Response Time and Interchangeability Effects on the Tube-Like and the Badge-Like Passive Direct-Read Monitors

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Introduction

Direct-read passive monitors can be classified into two generic models: the tube-like model and the badge-like model. The nature of the designs of these two models lead to inherited characteristics which play a major role in the performance and accuracy of these devices. One of the major characteristics is the distance in which the analyte travels from the surrounding atmosphere to the detection media. This distance is usually referred to as the length-of-diffusion path. For direct-read passive monitors, response time and interchangeability are tow important metrological characteristics which are directly influenced by the length of diffusion path. In this work, an evaluation of the response-time and interchangeability effects was carried out for each model. The performance of these two models were tested for ammonia and hydrogen sulfide.

Experimental

Two tube-like and one badge-like monitors were exposed to different concentration profiles ranging between zero and eight times the permissible exposure limits. In a typical experiment the monitors were tested at 23 ± 2°C, 55 ± 3% RH, 0.12 - 0.15 m/sec and 760 ± 10 mm Hg.

Theoretical Background

The first Fick's law of diffusion was used as a theoretical model for length of stain passive samplers. Later, this model was used as base for all passive samplers.

$$F = D (A/L) (CA - CS) \text{ equation 1}$$

Where
- F = Mass transfer rate (ng/sec)
- D = Diffusion coefficient (cm2/sec)
- A = Cross section of the diffusion path (cm2)
- L = Length of diffusion path (CM)
- CA = Ambient concentration of the contaminant (ng/cm3)
- CS = Contaminant concentration on the sorption or reagent surface (ng/cm3)

Equation (1) is related to the simple model of a passive device shown in Figure 1. In case of complete reaction, C2 = 0 and

$$F = D (A/L) CA, \text{ equation 2}$$

The mass of contaminant M, reacting to form colorimetric results (Q), can be expressed as

$$M = F \times T, \text{ equation 3}$$

Q is proportional to the collected mass, M.

$$Q = K \times M, \text{ equation 4}$$

Q = Ki (CA - TC), equation 5

Where K, Ki = constant

TC = exposure time (hr)

For both types of monitors, the relation between Q and (CA x TC) can be determined empirically.

The badge-like monitor (Figure 2) tested in this study uses this approach and the exposure does (CA x TC) is related to relative color units determined by optical reader.

For all monitors using the theoretical model given here, the time for which a contaminant is going along the diffusion path L is given by the equation:

T - L2/2D, equation 6

Tube-like monitors (Figure 3) are characterized by increasing the length of stain (L) which measures Q and simultaneously, the length of the diffusion path (L).

Response time (RT) can be defined as the time period between the change of the CA and first measurable effect on the monitor readings. This definition includes the time for which contaminant moves along the diffusion path (L), (equation 6), and the time (TC) necessary to develop a measurable colorimetric effect (Q). For the badge-like monitor (RT) is given by:

RT = T + TC = constant, equation 7

Whereas, for the tube-like monitor, the colorimetric result Q is given by the length of stain (L) as a function of exposure does (CA x TC).

L2 = K(CA x TC), equation 8

or

TC = L2/KCA

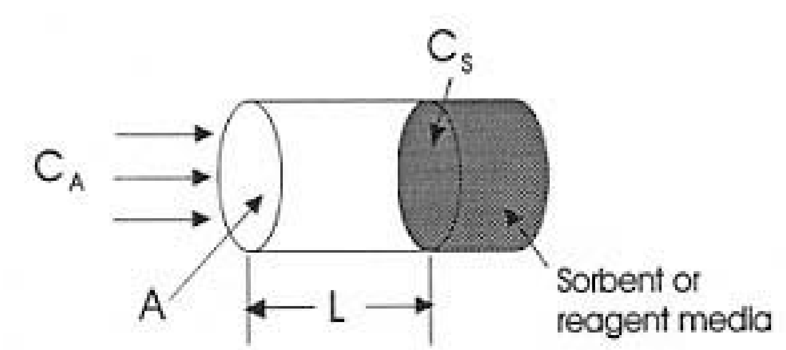
Hence, the time period required to receive a measurable effect for a given (L) can be described as:

RT = L2/2D + delta L2/KCA

where delta L is the smallest first measurable fraction of L.

