PATTERNS OF URBAN AIR POLLUTANTS: AN OVERLOOKED FACTOR WHEN OPERATING VENTILATION SYSTEMS

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ABSTRACT

In most cities, vehicles are the main sources of pollutants. The concentration of pollutants is then known to vary with traffic intensity. Ventilation flows should be adjusted accordingly, which would give improved air quality, especially in dwellings.

KEYWORDS

Urban, air pollutant, diurnal concentration, ventilation air flow.

INTRODUCTION

When ventilating offices and dwellings, the cleanest air possible should be supplied. The levels of pollutants in outdoor air vary considerably over a given period, e.g. a day, because vehicles are usually the dominant pollutant sources. Traffic density usually shows a similar pattern from day to day, see Fig. 1. This article will study how the pattern can be used. The emphasis here is on traffic density, but there are also variations according to the height of a dwelling above a street, see e.g. Peterson (1993).

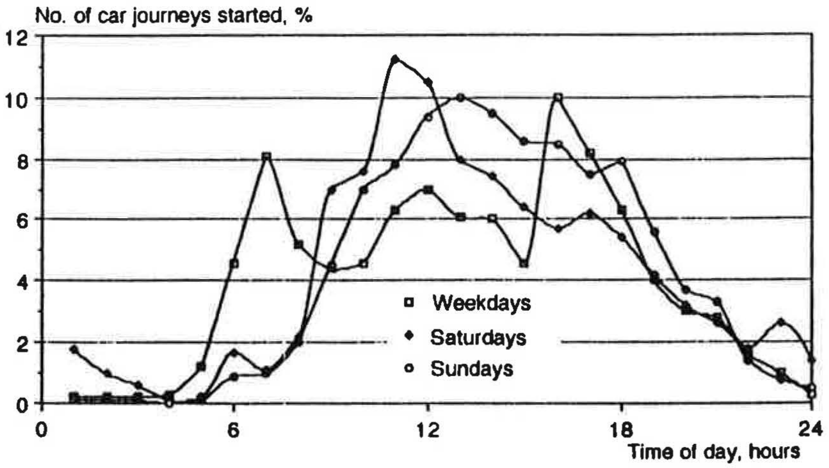

Fig. 1. No. of car journeys undertaken in Gothenburg, as % of daily total, from Henriksson (1993).

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TEMPORAL POLLUTANT PATTERNS

The short- and long-term health effects of many pollutants are not known in detail. However, some of the more common effects mentioned are: fatigue and difficulty concentrating (CO); difficulty breathing (NO_x); lung cancer (polycyclic aromatic hydrocarbons (PAH), soot); hypertension (lead); cancer (hydrocarbons); immunodeficiency (O_3); chronic pulmonary disease (PAH). Threshold limiting values and ways of reducing pollutants levels vary from country to country, but given thresholds are sometimes exceeded more than half the time, see e.g. Nordqvist (1989) for NO_x and CO, and Ballaman (1993) for O_3. The highest levels are reached during rush hours, where not only is the traffic density high, but there is a lot of stop-start driving with uneven combustion. *One* way of reducing their health effects is to reduce the supply air flow during periods of peak pollution. The negative effects of reducing ventilation then need to be borne in mind, e.g. the possible build-up of pollutants from continuously emitting indoor sources.

Several kinds of pollutants are produced by vehicles. Particles are formed by *friction* from tyres, metallic studs on winter tyres, brake linings and discs, etc. Some hydrocarbons *evaporate* directly into the air. Some compounds formed by *combustion* are CO, CO_2, hydrocarbons (both aliphatic and aromatic), particles and soot, plus combinations, e.g. particle-bound PAH. Figure 2 shows some measured levels of particle-bound PAH.

Not all pollutants follow traffic patterns. The formation of ozone from the NO_x in vehicle exhausts is catalysed by ultra-violet light. Ozone levels thus depend on a combination of traffic density and solar intensity, see Fig. 3. The patterns of small particles do not follow traffic patterns, because there are already significant background levels in the air. Larger particles, however, more closely follow traffic patterns, Fig. 4, as the particles produced by friction fall into this category.

