TBV science

1 Introduction

1.1 This report presents the results of the 1992/93 London Wide Benzene Monitoring Programme. The report describes results collected from July 1992 to December 1993 which covers the second and third year during which the programme was in operation. The Benzene Monitoring Programme forms part of the London Wide Environmental Programme (LWEP).

1.2 The 1992/93 Benzene Monitoring Programme was sponsored by the following London Boroughs:

London Borough of Bexley
London Borough of Brent
London Borough of Camden
London Borough of Enfield
London Borough of Harrow
Royal Borough of Kensington and Chelsea
Royal Borough of Kingston upon Thames
London Borough of Richmond
London Borough of Wandsworth
City of Westminster

1.3 The main objective of the Benzene Monitoring Programme is to determine the ambient concentrations of benzene to which people are exposed in urban areas. The programme was initiated in response to continuing concern that people living within urban areas are often exposed to elevated concentrations of benzene which may be harmful to human health.

1.4 During the 1992/93 programme, participating boroughs maintained up to 5 monitoring sites, giving a total of 48 sites across Greater London. Benzene levels were surveyed using the passive diffusion sampler technique developed at TBV Science (formerly Rendel Science and Environment) specifically for monitoring ambient benzene levels. Diffusion samplers were despatched to participating boroughs at regular intervals, exposed by local staff and returned to TBV Science following a standard exposure period.

2 Sources Of Benzene

2.1 Benzene is an aromatic hydrocarbon occurring as a colourless, clear liquid. Benzene is one of a group of substances known as volatile organic compounds (VOCs), with benzene being a non-methane or NMVOC.

2.2 Benzene occurs naturally as a constituent of natural gas and of light oil recovered from coal carbonisation gases. Benzene is also synthetically produced by other industrial processes including the pyrolisis of petrol. In Western Europe in the early 1980s production of benzene was estimated to be 6.9 million tonnes, with the UK, Federal Republic of Germany and Netherlands being the major producers.

2.2 Benzene is added to petrol as an anti-knock agent. Since 1 July 1989 the content of benzene in petrol in the UK has been limited to 5% by volume in leaded or unleaded petrol by the EC Directive COM(84)226. In practice this amount varies since refineries may use a variety of other compounds to obtain the same effect depending upon the availability and cost. The amount of benzene in both leaded and unleaded petrol in the UK tends to average at approximately 2% by volume (DoE EPAQS, 1994)

2.3 Benzene in ambient air arises mainly from human activities, in particular the use of petrol and oil, although natural benzene emissions occur from plant and animal matter and see pages from petroleum reservoirs. Table 1 illustrates that motor vehicles are the major source of man-made emissions of benzene in the UK, with vehicle exhausts contributing to 78% of total emissions. An additional significant source of benzene is petrol evaporation from vehicles and evaporative emissions from the handling, distribution and storage of petrol.

2.4 Tobacco smoke contains high concentrations of benzene (up to 200 mg m^{-3}) and is a further source of environmental benzene, as is diet; benzene is found in drinking water and some foods and therefore enters the body via normal ingestion processes.

2.5 The recent publication by the Expert Panel on Air Quality Standards (EPAQS) highlights the importance of cigarette smoke as a source of benzene, particularly in rural areas where outdoor ambient concentrations are much lower than in urban areas. The Panel calculates that a non-smoker living in an unpolluted rural area may be exposed to as little as 120 μg benzene daily, while a smoker on 20 cigarettes per day may be exposed to as much as 1,250 μg daily.

3 Health Effects

3.1 There is a large body of data implicating human occupational exposure to benzene as a cause of injury to bone marrow and of subsequent haemotoxic effects and possible death. However, the concentrations concerned (usually 10 to 100 mg m^{-3}) are orders of magnitude higher than concentrations to which the public are usually exposed, and therefore these toxicological effects are of little relevance when considering the health effects of ambient concentrations of benzene.

3.2 There is most concern regarding the effects of long-term exposure to benzene, as benzene is a known human carcinogen, acting in a genotoxic fashion by modifying the genetic makeup of living cells. As such benzene is strongly linked to the formation of leukaemia's of various types. Several epidemiological studies of benzene exposed workers have revealed a significant association between acute leukaemia and occupational exposure to benzene at concentrations greater than 90 mg m^{-3} and probably greater than 350 mg m^{-3} (Rinsky *et al*, 1981).

3.3 Epidemiological studies have been used by organisations, including the WHO to calculate a quantitative dose/risk relationship which can then be used to predict the risk to the members of the public from ambient levels of benzene. Long-term chronic exposure to benzene is relevant, rather than short term peaks. Based on the quantitative dose/risk relationship calculated for benzene the WHO estimated the 'unit lifetime risk' resulting from continuous exposure to a benzene concentration of 1 μg m^{-3} for a period of 70 years to be $4x10^{-6}$, that is there will be 4 cancers (incidences of leukaemia) per million people per 1 μg m^{-3} benzene over a 70 year lifetime exposure.

