}$, $\bar{P}$.

Table 6

Comparison of concentrations of methyl methacrylate

	Mass concentration of methyl methacrylate/(mg m^{-3})					
	Sampling tube	Dosimeter		Sampling tube	Dosimeter	
	x	$y_1(\bar{K})$	$y_2(\bar{P})$	x	$y_3(K)$	$y_4(P)$
1	10.4	10.1	10.9	10.4	14.9	18.7
2	22.8	21.1	23.2	22.8	29.1	32.9
3	25.7	26.1	25.2	55.2	59.9	57.3
4	39.2	40.1	42.1	70.2	87.9	110.3
5	56.2	58.1	58.7	106.5	110.9	128.5
6	31.1	30.5	32.2	67.7	82.9	128.7
7	100.9	110	107	129.5	168.1	182.3
8	135.1	130.9	140.2			
9	30.1	32.0	32.5			
10	189.1	181.9	182			

$y_1 = 1.8266 + 0.9718x$
$r = 0.9976$
$s_a = 2.0103$
$s_b = 0.02368$

$L(a)_1 = -5.6263$; $L(a)_2 = 9.2795$
$L(b)_1 = 0.8840$; $L(b)_2 = 1.0596$

Zone of reliability/(mg m^{-3})

$x = 10$	$x = 30$	$x = 90$
$y_1 = 7.9$	$y_1 = 27.2$	$y_1 = 84.9$
$y_2 = 10.2$	$y_2 = 30.9$	$y_2 = 89.3$
$y_3 = 12.9$	$y_3 = 36.7$	$y_3 = 94.7$

$y_2 = 2.4439 + 0.9828x$
$r = 0.9982$
$s_a = 1.7773$
$s_b = 0.0209$

$L(a)_1 = -4.1451$; $L(a)_2 = 9.0329$
$L(b)_1 = 0.9051$; $L(b)_2 = 1.0604$

Zone of reliability/(mg m^{-3})

$x = 10$	$x = 30$	$x = 90$
$y_1 = 7.2$	$y_1 = 26.9$	$y_1 = 86.1$
$y_2 = 10.9$	$y_2 = 30.8$	$y_2 = 90.9$
$y_3 = 12.2$	$y_3 = 36.9$	$y_3 = 95.7$

$y_3 = -0.1453 + 1.1999x$
$r = 0.9838$
$s_a = 7.4903$
$s_b = 0.0976$

$L(a)_1 = -34.6315$; $L(a)_2 = 34.3410$
$L(b)_1 = 0.7509$; $L(b)_2 = 1.6489$

Zone of reliability/(mg m^{-3})

$x = 15$	$x = 30$	$x = 90$
$y_1 = -11.0$	$y_1 = 11.9$	$y_1 = 87.2$
$y_2 = 17.9$	$y_2 = 35.9$	$y_2 = 107.8$
$y_3 = 46.8$	$y_3 = 59.8$	$y_3 = 128.5$

$y_4 = 5.2393 + 1.3412x$
$r = 0.9501$
$s_a = 15.1257$
$s_b = 0.1969$

$L(a)_1 = -64.4009$; $L(a)_2 = 74.8795$
$L(b)_1 = 0.4345$; $L(b)_2 = 2.2478$

Zone of reliability/(mg m^{-3})

$x = 15$	$x = 30$	$x = 90$
$y_1 = -33.0$	$y_1 = -2.8$	$y_1 = 84.3$
$y_2 = 25.4$	$y_2 = 45.5$	$y_2 = 125.9$
$y_3 = 83.7$	$y_3 = 93.8$	$y_3 = 167.6$

Table 7

Comparison of concentrations of butyl acrylate

	Mass concentration of butyl acrylate/(mg m^{-3})							
	Sampling tube	$\bar{K}$	Sampling tube	$\bar{P}$	Sampling tube	K	Sampling tube	P
	x_1	y_1	x_2	y_2	x_3	y_3	x_4	y_4
1	7.5	7.9	7.5	7.1	60.5	93.2	60.5	132.1
2	5.9	4.7	5.9	5.2	55.1	71.1	55.1	81.2
3	42.1	40.5	11.5	11.0	36.8	72.0	36.8	101.5
4	37.0	34.3	45.7	48.5	42.8	62.9	42.8	78.2
5	58.1	60.6	50.5	48.0	67.1	99.6	67.1	120.4
6	31.9	37.8	18.9	21.1	17.5	20.9	17.5	27.1
7	105	111.1	105	99.1	7.2	15.0	7.2	14.1
8	126.5	120.1	126.5	126.5				
9	161	155.5	161	165.8				

$y_1 = 1.6861 + 0.9693x_1$
$r = 0.9969$
$s_a = 2.3569$
$s_b = 0.0287$

$L(a)_1 = -4.3727$; $L(a)_2 = 7.7449$
$L(b)_1 = 0.8954$; $L(b)_2 = 1.0431$

Zone of reliability/(mg m^{-3})

$x = 15$	$x = 30$	$x = 90$
$y_1 = 10.9$	$y_1 = 27.2$	$y_1 = 85.7$
$y_2 = 16.2$	$y_2 = 30.8$	$y_2 = 88.9$
$y_3 = 20.4$	$y_3 = 35.0$	$y_3 = 93.1$

$y_2 = -0.4562 + 1.0073x_2$
$r = 0.9986$
$s_a = 3.3001$
$s_b = 0.0202$

$L(a)_1 = -4.6329$; $L(a)_2 = 3.7206$
$L(b)_1 = 0.9554$; $L(b)_2 = 1.0593$

Zone of reliability/(mg m^{-3})

$x = 15$	$x = 30$	$x = 90$
$y_1 = 11.9$	$y_1 = 27.6$	$y_1 = 86.9$
$y_2 = 14.7$	$y_2 = 29.8$	$y_2 = 90.2$
$y_3 = 17.2$	$y_3 = 32.9$	$y_3 = 93.4$

$y_3 = 3.7912 + 1.4222x_3$
$r = 0.9646$
$s_a = 7.9825$
$s_b = 0.1739$

$L(a)_1 = -32.9610$; $L(a)_2 = 40.5433$
$L(b)_1 = 0.6213$; $L(b)_2 = 2.2230$

Zone of reliability/(mg m^{-3})

$x = 15$	$x = 30$	$x = 90$
$y_1 = -1.5$	$y_1 = 27.7$	$y_1 = 89.2$
$y_2 = 25.1$	$y_2 = 46.5$	$y_2 = 131.8$
$y_3 = 51.7$	$y_3 = 65.2$	$y_3 = 174.4$

$y_4 = 3.9429 + 1.8362x_4$
$r = 0.9163$
$s_a = 16.4715$
$s_b = 0.3892$

$L(a)_1 = -71.8937$; $L(a)_2 = 79.7795$
$L(b)_1 = 0.1837$; $L(b)_2 = 3.4887$

Zone of reliability/(mg m^{-3})

$x = 15$	$x = 30$	$x = 90$
$y_1 = -23.4$	$y_1 = 20.4$	$y_1 = 81.4$
$y_2 = 31.5$	$y_2 = 59.0$	$y_2 = 169.2$
$y_3 = 86.32$	$y_3 = 97.6$	$y_3 = 257.0$

The above-mentioned model experiments as well as the field-work measurements demonstrate the independence of dosimeters $\bar{K}$ and $\bar{P}$ of air flow. The deviations from correct values are due to further factors in field-work measurements such as inhomogeneity of concentration, its rate of change, laminarity or turbulence of flow, and other factors of accidental character.

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