It is obvious that (RT) is a square function of (L) and depends also on CA.

Figure 1: Passive Monitors - Generic Model



Discussion

The results received for different concentration profiles confirmed the expected deviations in the response time for the tube-like monitors. The response time increases with exposure dose. The interchangeability for tube-like monitors is also affected by the concentration profile and exposure dose. The interchangeability is a more complex characteristic. It involves an integrated effect of the response time which is summarized along the length of exposure, and in turn under estimates the results of the exposure. It also involves the effect of exposure-inertion. After a high peak when CA dropped, the mass of the pollutant adsorbed onto the material with length (L) - dead volume becomes a secondary source of exposure by desorption. Both of these effects are (L) - related and in general, this is a major concern for the tube-like monitors in which (L) increases with exposure.

Conclusion

- In case of constant concentration, all tested monitors performed satisfactory.
- For intermittent exposures, tube-like monitors showed considerable deviations. Complex exposure profiles lead to unsatisfactory performance.
- Badge-like monitors followed all concentration profiles tested and gave satisfactory performance.

Figure 2: Exposure at Constant Concentration

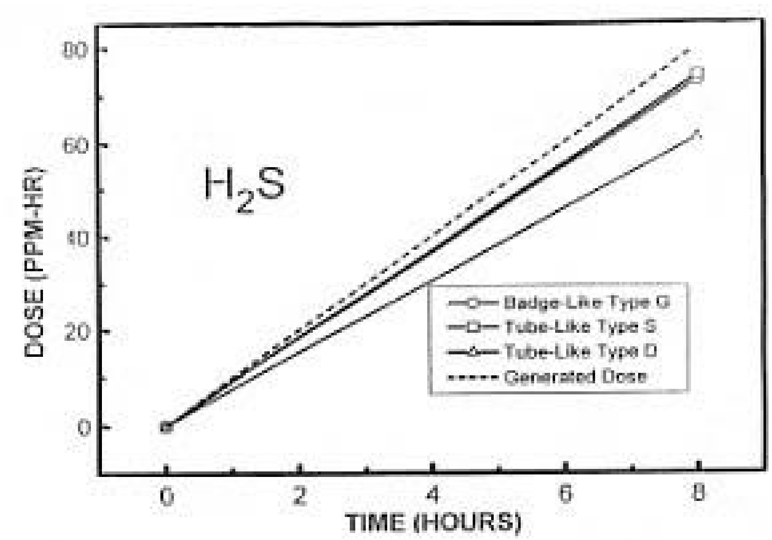


Figure 3A: Exposure at Constant Concentration

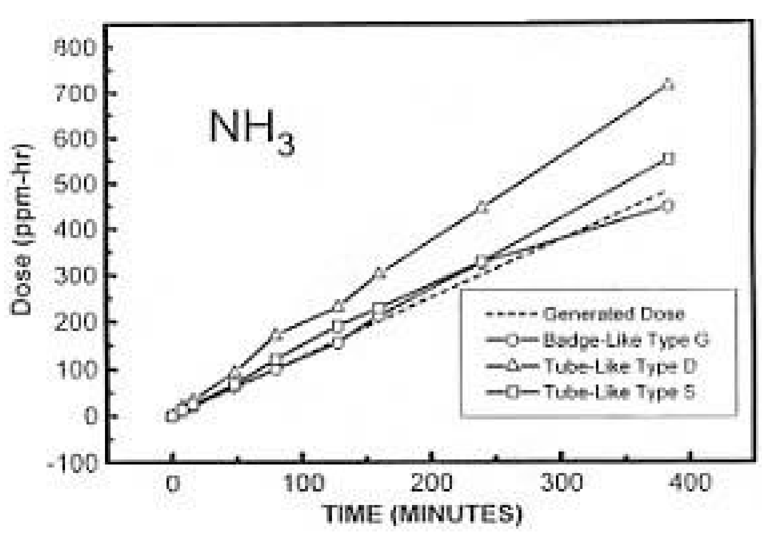


Figure 4: Interchangeability Effect and Response Time at Intermediate Concentration

