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## Executive summary

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In 2008 the Dutch government ascertained that the quality of the indoor environment in primary schools could be improved. The concerns were mainly related to air quality during the heating season, temperatures in classrooms during the summer and annoying noises. Also acting on behalf of her colleagues at the Ministry of Housing, Communities and Integration, the Ministry of Education, Culture and Science and the Ministry of Health, Welfare and Sport, the Minister of the Environment and Spatial Planning asked the Health Council of the Netherlands what is known about how children's health and cognitive performance are affected by the indoor environment in schools. The five questions the minister put to the Health Council are answered separately below. Following on from the government vision on the indoor environment in primary schools, this advisory report mainly focuses on pupils in primary schools.

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### Effects on health and cognitive performance

Question 1. What are the most important factors in the school indoor environment that may have a harmful effect on the health of children and teachers and the cognitive performance of children? At what level of exposure can these effects occur?

The Committee divided this question into two parts concerned with effects on health and cognitive performance and provided details of the latest scientific knowledge. Given the emphasis in the request for an advisory report on carbon

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dioxide (CO<sub>2</sub>) as an indicator of ventilation and air quality, when considering the indoor air of primary schools the Committee focused on pollutants which undergo changes in concentration as a result of ventilation. This emphasis is also in line with the opinions of the civic organisations that were consulted. Other environmental factors which are related to ventilation, such as temperature and noise, are only discussed indirectly by the Committee.

### Health effects

*Chemical substances.* Research abroad indicates that building and furnishing materials, such as formaldehyde, plasticisers and other volatile and semi-volatile organic substances in classrooms may lead to adverse health effects in children. This especially applies to sensitive groups such as children with asthma. The air in classrooms may also be polluted by outdoor air, when they are close to busy roads for example. This can also lead to adverse health effects.

*Particulate matter.* Various European studies on the air in classrooms found concentrations of particulate matter in excess of the exposure limit for outdoor air\*. This mainly applied to the coarser fraction of particulate matter, which enters air through the activities of pupils. This particulate matter could plausibly exacerbate respiratory symptoms, especially in the case of the asthmatic pupils, but no research has been conducted into this.

*Infectious micro-organisms.* Infections can be transmitted in various ways, particularly through physical contact or through the air. Schools play a major role in spreading viral infections through the population. The likelihood of respiratory infections such as influenza being spread via schools is partly determined by the concentration of pathogens in classroom air. However, no suitable study has been conducted on the link between ventilation and the prevention of infections caused by pathogens in schools.

*Other microbiological factors.* Studies in other countries indicate a link between, on the one hand, indoor dampness and fungal growth and, on the other hand, inflammatory reactions in mucous membranes and respiratory symptoms. Non-infectious bacterial and fungal components that could lead to an increase in respiratory symptoms have been found in the indoor air and floor covering of classrooms. Exposure to various types of allergens also occurs in schools. In particular, exposure to cat allergens carried by classmates with pets at home can lead to respiratory symptoms caused by an allergic reaction.

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\* 24-hour exposure limit for particulate matter (PM<sub>10</sub>): 50 µg/m<sup>3</sup>

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*Perceived indoor air quality.* In experiments with volunteers the CO<sub>2</sub> concentration in indoor air was used as a measure for the concentration of body odour substances. The experiments revealed that in the concentration range up to 1,500 ppm CO<sub>2</sub> a relationship between CO<sub>2</sub> concentration and an annoying odour was only demonstrated upon entering a room. There was no relationship when the length of time spent in the room was longer. In the case of average CO<sub>2</sub> concentrations (approximately 2,000 ppm), such as those detected in a random sample of Dutch classrooms in 2007, it is plausible that some pupils and teachers will experience an annoying odour upon entering the classroom.

*Ventilation.* Investigations at schools often use the CO<sub>2</sub> concentration in classrooms as a measure of ventilation. The Committee's opinion after examining the scientific literature is that in by far the majority of studies there are no indications of a relationship between health complaints and an average CO<sub>2</sub> concentration below 1,200 ppm\*. One study conducted in Swedish schools found an indication that there had been a decrease in asthma following the installation of a new ventilation system, after which the average CO<sub>2</sub> concentration decreased from 1,000 to 800 ppm. The decrease in asthma cannot be explained by CO<sub>2</sub>, as CO<sub>2</sub> only produces effects at concentrations of many thousands of ppm. In the classrooms concerned, the concentration of other airborne substances also decreased and this may have led to fewer asthma symptoms there.

