A PASSIVE DOSIMETER FOR EVALUATING EXPOSURE TO HYDROGEN FLUORIDE

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SUMMARY: A passive dosimeter designed to measure exposure to hydrogen fluoride was tested under laboratory conditions over the concentration range of 0.56 – 4.47 mg HF/m^3. The lowest concentration was chosen to be close to the Polish TLV (0.5 mg HF/m^3). The dosimeter consists of a Whatman No.1 filter paper impregnated with K_2HPO_4 placed in a polyethylene holder protected by a polyethylene screen. After exposure the filter is eluted with 0.1 M sodium citrate and the fluoride concentration determined potentiometrically.

Keywords: Airborne HF, Hydrogen fluoride, HF dosimeter, Industrial exposure, Passive dosimeter.

INTRODUCTION

Fluorine compounds are major environmental pollutants. In Poland they rank seventh on the list of most dangerous chemical substances.[1] Large amounts of them are present in the work-place and in the vicinity of aluminium and magnesium foundries, phosphoric acid and phosphate fertilizer plants, petroleum refineries, pottery kilns, and factories where glass etching, erasing, or welding is performed. The most common fluorine compound present in the industrial environment is hydrogen fluoride.[2,3]

In order to prevent excessive exposure of workers to toxic compounds, continuous monitoring of the occupational environment is advised. One of the methods used in monitoring of industrial pollutants is passive dosimetry for obtaining reliable information on individual exposure to airborne contaminants. This technique is used successfully to evaluate exposure to nitrogen oxide, sulfur dioxide, formaldehyde, and some organic solvents. In addition to reports of active dosimeters for monitoring exposure to hydrogen fluoride, [4,5] a passive device containing an alkali-impregnated polypropylene collection element has been described.[6]

Passive dosimeters are appropriately selected and prepared with adsorbents located in open holders attached to work clothing in the breathing zone. The adsorbent passively adsorbs volatile substances from the surrounding atmosphere. The movement of air to the dosimeter occurs freely, in contrast to the operation of an active dosimeter, in which a source of suction and a device for measuring the sampling rate are necessary.

After sampling during one or more working shifts, adsorbed substances are analyzed or sealed until next sampling. The average HF concentration in air is calculated taking into account exposure time and calibration constants determined under laboratory and field conditions.[7-9]

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The main advantages of passive dosimetry are: simplicity in use, small size, low cost, and no requirement for suction. In comparison to active dosimeters this method is less sensitive to short-time concentration changes and has a lower effectiveness of sample concentration.

The aim of this study was to construct and test a passive filter-paper dosimeter designed to measure exposure to hydrogen fluoride according to the reaction with dipotassium hydrogen phosphate:

$$K_2HPO_4 + HF \rightarrow KH_2PO_4 + KF$$

In particular, the relationships between the HF concentrations in air and fluoride adsorbed on the dosimeter in a definite time had to be determined.

MATERIALS AND METHODS

The calibration study was performed with a specially constructed apparatus (Figure 1) made of inert plastics: polyethylene and polypropylene.

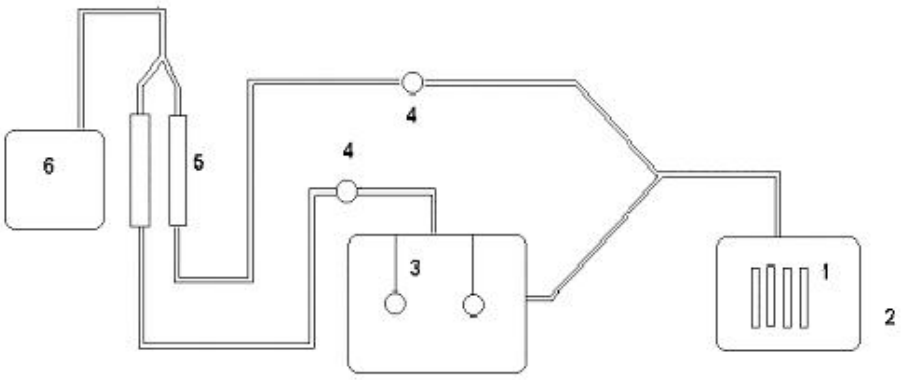

Figure 1. Scheme of the calibration apparatus.

