

Chapter 3

Bromine

3.1. Background

3.1.1 Basic chemical information

55. Bromine (Br_2) is a reddish-brown liquid at room temperature. Bromine has a high vapour pressure (175 mmHg at 20°C) and has a pungent odour. Bromine is highly reactive and water soluble (3.5 g/100 ml), producing a mixture of hypobromous (HOBr) and hydrobromic (HBr) acids. Under some conditions a proportion of bromic acid (HBrO_3) can also be formed, but this reaction has little or no relevance for dissolution of bromine in the presence of organic matrices.

Conversion factors at 25°C and 101 kPa

$$1 \text{ ppm} = 6.6 \text{ mg/m}^3; 1 \text{ mg/m}^3 = 0.15 \text{ ppm}$$

3.1.2 Sources

56. Releases of bromine to air are not estimated by the National Atmospheric Emission Inventory and reporting is only required by the Environment Agency where the release is greater than one tonne per annum or as a specific permit condition. From the limited information available the largest point sources appear to be those at which bromine is used in chemical manufacturing. However, the total declared release was less than one tonne in 2002.

3.1.3 Ambient levels

57. No measurements of ambient bromine levels have been reported in the United Kingdom. Measurements are not made regularly around the one production plant in the United Kingdom.

3.2. Health effects

58. The Panel considered animal studies involving exposure to bromine vapour and human studies of acute exposures (including one study of an accidental industrial release in an urban area) and chronic occupational exposures.

3.2.1 Animal studies

59. Bromine is acutely toxic with an LC_{50}^3 (observed up to 30 days after the end of exposure) observed in male albino mice following 9-minute exposures to 750 ppm (4950 mg/m³) and 100-minute exposures to 240 ppm (1584 mg/m³) (Bitron and Aharonson, 1978). Post mortem examinations conducted on guinea pigs and rabbits after exposure to bromine vapour at 300 ppm (1980 mg/m³) for three hours revealed evidence of pulmonary oedema (fluid in the lungs), with deposits on the surface of the upper airways and bleeding from the stomach lining (Perry *et al.*, 1994).
60. Rats, mice and rabbits inhaling 0.2 ppm (1.3 mg/m³) of bromine for four months developed disturbances in the respiratory (breathing), nervous and endocrine (hormone) systems. However, no adverse effects were observed after four months at 0.02 ppm (0.13 mg/m³) (NRC, 1981).

3.2.2 Acute and subacute effects in humans

61. Initial irritant symptoms of bromine vapour inhalation include: shortage of breath, coughing, choking and wheezing, with immediate or delayed bronchoconstriction (constriction of the large air passages that lead to the lungs), inflammation of the windpipe, 'laryngeal spasm' and swelling of the throat. With increased exposure extending deeper into the lung, abscesses in the larger airways and inflammation of the lungs may occur. Acute impairment to breathing may lead to severe hypoxaemia (shortage of circulating oxygen), metabolic acidosis, measles-like rash and subsequent death (IPCS, 1999).
62. Calabrese and Kenyon (1991) report that bromine has a mean odour threshold of about 0.05 ppm (0.33 mg/m³): the geometric mean of a range of reported values. Ruth (1986) reported a wider range of odour threshold from 0.05-3.8 ppm (0.33-25 mg/m³). Lachrymation (watering eyes) has been reported at exposure concentrations below 1 ppm (6.6 mg/m³) (HSDB, 2003). Elkins (1959) reported that workers exposed to 1 ppm (6.6 mg/m³) bromine found this level excessively irritant.
63. A report by Morabia *et al.* (1988) on an accidental release of bromine in an urban area has provided some useful information on human responses. The exposure assessed using chlorine-reactive detection tubes was in the range 0.2-0.5 ppm (1.32-3.30 mg/m³), although the

³ LC_{50} is that concentration lethal to 50% of those exposed of the stated time.