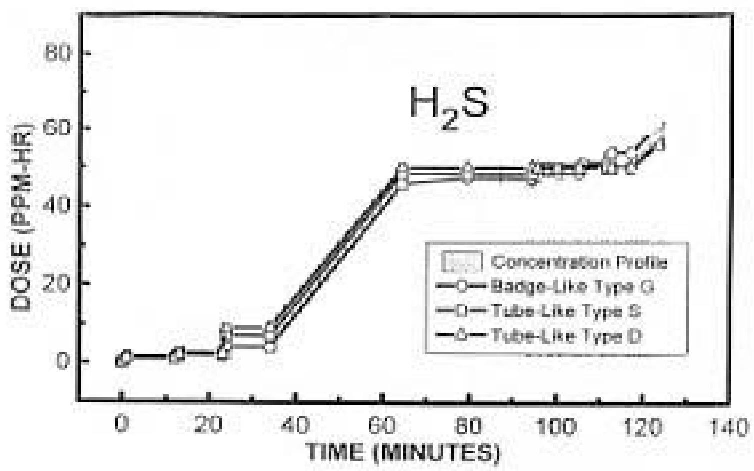


Figure 4A: Enlarged View from Figure 4 Short-Term Exposures

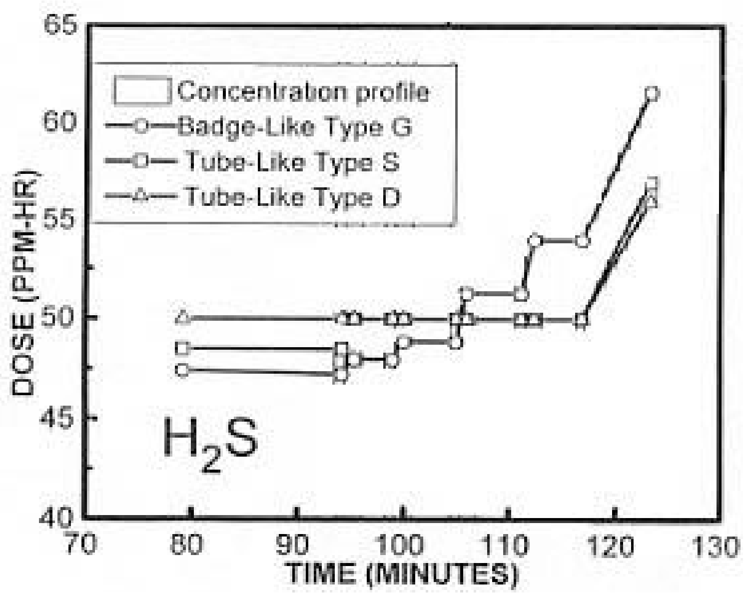


Figure 5: Interchangeability Effect and Response Time at Intermediate Concentration

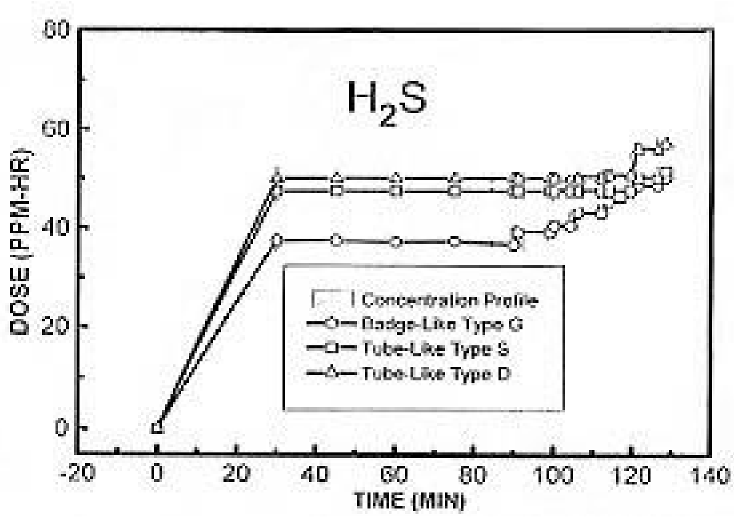


Figure 5: Interchangeability Effect and Response Time at Intermediate Concentration