1. HF emitting system – 14-mm diameter polyethylene test tubes (see insert) filled with 20% HF (approx. external area of the test tube 53 cm^2)
2. Polyethylene chamber (1.5 L)
3. Chamber containing dosimeters (5 L)
4. Impregnated 38-mm diameter filter papers
5. Air flow measuring rotameters
6. Membrane pump

After many trials with different HF emitting systems, the standard air mixtures were obtained by permeation, wherein the HF emission source was a hydrofluoric acid solution placed in 14-mm i.d. polypropylene test tubes stoppered with polypropylene stoppers. The number of test tubes used depended on the desired HF concentration. After equilibration, the concentration of HF in the measuring system did not change significantly for at least 48 hrs. Whatman No.1 filter paper impregnated with dipotassium hydrogen phosphate, K_2HPO_4, was chosen as the chemisorbent. The impregnation was performed by dipping the filter paper into a 10% solution of K_2HPO_4 and then drying. The dosimeter consists of an impregnated 38-mm diameter Whatman No.1 filter paper placed in an open polyethylene holder (protected by a polyethylene screen) with a clip enabling it to be worn on work clothing (Figure 2).

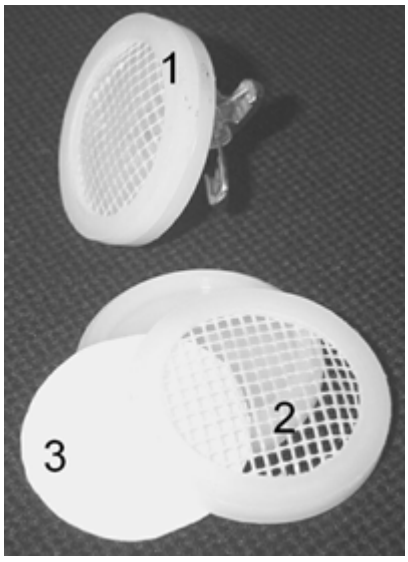

Figure 2. Dosimeter

1. Polyethylene holder,
2. Polyethylene screen,
3. Filter (38-mm diameter Whatman No.1 filter paper).

During the calibration procedure the HF concentrations were chosen over a range close to the Polish TLV (0.5 mg/m^3). The airflow in the exposure chamber was adjusted to five air changes per hour to imitate normal movement of the workers. Control of the HF concentration in the air was performed every few hours, and the amount of F^- adsorbed in the dosimeter was analyzed 4-6 times during the 48-hr period. This time interval is equal to a six-day week with 8-hr working shifts. Six dosimeters were always present in the exposure chamber. When one of them was taken out for analysis another new one was put into the exposure chamber.

After exposure, the filters were eluted with 10 mL of a 0.1 M solution of sodium citrate,[10] and the F^- concentration was determined by a fluoride ion specific electrode (Orion) with a 920A potentiometer.[11]

The amount of fluoride adsorbed on the dosimeter was measured for four different concentrations of HF and various volumes of air. The mean weighed HF concentrations in air were 0.56, 0.92, 2.53, and 4.47 mg/m^3. The fluctuation of HF concentration in a particular series of determinations did not exceed 18%. Results are given in the Table and in Figures 3 and 4.

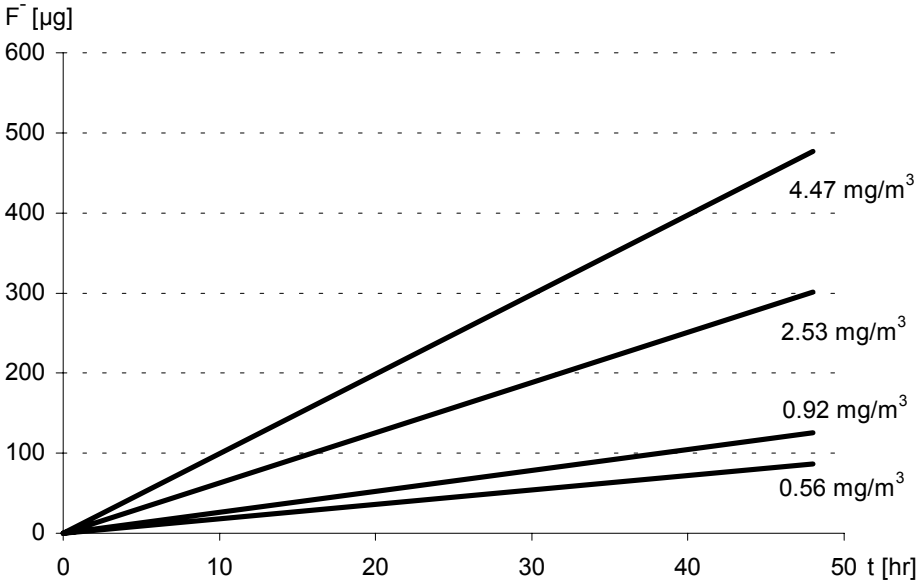

Figure 3. Time and airborne HF concentration relationship to F^- collected by the dosimeter.