- initial concentration in the bromine cloud following the release was probably much higher. As a result of the release 91 people (about 0.4% of the estimated exposed population) were seen at the local university hospital. Among the 59 whose complaints were recorded, the main symptoms were conjunctivitis (90%), upper respiratory tract irritation (68%), coughing (47%) and headache (46%). A follow-up after one month found that symptoms persisted for more than three days in 22% of those with eye irritation and 29% of those with upper airway irritation.
64. The delayed effects of severe exposure to bromine vapour following spillage caused by a traffic accident were studied by Carel *et al.* (1992). The exposures lasted from 45 to 240 minutes and a cloud of bromine was clearly visible. No concentrations were estimated. Six of the exposed people were studied and all experienced acute eye and skin irritation. Five were hospitalised for one to four days and four received intravenous corticosteroids for their complaint of shortness of breath. At follow-up six to eight weeks later, a wide range of symptoms was reported, but there were no abnormalities in clinical signs or from special investigations, which included chest X-ray and a range of blood tests. There was considerable delay in their returning to work, but the reasons for this included psychological factors resulting from the incident.
 65. Another accidental exposure, probably to both bromine and hydrogen bromide, occurred in two individuals using a hot tub in which a bromine-based disinfectant had been used (Burns and Linden, 1997). Both subjects were non-smokers and had no previously reported respiratory problems. It is not known what concentrations were present. Both had acute upper and lower respiratory tract and eye symptoms but there was little clinical or radiological evidence of lung abnormality. However, pulmonary (lung) function testing up to 10 months following the acute exposure revealed strongly positive responses to methacholine challenge, consistent with reactive airways dysfunction syndrome (RADS, see Appendix 2).
 66. Regular occupational exposure to bromine at concentrations ranging from 0.3 to 0.6 ppm (1.32 to 3.96 mg/m³) was associated with headache, loss of appetite and pains in the joints, abdomen and chest (Alexandrov, 1983). Alexandrov recommended that a concentration of 0.08 ppm (0.53 mg/m³) should not be exceeded in cases of prolonged exposure. Henderson and Haggard (1943) quote a maximum permitted level for prolonged exposure of 0.1-0.05 ppm (0.66-0.99 mg/m³) based on several earlier publications.
 67. The Health and Safety Commission of the Health and Safety Executive (HSE, 2002) has set an occupational exposure standard of 0.1 ppm (0.66 mg/m³) averaged over eight hours and a short-term exposure limit of 0.3 ppm (1.98 mg/m³) averaged over 15 minutes. The American Congress of Governmental Occupational Hygienists (ACGIH, 2001) set a threshold limit value (TLV) also at 0.1 ppm (0.66 mg/m³) but with a short-term limit at 0.2 ppm (1.3 mg/m³) averaged over 15 minutes.

68. The United Kingdom Committee on Toxicity (CoT) considered the dietary intake of bromide in 2003. The Committee reviewed an evaluation by the Joint Evaluation Committee for Food Additives (JECFA) and the Joint Meeting on Pesticide Residues (JMPR), both of which are Subcommittees of the World Health Organisation (WHO) and the Food and Agriculture Organisation (FAO) that established an acceptable daily intake (ADI) in the region of 0-1 mg/kg body weight. CoT considered it inappropriate to recommend a range of intake that included zero, as it is uncertain whether bromine is an essential trace element. CoT considered the upper bound of 1 mg/kg body weight/day to be unlikely to pose a risk to health. The estimated dietary intake is equivalent to about 0.06 mg/kg/day and it is unlikely that exposure by inhalation will significantly erode the margin between this value and the ADI.

3.2.3 Carcinogenicity

69. No long-term studies on the carcinogenicity of bromine are available. No epidemiological studies on human exposures to bromine are available.

3.3. Justification for the air quality guideline value

70. The Panel noted that the chemical reactions of bromine are similar to those of chlorine, but the effects in the lung are more severe. This probably reflects the lower reactivity of bromine and hypobromite, allowing penetration into the superficial tissues of the lung rather than reacting at the surface. As a result tissue damage will be increased. This damage will take more time to recover and may vary with the individual concerned. This is the probable reason why the adverse effects arising from exposure to low levels of bromine are difficult to define. Nevertheless, the primary effects result from the irritant effects of bromine vapour.
71. The information available on the irritant effects of bromine at low concentrations in humans is sparse and is of insufficient quality to define exposure levels and their effects with a high degree of confidence (IPCS, 1999). Bromine inhalation is also associated with subacute effects but these are likely to result from repeated irritation and they are found at comparable exposure levels to those associated with acute responses.
72. In the Panel's judgement, a concentration of 0.1 ppm (0.66 mg/m³) can be considered as a no observed adverse effect level (NOAEL) for irritant or potentially inflammatory effects on the lower respiratory tract and outer eye. To take into account the relatively sparse data on which this value is based and the severity of the irritant response reported, the Panel considered that in this case a safety factor of 10 should be applied to protect a greater number of susceptible individuals in the general population. The Panel accepted that at 0.01 ppm (0.07 mg/m³), irritant effects would be very unlikely, even in these individuals.

73. The Panel considered that there were no grounds for regarding bromine as a human carcinogen.

3.4. Recommendation

74. **The Panel recommends that a concentration of bromine gas or mass equivalent aerosol not exceeding 0.01 ppm (0.07 mg/m³) over a 1-hour averaging period should protect against irritant and inflammatory responses to the skin, eyes and breathing airways. Long-term effects at these low concentrations are considered most unlikely.**

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