MOTORISTS	PASSENGERS
WALKING	CYCLING
INDOOR	OUTDOOR
CHILDREN	PARENTS

Exposure to Traffic Exhaust

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Exposure to traffic exhaust

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In our urban society, everybody is always exposed to, and surrounded by, varying concentrations of chemical compounds from traffic exhaust. This major air pollution problem is becoming increasingly recognized as a threat to public health. The degree of hazard is related to the dose of the harmful substances absorbed, and thus in turn to the extent of the exposure and to physiological parameters.

There is no such thing as a harmless dose

With regard to chemical and toxicological complexity, traffic exhaust compares well with tobacco smoke. Consequently, no exact answer can be given to the commonly-posed question as to how dangerous traffic exhaust is. On the other hand, the following two statements are useful guidelines when dealing with air pollution from traffic exhaust.

The degree of health hazard becomes rapidly smaller with decreasing doses, but not even the smallest doses can be regarded as harmless.

An initial decrease in dose produces a comparatively large reduction of the health hazard, i.e. the first decrease is always the most valuable.

Toxicologically, the first statement refers to the presence of a large number of mutagenic and carcinogenic compounds in auto exhaust. For such compounds no harmless levels are though to exist (Cederlöf et al 1978). The second statement is based on the conventional toxicological concept of threshold levels (Casarett and Doull's Toxicology 1980) for the very numerous, genetically inactive exhaust components. From an ecological point of view, the same two conclusions can be drawn. Human beings as well as other organisms are biologically adapted to "clean air", and the larger the deviations from normal, the larger the health hazards according to basic ecological principles related to the concept of limiting factors (Odum 1971).

Several countries as well as WHO define exposure limits for air pollutants such as carbon monoxide and nitrogen dioxide in order to protect public health. Although such limits presuppose the occurrence of the particular compound alone, they are sometimes referred to in discussions on traffic exhaust pollution. It is important to realize that such comparisons grossly underestimate the health hazards from traffic exhaust because the additive and synergistic effects of the multitude of other chemical components are not taken into account.

Assessing exhaust exposure

A knowledge of exposure levels in various environments is needed in order to plan effective measures aiming at reducing exposure. Extensive measurements of the amount of air pollution from traffic exhaust has been made all over the industrialized world. Traditionally, the samples have been taken to a large extent at more or less standardized situations, especially in streets. Recently, exposure-related methods have been more widely introduced, although such methods have been applied in work environments for a long time. Small mobile stations, and above all, personal sampling equipment permit very versatile assessments of exhaust exposure.

Traffic exhaust is composed of several hundred chemical compounds which can be determined by modern analytical methods. The spread of both gaseous and particulate components is fairly uniform, however. Therefore, it is usually sufficient to measure one component, e.g. carbon monoxide, or a few characteristic components, in exposure studies. It should be observed that this approach applies to traffic exhaust but not to ozone and similar secondary pollutants, which often constitute another severe problem.

Exposure assessments reported in this chapter are based mainly on studies of unburnt hydrocarbons from traffic exhaust. Samples were taken with personal sampling equipment and analyzed by gas chromatography (Mattsson & Petersson 1982). The characteristic composition of hydrocarbons from petrol exhaust permits a differentiation from diesel exhaust and industrial and other sources.

A few basic data on fuel and on emission control systems will roughly define the composition of petrol as well as diesel exhausts in any region. It is well known that the composition varies somewhat with the mode of driving, temperature, condition of the engine and other factors. The ratio between certain components may also be somewhat different inside a vehicle, at the roadside, inside a house, and indeed at any point and time. Furthermore, many hazardous chemical species disappear by reaction, and others are formed by reaction at various distances from the exhaust pipe.

Basically, however, traffic exhaust should be viewed as spreading uniformly when strategies for assessing and reducing exposure are worked out. It is remarkable that "passive" smoking is commonly thought of in this way, whereas the similar problem of exposure to traffic exhaust is very seldom discussed in the same simple and straightforward terms.

Distance reduces exposure

Traffic exhaust is rapidly diluted by horizontal as well as vertical mixing. Consequently, concentrations decrease rapidly with the distance from the exhaust pipes. This elementary principle should be central in all local efforts to reduce exposure to traffic exhaust.

Representative figures for horizontal spreading are given in Table 1. At a distance corresponding to one block, concentrations are only about one tenth of those close to traffic. The difference is smaller when there is plain ground between the two points, and larger when there are trees, houses, or hills between them. When vertical mixing is restricted, e.g. by nocturnal ground-level inversions, the ratio is smaller but the absolute concentrations higher. The opposite is true under weather conditions with efficient vertical mixing. Concentration lowering with height tends to be even more efficient on average, due to the often limited vertical mixing.