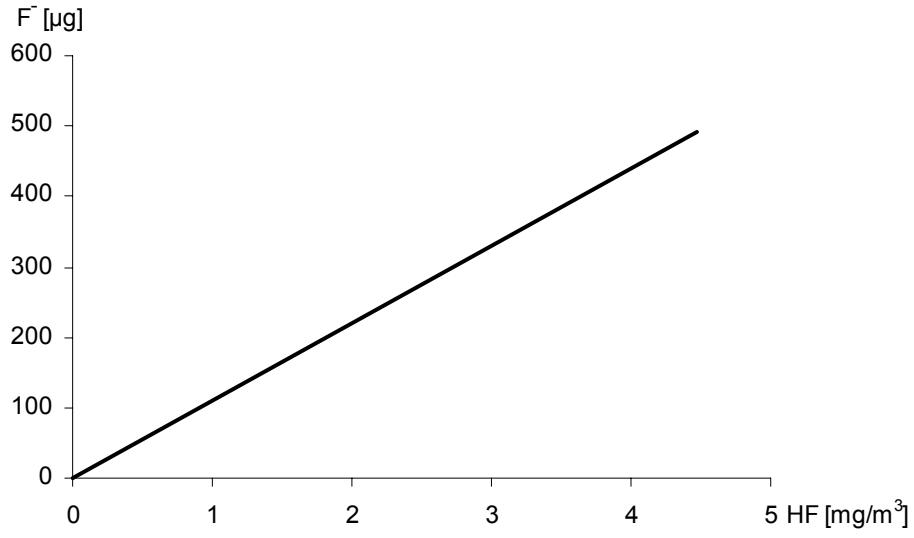

Figure 4. 48-Hour incremental relationship between HF concentration in air and fluoride content on the dosimeter

Table. Calibration of the dosimeter

Sample No.	Exposure time [hr]	Volume of passed air [L]	Amount of F^- [µg] adsorbed by dosimeter	Increase of F^- in dosimeter vs. time [µg/hr]
Series 1. Average weighed concentration of HF 0.56 mg/m^3				
1	17.0	510	29.4	1.73
2	24.0	720	41.0	1.71
3	30.0	900	62.0	2.07
4	36.0	1080	68.0	1.89
5	48.0	1440	81.0	1.69
Series 2. Average weighed concentration of HF 0.92 mg/m^3				
1	6.0	180	10.7	1.78
2	16.0	480	35.8	2.24
3	22.0	660	65.5	2.98
4	30.0	900	86.2	2.87
5	36.0	1080	91.4	2.54
6	48.0	1440	122.0	2.54
Series 3. Average weighed concentration of HF 2.53 mg/m^3				
1	12.0	360	101.0	8.42
2	18.0	540	134.0	7.44
3	26.0	780	158.0	6.08
4	31.0	930	212.0	6.84
5	41.0	1230	235.0	5.73
6	48.0	1440	297.0	6.19
Series 4. Average weighed concentration of HF 4.47 mg/m^3				
1	4.5	135	51.1	11.36
2	14.5	435	157.0	10.83
3	21.5	645	207.0	9.63
4	48.0	1440	475.0	9.90

RESULTS AND DISCUSSION

The experiment shows a linear dependence between the amount of fluoride adsorbed on the impregnated filter paper by the dosimeter and the exposure time at a given HF concentration in air. In addition, a relationship between air hydrogen fluoride and the amount of F^- adsorbed by the dosimeter in comparable time intervals was assessed.

From the experiment a linear relationship between the HF concentrations in air and the F^- amount on the filter paper after a given period of time was obtained. Although the dosimeter is ready for use, it requires further testing under different field conditions (sampling temperature, relative humidity, and effects of other compounds).

Nevertheless, it is already possible to use this simple device to estimate at least approximate concentrations of HF in air. In the reality of field conditions this degree of accuracy is sufficient in most cases for rough estimations. Taking into consideration the simplicity of measurement and low cost, passive dosimetry, in spite of all its limits, may be used effectively in monitoring HF in the work environment.

ACKNOWLEDGEMENT

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