TDTS 13

Evaluation of the Bio-VOC – A low-cost, simple device for biological monitoring of VOCs in breath

Summary

An easy-to-use device for sampling of volatile organic compounds (VOCs) in breath is described, and its successful use shown for a range of applications.

Background to biological monitoring

Volatile organic compounds (VOCs) are widely used in industry, and are also present in the wider environment, although in relatively low concentrations. Many VOCs are toxic, so monitoring in workplace air has become standard practice in a number of industries. However, these chemicals can be absorbed through the skin or ingested, as well as being inhaled. Thus, a low atmospheric concentration of VOCs does not necessarily mean that personal exposure levels will also be low.

Biological monitoring addresses this issue, by measuring the actual bodily burden of VOCs. This facilitates assessment of short-term (acute) exposure, and can also provide an indication of chronic exposure. Historically, biological monitoring methods have involved the study of urine or blood samples. However, collection of these samples is expensive, intrusive, poses biohazard issues and requires qualified medical personnel. These limitations have prevented widespread acceptance of biological monitoring as a routine environmental health and safety tool.

The Bio-VOC™ breath sampler

The Bio-VOC breath sampler from Markes International (Figure 1) does away with the above-mentioned problems of current biological monitoring methods. As well as being low-cost, it is simple to use, and does not require operation by qualified medical personnel.

The principle behind the Bio-VOC comes from pioneering work carried out at the UK Health & Safety Laboratory (HSL). It harnesses the fact that the concentration of VOCs in the blood is in equilibrium with the concentration in the air in the aveolar portion of the lungs. This is because both capillary blood vessel walls and aveoli walls are thin enough to allow the free exchange of chemicals through the tissue membranes. Therefore VOC concentrations in aveolar (end-tidal) air are proportional to those in blood.

Figure 1: Markes' Bio-VOC and accessories. A: Bio-VOC body. B: Disposable cardboard mouthpiece. C: Plunger for transferring sample to sorbent tube. D: Stainless steel sorbent tube suitable for thermal desorption.

Using the Bio-VOC

The individual exhales into the sampler through a disposable mouthpiece until the lungs are as empty as possible (Figure 2). It is estimated that an adult exhaling

Figure 2: Exhaling into the Bio-VOC breath sampler.

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deeply expels at least 4 L of air, and that the last 2000 mL of this comes from the alveolar air portion of the lungs. It is important that only the alveolar air is sampled, not that from the mouth or bronchial passages. Given that the Bio-VOC holds 129 mL of air, 1 L of alveolar air typically needs to pass through the device to ensure an undiluted sample. After sample collection, the mouthpiece is removed and replaced with the plunger. A thermal desorption (TD) tube containing one or more suitable sorbents is fitted to the outlet end. The plunger is pushed in steadily and displaces the trapped air sample onto the tube (Figure 3). The sorbent tube can either be analysed immediately by conventional TD–GC(MS), or sealed with long-term storage caps for testing at a later date.

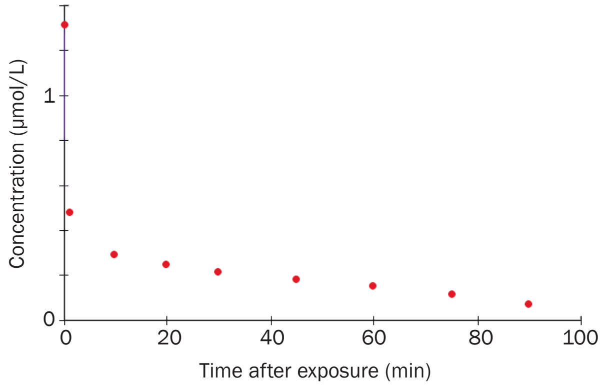

Figure 4: Rapid fall of the concentration of butanone in breath after exposure ends.