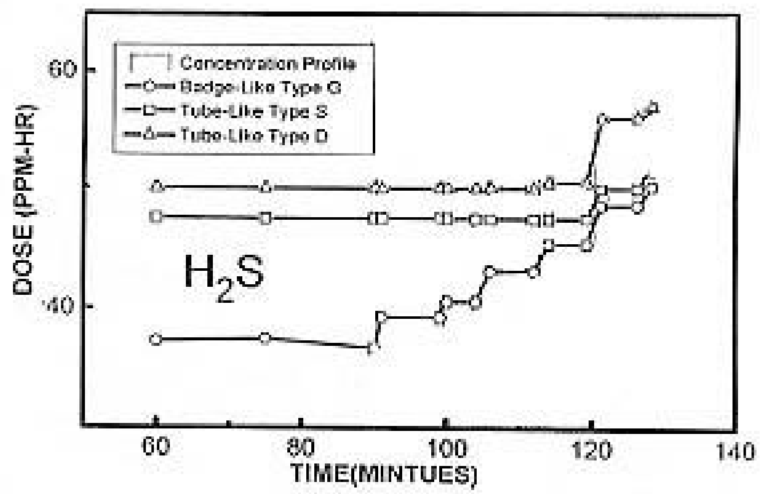


Figure 5A: Enlarged View from figure 5 Short-Term Exposures

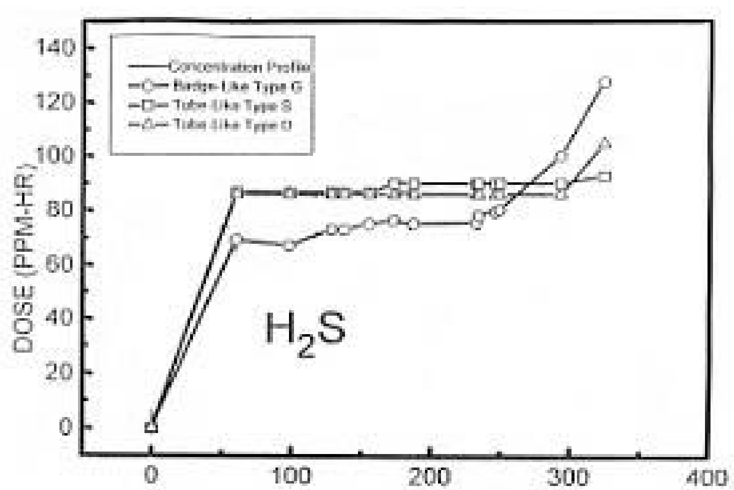


Figure 6: Behavior of the Monitors at Complex Concentration Profile

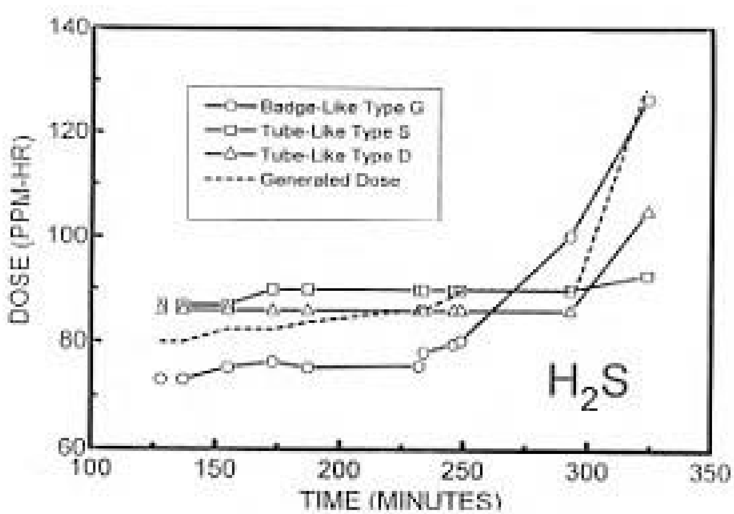


Figure 6A: Enlarged view of Figure 6