The production of air pollutants is therefore proportional to traffic intensity, type of driving, solar intensity and dispersion rate. The dispersion of pollutants depends on factors like wind speed and other weather conditions, and sedimentation rates. There are also seasonal variations. Some expected long-term changes over the next 10–20 years were given by Joumard (1993), who based his assumptions on changes in traffic and pollution regulations in France. The main changes were increases in CO_2 (2–3% per year), particles (2–4% per year) and NO_x (0–2% per year).

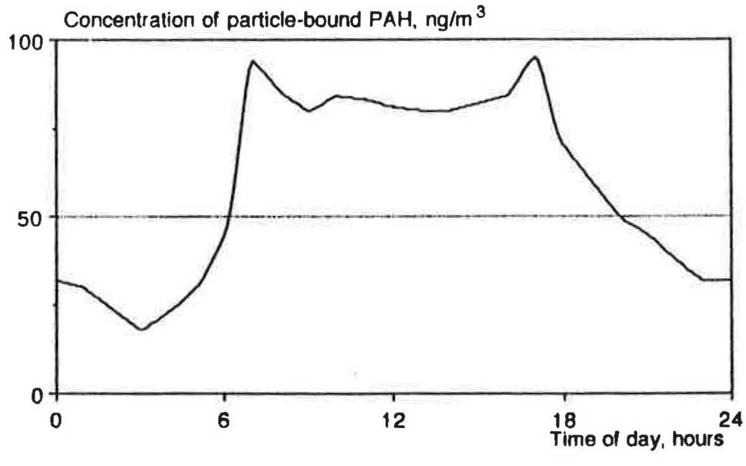

Fig. 2. Diurnal levels of polycyclic aromatic hydrocarbons (PAH) in the outdoor air, measured with infra-red light by Kjaerboe *et al* (1993).

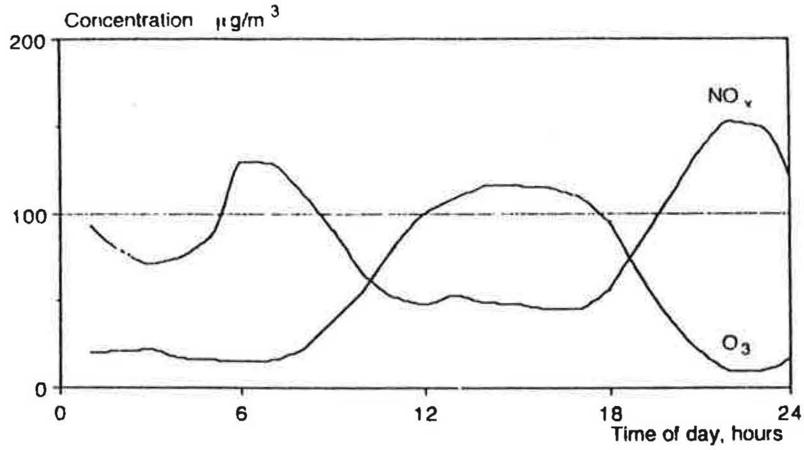

Fig. 3. Levels of NO_X follow vehicle density levels. Levels of O_3 follow the level of solar intensity. From Ballaman (1993).

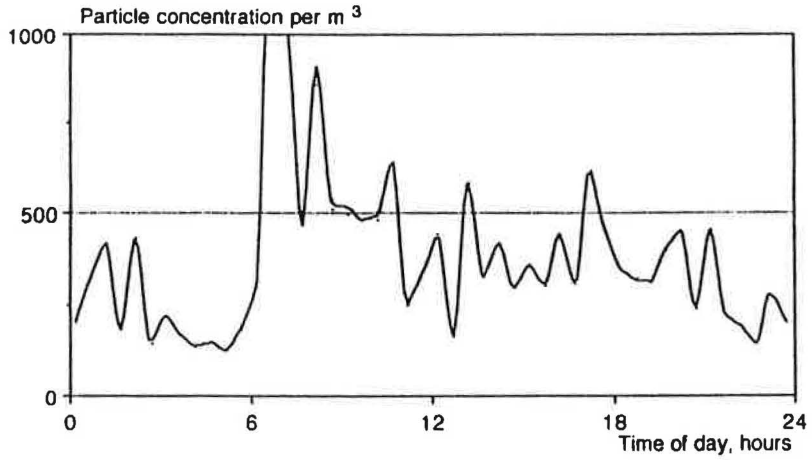

Fig. 4. Concentrations of large particles ($10 < d < 25$ µm, where d = mean particle diameter). Measured in urban air (Stockholm) with a laser counter, see Kjaerboe (1993).