Obviously, the most efficient way of reducing one's exposure to traffic exhaust is to keep at a distance from exhaust pipes. The larger the distance the better, but the first few metres are the most important. This easily understood principle enables individuals to reduce their exposure to exhaust fumes in the immediate environment. Again, comparisons with the tobacco smoke problem may be helpful in understanding the problem.

Motorists and passengers

As indicated in Table 1, exposure inside motor-cars is usually much higher than outside exposure even on the near-by pavement. The reason is that each vehicle is enveloped by exhaust from the motor-car ahead. The shorter the distance to the motor-car ahead, the higher are the exhaust levels in the air passing into the vehicle behind. In addition, the motorist and his passengers are often exposed to very high concentrations of exhaust and fuel vapours in garages, inside parked cars, and at petrol stations.

A study in Göteborg, Sweden, demonstrated that the average levels of petrol exhaust in motor-cars were about three times higher than in buses and trams in which the air intakes are higher from the ground and which will partly use separate carriage-ways (Petersson 1981). Where the tram lines were separated from exhaust-producing traffic, levels were still lower. Buses, on the other hand, were found to contain not only petrol exhaust but also diesel exhaust from their own engines. Diesel exhaust probably leaks into the bus mainly through open doors at bus stops.

Table 1. Relative values of auto exhaust concentration, by site of sampling.

Inside motor-car in queue	30
On pavement by traffic stream	10
10-20 m from traffic stream	5
50-100 m from traffic stream	1

Exposure inside vehicles and particularly inside motor-cars merits attention not only because of the comparatively high exhaust levels but also because of the frequent every-day use of motor-cars. A particular point of concern is the frequent use of motor-cars by pregnant women, and for transporting small children. A comforting point is that the individual can do much to reduce exposure, e.g. by keeping motor-car trips to a minimum, by avoiding heavy traffic, and by always keeping an adequate distance from the vehicle ahead. Proper regulatory measures should make it necessary or at least easier for the motorist to keep a reasonable distance. They should also prevent queues at street and road sections which have bad ventilation and are located near to housing.

Walking and cycling

People who are walking or cycling are normally exposed to lower concentrations than those inside motor-cars, because of their position outside the mainstream of exhaust fumes. On the other hand, it must be remembered that health hazards are related to the dose inhaled rather than to the exposure expressed as the concentration in air. The lung ventilation, i.e. the air intake, is larger for pedestrians and particularly for cyclists because of their physical activity (Åstrand 1977). A comparison between a cyclist and a mo-

torist when covering identical distances is given in Table 2 (Petersson 1981, Lidström, 1980). The dose inhaled by the cyclist when cycling uphill is very high because of his physical efforts. On the other hand his dose is very much lower on cycle tracks well separated from exhaust-producing traffic. It should also be emphasized that the total exposure of the motorist is more unfavourable than is apparent from Table 2 because of exposure related to parking and petrol.

Table 2. Comparative air intake and traffic exhaust dose of cyclists and motorists at different distances between road (street) and cycle track.[1]

	Time	Air intake	Dose at 0 m	Dose at 3 m	Dose at 50 m
Normal ground	2	2.5	4	2	0.5
Level ground	1.5	2	2.4	1.2	0.3
Uphill	3	4	10	5	1

1 Concentration ratios cyclists/motorist were assumed to be 0.8 at 0 m, 0.4 at 3 m and 0.1 at 50 m.

Many similarities exist between pedestrians and cyclists with respect to exposure and dose. The lung ventilation on walking is normally lower than when cycling, but on the other hand lung ventilation is very high on jogging and running (Åstrand 1977). The more strenuous and long-lasting a physical activity is, the more important it is to keep as long distance as possible from exhaust pipes. The uptake of children during play activities may be high and playgrounds should always be properly located with respect to traffic and vehicles.

Cycle tracks and foot-paths efficiently separated from traffic and parking are a very important means of reducing the uptake of exhaust fumes by cyclists and pedestrians. Indeed, the traditional street with pavements close to and on both sides of the traffic is clearly unsatisfactory and can almost be said to maximize exposure to exhaust. Current designs of street crossings are hazardous for similar reasons. In Figure 1 the fluctuations in exposure when walking along a street are illustrated. The maxima correspond to waiting at, and crossing, streets close to passing or stationary

vehicles. The two lowest levels correspond to street sections free from private motor vehicle traffic. Similar diagrams based on a knowledge of concentrations in various types of urban micro-environments are useful in planning and effecting changes aiming at reducing exposure to exhaust fumes.