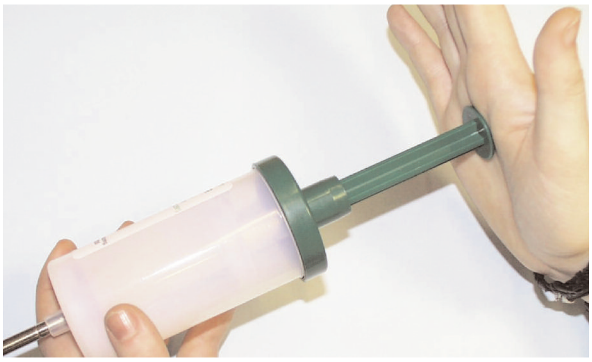

Figure 3: Transferring a sample from the Bio-VOC into a sorbent tube.

In biological monitoring, it is important to remember that the concentration of VOCs in an individual's breath/blood will start to decrease soon after exposure ends. Initial decay is rapid, but soon starts to level off (Figure 4). Timing is therefore critical, and ideally the sample should be collected in a clean area 10 minutes after the end of exposure.

Applications

1. The dry-cleaning industry

The Bio-VOC has proven to be very useful for monitoring biological exposure to tetrachloroethene (aka perchloroethylene) in the dry-cleaning industry. This chemical is fat-soluble, has a long half-life and is poorly metabolised, with only 1–2% being excreted in the urine. This means it can build up in fatty tissue after prolonged exposure even at low levels – a key indicator for use of biological monitoring. Data obtained using the Bio-VOC has demonstrated its performance for both low (background) levels and acute (high) exposures to tetrachloroethene (Figure 5).

2. The shoe industry

A wide range of solvents are used during shoe manufacture. The greatest potential for dermal exposure occurs when applying a special glue to the soles of the shoe, an operation commonly carried out by hand. Breath sampling showed relatively high biological exposure to a large number of solvents (Figure 6).

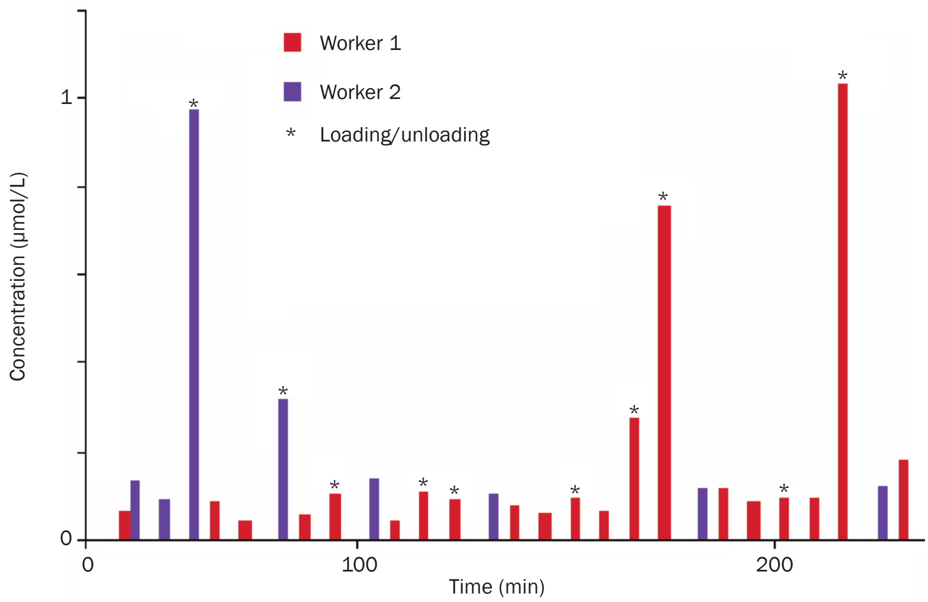

Figure 5: Monitoring of dry-cleaning workers handling tetrachloroethane using the Bio-VOC shows performance at both background-level and high exposures. In this case, it is clear that exposure is greatest when loading and unloading machines.