VARIATIONS IN VENTILATION REQUIREMENTS WITH TIME

Air flows should determined by the number of people in a room and how they use the room. For dwellings, ventilation is required mainly during non-working hours. Dwellings can thus be ventilated with minimum flows during working hours, if they are unoccupied. In this way, large amounts of energy can be saved and the air quality can be improved. For example, if a dwelling is ventilated with a constant flow q throughout the day, quantities of PAH according to Fig. 2 will be drawn in. It can be calculated that this will result in the indoor levels shown by curve 1 in Fig. 5. If a flow of $0{,}6q$ is used during periods of high PAH levels, and $1{,}4q$ during periods of low PAH levels, then the amount of PAH drawn in during the day is only 70% of that with constant air flows (curve 2). This is achieved without incurring any extra energy costs. If flows of $0{,}6q$ and q are used instead, then the amount of PAH is 80% of that with constant flows, and the amount of energy saved is about 30% (curve 3). These levels have been calculated numerically with a short time step (5 minutes or less) by computer. Decisions on how to adjust flows can be based on whether improved air quality or reduced energy costs are judged most important. Ventilation flows can be adjusted by home owners themselves, as they did with window ventilation, provided they have reasonably keen senses of smell and hearing.

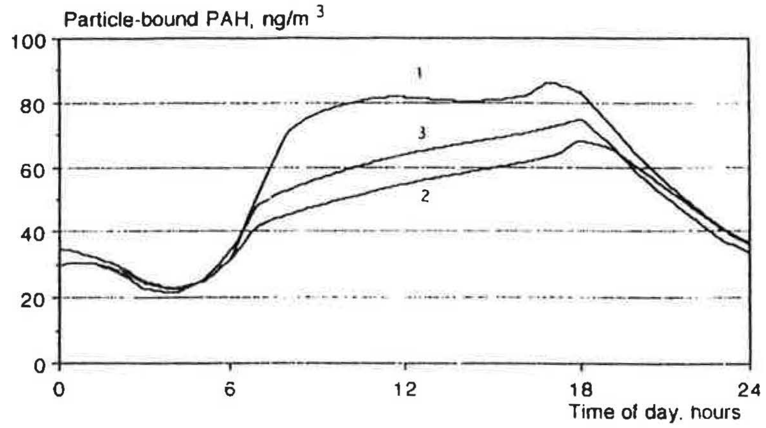

Fig. 5. Indoor concentrations of particle-bound PAH, calculated from the outdoor levels in Fig. 2.
Curve 1: Constant flow, q.
Curve 2: 0,6q between 06h 00 and 17h 00, 1,4q thereafter.
Curve 3: 0,6q between 06h 00 and 17h 00, q thereafter.

Offices and day-care centres are used during periods of high air pollution levels. The gains possible are thus less than those with dwellings. But some gains are possible, if full use is made of the building's capacity to absorb pollutants. Ventilation flows then need to be increased during periods of low pollutant levels (at night) to remove the pollutants absorbed by the furnishings during the day. Another way to reduce pollutant levels indoors is to use recirculated air during periods of high pollutant levels outdoors, or even to shut down the ventilation entirely. Activated carbon filters can be used to clean the recirculated air. Filters (both fibrous and activated carbon) can also be used to filter the incoming air.

SUMMARY

In many cities, it is reasonable for traffic density to form the basis for adjusting ventilation flows. The largest reductions possible in ventilation flows are in dwellings, where the largest ventilation requirements coincide with the "availability" of clean air. However, assessments should be made of pollutants from traffic and industry before general recommendations are made. The assessments can be based on both direct measurements and the available traffic statistics.

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