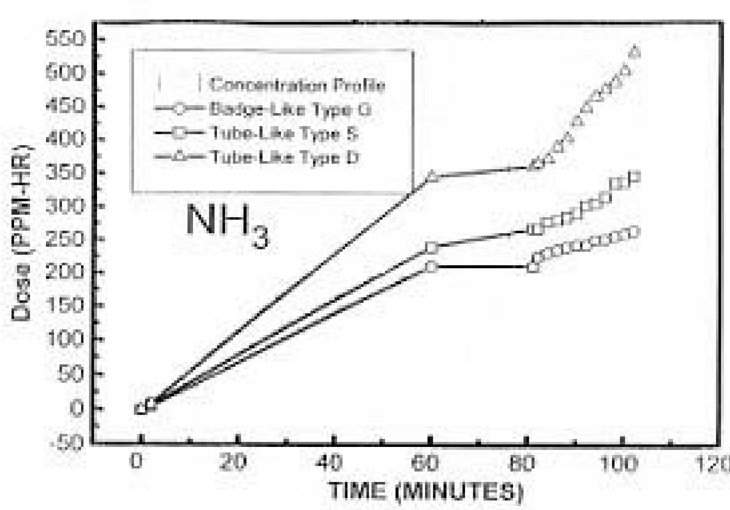


Figure 7: Behavior of the Monitors at Steady Exposure followed by Rapid Exposures

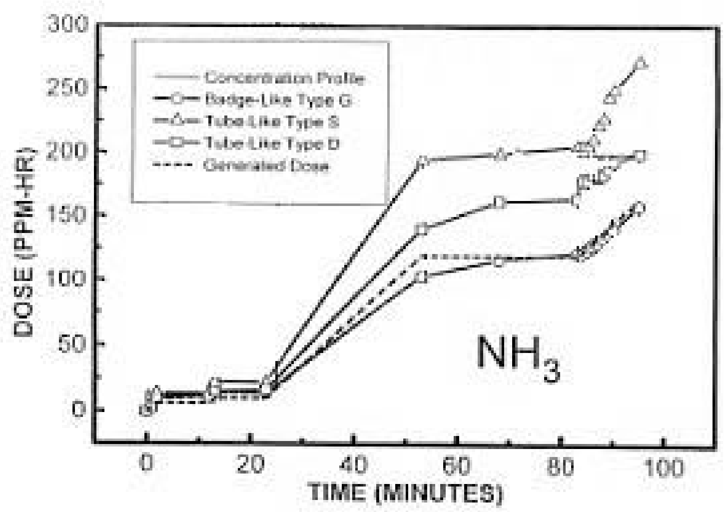
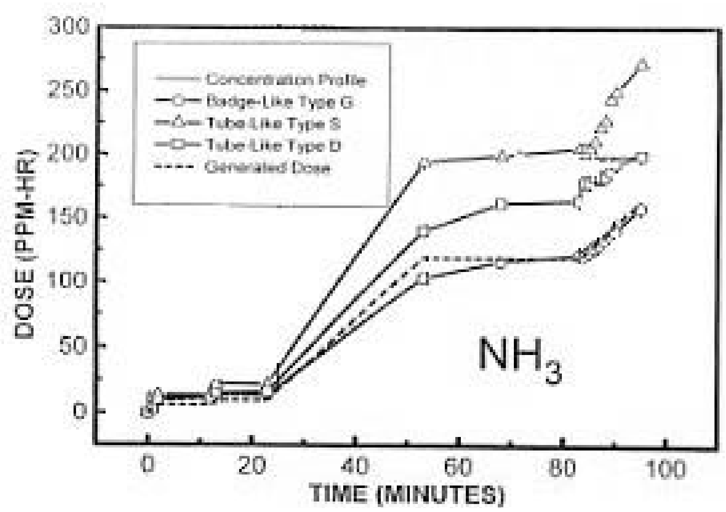


Figure 8: Behavior of the Monitors at Complex Concentration Profile



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