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The German view: Effects of nitrogen dioxide on human health – derivation of health-related short-term and long-term values

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Abstract

The presented overview concerning health relevant effects caused by nitrogen dioxide (NO_2) resumes the current state of results from animal experiments and human studies (epidemiology and short-term chambers studies).

NO_2 concentrations applied in animal experiments were mostly considerably higher than in ambient air. Therefore, short- and long-term limit values were derived from human data. Experimental studies conducted with humans demonstrate effects after short-term exposure to concentrations at or above 400 μg NO_2/m^3. Effects on patients with light asthma could not be observed after short-term exposure to concentrations below 200 μg/m³. On basis of epidemiological long-term studies a threshold below which no effect on human health is expected could not be specified.

Two short-term limit values have been proposed to protect public health: a 1-h value of 100 μg/m³ and a 24-h mean value of 50 μg/m³. Due to the limitations of epidemiological studies to disentangle effects of single pollutants, a long-term limit value cannot be easily derived. However, applying the precautionary principle, it is desirable to adopt an annual mean of 20 μg NO_2/m^3 as a long-term mean standard to protect public health.

Keywords: Nitrogen dioxide; Air pollution; Respiratory system; Effect-concentration; Short-term exposure; Long-term exposure

Introduction

The Commission on Air Pollution Prevention (= Kommission Reinhaltung der Luft, KRdL) of VDI (Verein Deutscher Ingenieure = Association of German Engineers) has been commissioned by the Federal Ministry for Environment, Nature Conservation and

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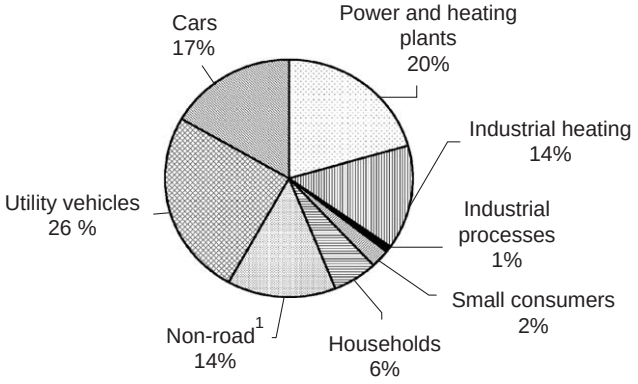
Nuclear Safety (BMU) to give a report on the effects of nitrogen oxides on human health. The study group "Effects of Nitrogen Oxides on Human Health" of the KRdL presented its report "Evaluation of health effects of nitrogen monoxide and nitrogen dioxide" to the BMU in May 2003. The summarized and updated results of this report are presented here and compared to an assessment of the effect-relevant aspects of nitrogen dioxide (NO_2) issued by a WHO study group in January 2003 (WHO, 2003).

Sources of nitrogen oxides in Germany

Based on calculations of the total load of nitrogen oxides (NOs), an environmental input of 1600 kt/year is assumed (UBA, 2002). The major groups of nitrogen oxide emitters in Germany are shown in Fig. 1. The traffic-associated input clearly dominates, whereas emissions from power plants, industrial heating facilities and other industrial sources (e.g., the chemical industry) add up to approximately one-third of the total amount. Since traffic emissions occur mainly in close proximity to the ground, and industrial emissions – especially from power plants – are often expelled through high smoke stacks, traffic contributes even more to ambient levels than would be expected from their emission percentage.



[1]Rail and air traffic, shipping, agriculture, construction machinery etc.

Fig. 1. Proportional contribution of emitters to total NO_x emission in Germany in the year 2000 (Lenz and Prüller, 2003).

The highest ambient air load can therefore be assumed to be at locations with high road-traffic density.

Ambient air pollution by nitrogen oxides

The ambient air pollution caused by NO and NO_2 depends on the respective surroundings. Since car traffic is a major source of ambient NO_x, high nitrogen oxide concentrations are measured alongside roads with high traffic density (Table 1).

Whereas NO concentrations at monitoring stations close to industrial plants do not vary significantly from urban background, high annual NO_2 means of more than 40 μg/m^3 are almost exclusively detected along traffic arteries. Differences are even more pronounced for annual NO mean concentrations. At roadside sites the time between emission and detection of NOs is too short for complete oxidation to NO_2 and mixing with ozone-rich ambient air. This is in contrast to urban backgrounds where the major part of NOs is oxidized to NO_2. Accordingly, higher NO concentrations are measured at roadsides, as demonstrated by peak values. Peak values can exceed simultaneously measured NO_2 peaks by a factor of 5 and increase up to 900 μg/m^3 for a short time. However, according to measurements by Dutch researchers, high NO_x concentrations decrease in the near of major roads to urban background levels within a distance of 100–150 m from busy roads (Roorda-Knape et al., 1998). Depending on type of building density and wind direction, "tubes" of increased NO concentration that extend only a few hundred metres must be expected close to busy roads.

General effects of nitrogen dioxide

Symptoms caused by NO_2

NO_2 is a strong respiratory irritant. Like other gases with low to moderate solubility in water (e.g., ozone), NO_2 reaches deeper regions of the respiratory tract. The bronchotracheal and alveolar regions are the predominating sites of action (Chitano et al., 1995).

Table 1. Typical concentration ranges (μg/m^3) of NO and NO_2 at monitoring stations under different ambient-air qualities in Germany (as measured in 2002)

Type of station	NO_2 annual mean	NO annual mean	NO_2 1/2 h_{max}	NO 1/2 h_{max}
Low mountain range, rural background	4–15	0.7–7	30–100	30–100
Urban backgrounds	20–40	5–30	90–200	100–900
Close to industrial plants	Similar to urban backgrounds			
Roadside stations on busy roads	27–74	28–100	125–430	350–1470

Source: monthly and annual reports of the measuring networks of the federal states of Germany.