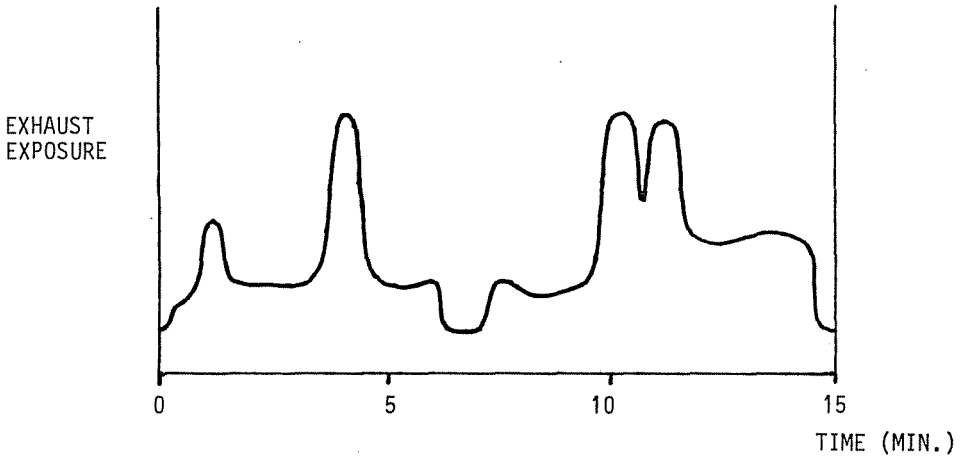

Figure 1. Variations of exposure during a walk along a street (The Avenue, Göteborg, Sweden).

Indoor exposure

Intuitively, people may think that they are protected against traffic exhaust indoors. This is not the case because exhaust enters with ventilation air from outside the building. In principle, indoor concentrations are the same as those of the air entering from outside. This means that it is essential to supply air from the least exhaust-exposed side of a house and preferably from a high level above ground (cf Table 1). In extreme cases, such as flats and shops with natural ventilation and facing narrow streets with dense traffic, indoor exposure may be very high.

Obviously, good opportunities for reducing indoor exposure are provided by keeping one side of a house "exhaust-free" rather than by levelling out the exhaust pollution in an area of a town. Currently prevailing efforts to reduce the top exhaust levels often give rise to a levelling-out effect and are then questionable. One street with, and the next parallel street without, exhaust-producing traf-

fic might be a fruitful planning model. This would also give cyclists and pedestrians, as well as parents and children, an important opportunity of avoiding traffic exhaust. The exposure-reducing effects would be surprisingly large (cf Table 1).

A potential danger concerning indoor exposure to exhaust and fuel vapours is indoor parking. The dilution of pollutants in air by mixing is restricted indoors. Therefore, even small emissions such as those from a single motor-car may produce high concentrations in a garage. The spread from a garage inside a house to other parts of the house is difficult to prevent. Therefore, parking inside houses should preferably be avoided or carefully controlled with respect to air pollution. In multi-story car parks exhaust levels are commonly about five times higher than in streets with much traffic in spite of efficient ventilation.

For the average citizen, exhaust exposure levels indoors at home and at work are considerably lower than in the traffic environment. On the other hand, exposure times are normally much longer indoors.

In Figure 2, these facts are illustrated. The exhaust dose, assuming constant lung ventilation, corresponds to the area under the curve. In real life, respiration is increased during the day-time and particularly with physical activity (Åstrand 1977), resulting in a corresponding increase in the absorbed dose. On an average, home, work-place, and traffic environment are likely to contribute about equally to the diurnal dose. Dose-reducing efforts are needed everywhere. Exposure (or dose) versus time diagrams may be helpful in discovering unacceptably large doses as well as contributions to the total dose which could be easily eliminated.