*Temperature, air movement and noise.* Research into the health effects of other ventilation-related indoor environmental factors has mainly been conducted among adults. Many schools have problems with high temperatures in summertime due to heat from the sun. In 2007, 45 percent of teachers reported often being too warm in the classroom during the summer. High temperatures may not only be linked to feelings of discomfort but also to headaches or tiredness. Other frequently occurring problems associated with ventilation, such as a too low temperature in the winter, draught and too much noise can lead to ventilation facilities not being used sufficiently because they are considered to reduce the level of comfort in the room so much.

## Effects on cognitive performance

*Ventilation.* One of the experiments studied indicated that pupils worked rather more slowly or made more mistakes when working under reduced ventilation in the classroom, associated with an increase in the CO<sub>2</sub> concentration from

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\* A maximum CO<sub>2</sub> concentration of 1,200 ppm was the basis of the 2003 Building Decree's minimum requirements for ventilation in new buildings .

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approximately 800 to 1,600 ppm. Based on the available data the Committee is unable to define a CO<sub>2</sub> concentration at which cognitive phenomena of this kind start to occur, or which factors in the indoor environment are responsible. However, when occurring repeatedly, it could be possible that these effects will adversely affect cognitive development. The Committee therefore recommends conducting further studies on the effect of indoor air quality on pupils' performance, also in the long term.

*Temperature and noise.* High noise levels in classrooms may adversely affect the cognitive performance of pupils. The same applies to indoor temperatures higher than 25°C.

#### The most important indoor environmental factors in relation to health

The Committee notes that exposure to various indoor environmental factors occurs in schools and that due to their nature they may have adverse effects on the health of pupils. However, no studies are available that indicate the level of exposure in the school situation at which adverse effects start to occur. In answer to the minister's first question, the Committee concludes that it is not possible to state scientifically what the most important indoor environmental factors in schools are that result in adverse health effects. Nevertheless, the Committee is concerned about exposure to particulate matter, pathogens, allergens, and high temperature and noise levels in classrooms.

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#### **Carbon dioxide as a measure of ventilation in classrooms**

Question 2. For which indoor environmental factors in schools is CO<sub>2</sub> a good indicator of ventilation? To what extent is CO<sub>2</sub> an indicator of air quality in classrooms?

The CO<sub>2</sub> concentration in a classroom is a good measure of the ventilation per person. To a limited degree CO<sub>2</sub> is also an indicator of body odours. CO<sub>2</sub> is less useful as an indicator of dust particles, allergens and pathogens dispersed by human beings. This is because the rate of CO<sub>2</sub> production is scarcely related to the rate of other substances dispersed by pupils. CO<sub>2</sub> is not a useful indicator of other substances and particles in indoor air, such as volatile organic compounds, plasticisers, dampness, fungi or outdoor air pollutants. CO<sub>2</sub> is therefore only a poor indicator of indoor air quality in classrooms. These conclusions do not affect the fact that increasing ventilation will reduce the CO<sub>2</sub> concentration as well as the concentration of other substances and small particles in the air.

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## Substantiation of the various CO<sub>2</sub> target values

Question 3. How do the background and reasons for choosing the CO<sub>2</sub> levels adopted by the Municipal Health Services relate to the CO<sub>2</sub> level adopted for policy purposes for the removal of pollutants from indoor air?

*CO<sub>2</sub> target values as recommended by the Municipal Health Services.* Municipal Health Services guidelines on assessing ventilation in schools recommend aiming for a CO<sub>2</sub> concentration of less than 800 ppm\* for indoor air in schools. The Municipal Health Services in the Netherlands based this CO<sub>2</sub> target value on a report produced by an expert group it had established. This expert group concluded that the literature contained indications that indoor environmental factors at CO<sub>2</sub> concentrations even lower than 1,200 ppm led to health complaints, exacerbation of asthma, an increased risk of infection and were an impediment to school children's cognitive performance. The Committee takes the view that the evidence of the research studied is too limited to be used as a basis for determining target values.