3.5 However, although the calculation of unit risk is arithmetically straightforward, the concept has several weaknesses as it rests upon the assumption that the dose response relationship is linear and there is no lower threshold for effects. Furthermore there are limitations in all methods used to extrapolate the results of studies into occupational exposure, concerned with very high concentrations, to ambient concentrations to which the public are exposed.

4 Air Quality Standards For Benzene

4.1 According to the WHO:

'No safe level for airborne benzene can be recommended as benzene is carcinogenic to humans and there is no known safe threshold level.'

4.2 Similarly the UK DoE Expert Panel on Air Quality Standards accept that benzene is a genotoxic carcinogen and that it is not possible to define an absolutely safe exposure level. However, the Panel consider that 'a concentration may be proposed at which risks are exceedingly small'. To this end the Panel have recently recommended an Air Quality Standard for benzene in the United Kingdom of **5 ppb** as a running annual average

4.3 The standard is set in terms of an annual average as this is likely to best reflect the integrated exposure of the population.

5.0 Methodology

5.1 Monitoring Sites

5.1.1 Descriptions of the 48 monitoring sites are given in Appendix A on an individual Borough basis. As motor vehicle emissions are a major source of benzene, each of the sites has been categorised according to distance from the nearest busy road. Sites are defined as Roadside if they are within 20 m of a busy road. An Intermediate location is one which is between 20 and 40 m of a busy road. A Background site is one which is beyond 40 m of any road, usually situated in a residential area.

5.2 Measurement Technique

5.2.1 Benzene measurements were made using a Perkin-Elmer diffusive sampler. This comprises a small stainless steel tube 9 cm long containing chromosorb 106 polymer, an adsorbent material with an excellent affinity for benzene. The tubes are sealed at both ends with protective caps. On exposure, the lower cap is removed and replaced with a diffusion cap which allows air to diffuse at a constant rate into the tube.

5.2.2 The Perkin-Elmer samplers operate on the principle that during exposure benzene in air will migrate to the adsorbent at a rate dependent on several quantifiable variables defined by Fick's First Law of Diffusion:

(a) The pathlength between the top surface of the monitor and the adsorbent bed

(b) The cross sectional area of the sampler

(c) The exposure time

(d) The diffusion coefficient of benzene through air

(e) The ambient concentration of benzene

5.2.3 All tubes were prepared by TBV Science. The tubes were despatched by post to each Borough and exposed on mounted perspex blocks for periods of 2 to 3 weeks, following which the diffuser head was replaced with the original protective cap. Upon receipt the tubes were stored refrigerated prior to analysis.

5.3 Sample Analysis

5.3.1 The exposed tubes were analysed using a Perkin-Elmer Automatic Thermal Desorption (ATD 50) gas chromatograph (GC) coupled to a flame ionisation detector. Well defined peaks are produced on the GC which correspond to the benzene component. These peaks are quantified by comparison with a wide range of injected standards. Owing to in-house technical difficulties, all exposed benzene tubes received since January 1993 were analysed under the direction of the Air Quality Group at TBV Science at an external laboratory. This laboratory are NAMAS accredited for the determination of benzene by the GC method.

5.3.2 The mass of benzene collected in the tube is then expressed as an average airborne concentration (ppb) measured over the monitoring period. This calculation is shown in Appendix B. The diffusion coefficient for benzene has been empirically calculated at TBV Science as described in Section 5.4 below.

5.3.3. Quality control procedures integral to the analytical procedure involve verification of the benzene peak and calibration against standard benzene in air mixtures produced dynamically using permeation tube reference sources. All cleaned tubes are analysed prior to exposure to ensure no benzene is retained by the chromosorb.

5.4 Empirical Determination of the Benzene Diffusion Coefficient

5.4.1 Benzene tubes were exposed to a known benzene concentration in air generated using a permeation vial held at 50°C in a glass oven, in turn held in a thermostated water bath. The purge flow of pure air was generated through a glass ball filled heat exchanger from an Aadco Model 737 Pure Air Generator at a rate of 1 litre/minute.

5.4.2 The generated benzene/air mix was fed to a 30 cm diameter spherical glass reaction vessel. Diffusion tubes were mounted on a carousel turning at approximately 1.2 revs per minute.

5.4.3 Tubes were exposed over a period of two weeks and benzene uptake was determined by thermal desorption and detection with FID using internal standards. The diffusion coefficient was calculated according to the equation shown in Appendix B. A Photovac PID GC was used to determine any losses of benzene in the diffusion coefficient test rig.

5.5 Advantages of the Diffusion Tube Technique

5.5.1 The passive benzene sampler has several advantages, including its low relative cost, the fact that it is not labour intensive, is small and unobtrusive, requires only one 'high tech' central analytical facility and provides baseline data of acceptable accuracy. However, there are also disadvantages, namely that very stringent quality control measures are required to ensure data integrity and data may be lost owing to the FID flame being extinguished.