Chapter 5
Hydrogen chloride

5.1. Background

5.1.1 Basic chemical information

106. Hydrogen chloride (HCl) is a water-soluble, colourless to light-yellow, corrosive gas. It is 1.27-times denser than air. Anhydrous hydrogen chloride produces aqueous hydrochloric acid when dissolved in water.

Conversion factors at 25°C:

1 ppm = 1.49 mg/m^3 ; 1 mg/m^3 = 0.67 ppm

5.1.2 Sources

107. Estimates of the release of hydrogen chloride to air are reported by the National Atmospheric Emission Inventory and the Pollution Inventories of the Environment Agency and Scottish Environment Protection Agency. The main source of hydrogen chloride in the atmosphere is its release from combustion-related activities, particularly the large coal-burning power stations, with a minor source from the displacement reactions of acidic gases with sea salt particles. The ratio by mass of hydrogen chloride to sulphur dioxide in UK power station emissions is currently 0.088.

108. In the United Kingdom emissions of hydrogen chloride fell by 75% between 1970 and 2000 as a result of the decline in coal use and also the installation of flue gas desulphurisation at Drax and Ratcliffe power stations since 1993.

5.1.3 Ambient levels

109. Hydrogen chloride is monitored at only 12 rural locations in the United Kingdom as part of the Defra nitric acid network. In 2002 annual average concentrations ranged from 0.08 x 10^{-3} to 0.27 x 10^{-3} ppm (0.12 x 10^{-3} to 0.41 x 10^{-3} mg/m^3).

110. There is an absence of continuous and short-term observations of outdoor hydrogen chloride. However, SO_2 is expected to be a good surrogate for hydrogen chloride because they share common emission

sources and they are both reactive and acidic gases. On this basis, exposures to hydrogen chloride are expected to occur downwind of the large coal-burning power stations. As with SO_2, the pattern of hydrogen chloride air pollution is expected to be characterised by short-term peak concentrations typically lasting a few minutes to no more than a few hours at some point downwind of a power station where the plume reaches ground level. These episodes tend to occur as daytime turbulence breaks up night-time temperature inversions in a process called fumigation.

111. At the Ladybower Reservoir site in Derbyshire, which is exposed to plumes from a few distant high-level power station stacks, maximum 15-minute mean SO_2 concentrations have reached 0.19 ppm (0.5 mg/m^3, measured in 2001) and are about 20% higher than the maximum hourly mean concentrations. On this basis, maximum 15-minute mean hydrogen chloride concentrations could be reasonably expected to reach about 0.027-0.040 ppm (0.04-0.066 mg/m^3), although there are no monitoring data to confirm this expectation (see www.airquality.co.uk).

5.2. Health effects

112. The Panel considered animal studies involving exposure to hydrogen chloride and human studies of acute exposures that included occupational and one laboratory controlled exposure study, as well as chronic exposures focusing on carcinogenicity.

5.2.1 Animal studies

113. Hydrogen chloride is acutely toxic with LC_{50}[6] values of around 4700 ppm (7003 mg/m^3) in rats and 2650 ppm (3948 mg/m^3) in mice for a 30-minute exposure (Darmer *et al.*, 1974). Exposure of rats to 1300 ppm (1940 mg/m^3) for 30 minutes caused severe ulcerative changes to the nasal cavity compatible with hydrogen chloride's property as a strong acid. There were no effects on the lungs to nose breathers, although mouth-breathing animals developed equivalent damage to the upper respiratory (breathing) tract (Stavert *et al.*, 1991). In rats, chronic dosing studies at 10 ppm (14.9 mg/m^3) show that rhinitis (inflammation of the nose lining) and epithelial hyperplasia or squamous metaplasia (changes in the nature or number of cells) are common (Sellakumar *et al.*, 1985). This may be regarded as a lowest observed effects level (LOEL), but it is not known whether this value is directly applicable to human subpopulations (Kamrin, 1992). No other animal studies have been published that provide useful evidence on the health effects of ambient exposures to hydrogen chloride in humans.

114. Concerns have been raised in the past that co-exposure to hydrogen chloride and formaldehyde (HCHO) may enhance the known carcinogenicity of formaldehyde, possibly by the formation of bis(chloromethyl)ether (BCME), a human and animal carcinogen

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

(Sellakumar *et al.*, 1985). However, after careful review of the literature, at ambient concentrations this reaction was considered not to occur to any significant degree and so the Panel did not consider that hydrogen chloride would develop carcinogenic potential via this mechanism.