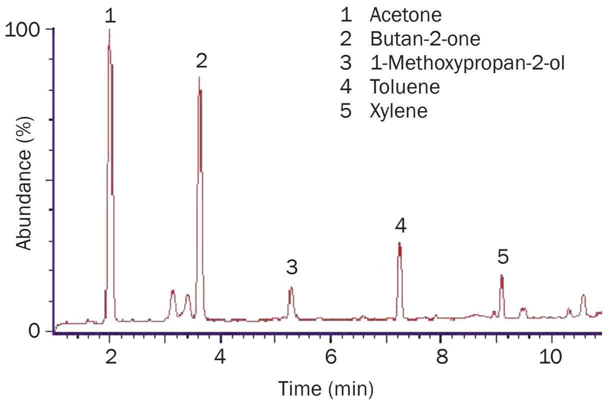

Figure 6: Solvents detected on the breath of shoe industry workers using the Bio-VOC.

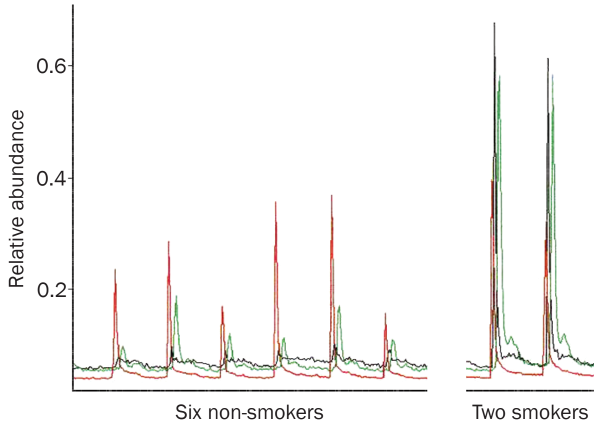

Figure 8: Breath analysis of smokers and non-smokers using the Easy-VOC. Black trace: Benzene (m/z 78); Green trace: Toluene (m/z 91); Red trace: Isoprene (m/z 67).

3. Clinical work

Other potential applications for the Bio-VOC include clinical diagnosis, as disease states can influence the VOC profile in breath. For example, it is well-known that acetone is responsible for the sweet smell detected on the breath of diabetics. Similarly, the presence of ammonia in the breath is a good indicator of kidney failure.

There has been speculation that a number of other illnesses could be diagnosed by the presence of an unusual compound or series of compounds in the breath of affected individuals (Figures 7 and 8).

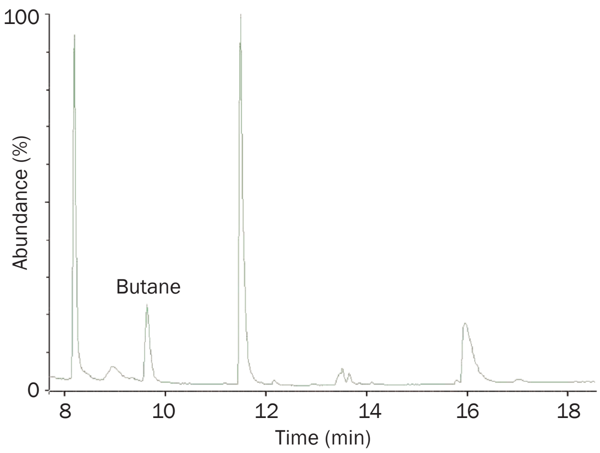

Figure 7: Chromatogram of a clinical breath sample collected using the Bio-VOC, and analysed by TD–GC/MS (selected ion monitoring at m/z 43).
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Summary

The Bio-VOC breath sampler has been used as a means of breath sampling in a number of environmental health & safety applications, and also has potential for disease diagnosis.

This popularity has stemmed from being low-cost and easy-to-use, and its compatibility with standard sampling and analytical equipment. Another advantage is that, once trapped on sorbent tubes, samples are stable for several weeks, unlike blood or urine.

The fact that sampling using the Bio-VOC is not invasive also make it suitable for large-scale studies – even those involving the general public.

Further work is required to improve interpretation of biological exposure data, but by allowing large-scale studies to be carried out, the Bio-VOC should make a significant contribution to this research.

Acknowledgements

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