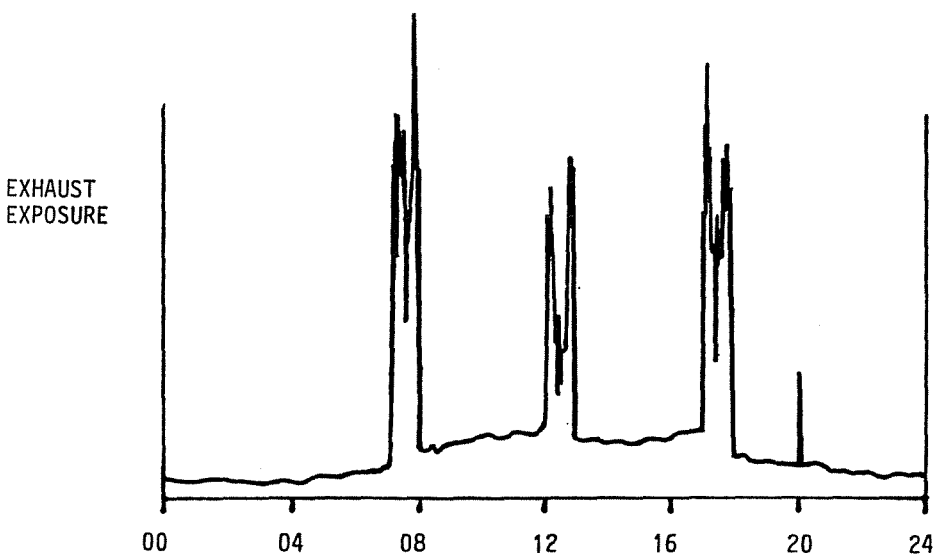

Figure 2. Typical diurnal exposure pattern of an individual in an urban environment.

Children – no time to lose

From several points of view, children's exposure to traffic exhaust merits special attention, as they are thought to be more vulnerable than adults with respect to most exhaust hazards. The potential effects of lead on children's health have been intensely debated. It is, however, often forgotten that inorganic lead is only one of a large number of exhaust components with potentially deleterious effects on their mental abilities and physiology. Even health authorities tend to over-emphasize comparisons with exposure limits set for individual compounds. Considering the extremely complex composition, additive and synergistic effects may actually be responsible for the worst health hazards.

An important point is the short time of maximum vulnerability of a small child. At the foetus stage, this time may be on the order of weeks. This contrasts with current planning periods of several years for the introduction of exhaust regulations and for improving urban traffic environments. Therefore, it is essential not only to speed up these important planning activities but above all to find means of reducing people's exposure, and particularly children's exposure as quickly as possible. As emphasized below, a surprisingly large amount can be done to this end, both at the municipal level and at the personal level.

Local reduction of exposure

A list of possible changes aiming at effective exposure reductions in local environments is given below. Most of them can give large reductions because of the rapidly decreasing exposure relative to increasing distance from the source of emission. Inexpensive changes which can be performed within a short time have been emphasized. It is hoped that these suggestions by a planning amateur will inspire professionals to find more and better solutions and above all to realize them as quickly as possible.

Very short time needed:

- Moving stop lines for vehicles, except bicycles, back from pedestrian crossings.

- Recommending long gaps between vehicles in queues, particularly those with children as passengers (information campaign).

- Introducing signs warning children from entering parking places, multi-story car parks and garages.

- Preventing unnecessary parking within and near houses.

- Discouraging parking near dwelling-houses by selective parking fees.

Short time needed:

- Zones free from exhaust-producing vehicles in housing areas.

- Every second street, if possible, reserved for exhaust-free traffic in urban areas.

- Regulations against high vehicle density in critical street sections.

- Foot-paths and cycle tracks far separated from exhaust producing traffic.

- Crossings designed and regulated to minimize exhaust exposure of pedestrians and cyclists.

- Stops for public transport vehicles to be kept free from high exhaust levels.

- Indoor parking and parking close to houses, eliminated and replaced by various measures.

- Unnecessary traffic and parking removed from nurseries, schools and hospitals.

- Ventilation improved in houses with an exposed location.

Parents can prevent exposure

In practice, there will always be some delay in performing environmental changes aiming at reducing exposure. Therefore, the particular importance of an immediate reduction in exposure make personal efforts to avoid exposure essential. The same is true of the analogous problem of passive smoking. At the individual level important changes in habits and behaviour can often be made from one day to the next. An unpredjudiced scrutiny of exhaust exposure of individuals is also likely to reveal possible improvements in the local environment. Pregnant women and parents have a particular reason to be concerned about the problem. The following list of questions is intended to give some ideas to parents in particular:

- Are your children using playgrounds well separated from exhaust-producing vehicles?

- Are your children choosing the best alternative with respect to exhaust exposure on their way to school?

- Are you choosing streets and shops with low exhaust levels when shopping with your children?

- Are you keeping a long distance to the vehicle ahead when driving with your children as passengers?

- Are you keeping your children out of your garage and parking places?

- Are you choosing separate cycle tracks and foot-paths when you are out with your children?

- Are you telling your children to avoid places where exhaust can be smelt?

- Your children are most vulnerable to exhaust now. What can you do from tomorrow on to reduce their exposure?