5.2.2 Acute and subacute effects in humans

115. Hydrogen chloride is a sensory and respiratory irritant. Being highly soluble in water, following inhalation the gas is readily deposited in the nose and upper respiratory tract. At raised concentrations and at high breathing rates, it may penetrate deeper into the lower respiratory tract. At high concentrations, as encountered in accidental exposures in industry, hydrogen chloride causes painful irritation of the eyes, nose, mouth and throat, and acute chemical injury to the lungs may cause severe difficulty in breathing and death. Fortunately, such exposures are uncommon, but a form of irritant-induced asthma – reactive airways dysfunction syndrome (RADS) – has been reported following such inhalation accidents (see Appendix 2). Between 1989 and 2003, 130 inhalation accidents involving hydrogen chloride have been reported to the Surveillance of Work-Related & Occupational Respiratory Disease (SWORD) database in the UK and of these 26 (20%) were reported as having led to asthma or RADS. However, the exposures involved are far higher than those encountered in ambient conditions.

116. For occupational exposure, the Health and Safety Commission has set a short-term exposure limit (measured as an average over 15 minutes) of 5 ppm for gas (8 mg/m^3 for aerosol) and a long-term exposure limit (measured as an average over 8 hours) of 1 ppm for gas (2 mg/m^3 for aerosol) (HSE, 2002a,b). The information on toxicity is only available for the gas and, therefore, the concentrations used for aerosolised hydrogen chloride are made equivalent in terms of airborne mass concentrations.

117. The information available on the sensory effects of hydrogen chloride at low concentrations in humans is sparse and, in the Panel's view, is of insufficient quality to define exposure levels and their effects with much confidence. The exception is the one inhalation study by Stevens *et al.* (1992) in which ten young volunteers with mild asthma were exposed to concentrations of 0.8 or 1.8 ppm (1.19 or 2.68 mg/m^3) and the respiratory effects of inhaling the gas while exercising for 15-minute periods were measured. No adverse respiratory symptoms and no decrement in lung function tests were found. In addition, the blinded testing included a 15-minute period of exposure to air. At these levels The volunteers were not able to detect any difference between air and hydrogen chloride, with symptom scores for unusual taste or smell being the same during the air and gas exposures.

5.2.3 Carcinogenicity

118. IARC (1992) concluded that there was no substantive evidence for carcinogenicity of hydrogen chloride in either humans or animals (group 3 unclassifiable). This evaluation included assessment of the effect of mineral acid mists in battery plants and steel mills, where acid mists have been suspected of causing an increase in respiratory cancer, although most such exposures involve mixtures of acids. Exposure to aerosols of hydrogen chloride is known to lead to dental discolouration and erosion (IPCS 1992). There are no studies on potential effects of hydrogen chloride on human reproduction.

5.3. Justification for the air quality guideline value

119. As its starting point the Panel took the need to consider the irritant effects arising from exposure to low levels of hydrogen chloride. In both anhydrous and aerosol forms, hydrogen chloride is a strong irritant that affects the conjunctivae (eye) and respiratory mucosa (moist lining of the breathing airways). Because of its high solubility in water, the major irritant effects of acute exposure are usually limited to the upper respiratory tract.

120. The Panel considered that a concentration of 1 ppm should be regarded as a no observed adverse effect level (NOAEL) for irritant or potentially inflammatory effects on the lower respiratory tract and outer eye, while noting that this view was based on the only available study of a small group of selected volunteers with mild asthma (Stevens *et al.*, 1992). In this study there were two exposure values where there was an absence of effect and the Panel chose the lower of the two as a more conservative option, particularly as the number of participants was small. To take into account the more susceptible individuals in the general population, the Panel considered that applying a safety factor of 2 would be adequate for exposure in the ambient air. This would be consistent with the approach adopted by the Panel in recommending the air quality standard for sulphur dioxide (EPAQS, 1995). The Panel therefore concluded that 0.5 ppm (0.75 mg/m^3) would be an appropriate guidance value for hydrogen chloride, which allowed for its irritant effects on the respiratory mucosa.

121. The Panel considered that there were no grounds for regarding hydrogen chloride as a human carcinogen.

5.4. Recommendation

122. **The Panel recommends that a concentration of hydrogen chloride gas or mass equivalent aerosol not exceeding 0.5 ppm (0.75 mg/m^3) over a 1-hour averaging period should protect against irritant and inflammatory effects on the eyes, skin and breathing airways. Long-term effects at these low concentrations are considered unlikely.**

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