*CO<sub>2</sub> target value as basis for the Building Decree.* The maximum CO<sub>2</sub> concentration of 1,200 ppm as basis for the Building Decree's minimum ventilation requirements in new buildings was originally intended to limit odour nuisance. In 1984 the Health Council of the Netherlands deemed this value acceptable for housing. At the time, the Health Council had largely based its opinion on data from an experiment conducted in 1981 with a small number of adult volunteers. The Committee takes the view that the quality of these data was very limited.

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## Reconsideration of the 1,200 ppm CO<sub>2</sub> target value

Question 4. The 2003 Building Decree's ventilation requirements in new buildings were aimed at avoiding odour nuisance and were based on the Health Council's report of 1984. Are there any reasons from the health point of view for reconsidering the present CO<sub>2</sub> target value of 1,200 ppm?

Since the Health Council's 1984 advisory report about twenty scientific papers have been published which contain information on the significance of air quality in schools for the health of pupils. Apart from odour nuisance upon entering a room, most of these studies did not demonstrate any adverse effects associated

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\* 98<sup>th</sup> percentile: the highest level, excluding the 2% highest measured levels

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with increasing CO<sub>2</sub> concentrations. Nevertheless, there is a great deal of uncertainty about the results, which means there may have been a failure to detect an effect. In two studies the Committee found indications that health complaints arose or there was a reduction in pupils' cognitive performance at average CO<sub>2</sub> concentrations of about 1,200 ppm. There were more indications of adverse health effects in schools at average CO<sub>2</sub> concentrations exceeding 1,500 ppm, but it is unclear to what extent. Based on the available data, the Committee is of the opinion that a CO<sub>2</sub> target value for ventilation may be in a relatively wide range around 1,200 ppm. However, the data are inadequate for indicating a scientifically based exposure limit. The Committee therefore sees no reason to deviate from the present maximum CO<sub>2</sub> concentration of 1,200 ppm as the basis for the minimum ventilation requirements for new buildings as stipulated in the Building Decree. This means that some children may experience odour nuisance upon entering the classroom and that a sensitive child may experience an adverse effect.

Where the CO<sub>2</sub> concentration is intended as a measure of ventilation, it should actually concern the difference between the concentration in indoor air and that in outdoor air. Given a usual concentration of 400 ppm in outdoor air, a maximum CO<sub>2</sub> concentration of 1,200 ppm in indoor air corresponds with a concentration difference between indoor and outdoor air of no more than 800 ppm. The Committee recommends applying a concentration difference of 800 ppm as exposure limit for the extent of ventilation.

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### **Recommended exposure limits for other indoor environmental factors in schools**

Question 5: To what extent is it possible to set recommended exposure limits for ventilation-related, indoor environmental factors other than CO<sub>2</sub>?

The Committee is of the opinion that it would be useful to develop recommended exposure limits for temperature and concentrations of particulate matter, non-infectious microbiological components and allergens in schools. However, no data on exposure-effect relationships are available for these factors.

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### **Recommendations for a healthy indoor environment in schools**

Given the finding that the average CO<sub>2</sub> concentration in Dutch classrooms is about 2,000 ppm, many schools ought to increase ventilation to keep CO<sub>2</sub> concentrations below 1,200 ppm. The Committee points out that the ventilation

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required for this can lead to – unnecessary – secondary effects, such as draught, noise nuisance or health effects caused by dust from the ventilation system's supply air filters, if they become contaminated due to poor maintenance. It is therefore necessary to have clean ventilation air and proper ventilation facilities as well as information on how to use them properly.

The scientific research on which the Committee has been able to base its findings is limited. Further research is therefore required into the effects of indoor air quality on the health and cognitive performance of pupils, especially those in sensitive groups, such as children with asthma, chronic headache or learning difficulties. In anticipation of the results of any such research, the Committee recommends a reduction in exposure to harmful indoor environmental factors in classrooms, as these may lead to health complaints especially in children with asthma. The government may stimulate this by establishing requirements and practical guidelines for:

- the design, installation, use and maintenance of ventilation facilities in schools, not only concerned with proper ventilation but also with minimising the emission of hazardous substances and the creation of draught and noise nuisance
- outdoor air drawn in to ventilate schools; in connection with this, ventilation systems in schools located in areas with polluted outdoor air, such as those close to busy roads, should have a suitable filtration system
- ensuring a healthy indoor climate in schools, by setting emission limits for irritating substances released by materials used in buildings, furnishings, teaching aids and equipment, and guidelines on the choice of floor covering and on classroom cleaning.