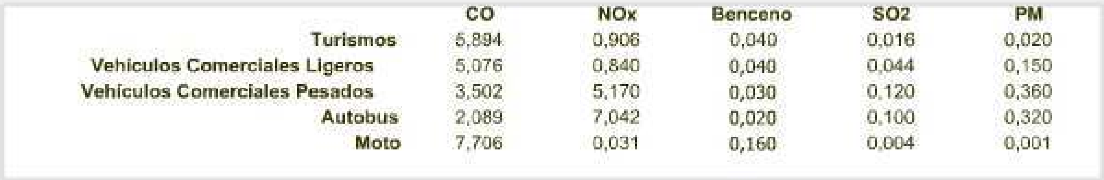
Explicación del Modelo

Para la realización de los cálculos se han considerado los siguientes Coeficientes de Emisión, expresados en gramos/vehículo-Km:



	CO	NOx	Benceno	SO2	PM
Turismos	5,894	0,906	0,040	0,016	0,020
Vehiculos Comerciales Ligeros	5,076	0,840	0,040	0,044	0,150
Vehiculos Comerciales Pesados	3,502	5,170	0,030	0,120	0,360
Autobus	2,089	7,042	0,020	0,100	0,320
Moto	7,706	0,031	0,160	0,004	0,001

Con los factores de emisión y los datos entrados por el usuario se calculan las concentraciones para cada contaminante en tres posibles situaciones:

- A Sotavento con viento perpendicular al eje de la calle
- A Barlovento con viento perpendicular al eje de la calle
- Con viento paralelo al eje de la calle

según las expresiones indicadas en el Anexo

y se calcula su promedio

Para valorar cada contaminante se compara su concentración con los Valores Límite que establece la legislación:

350 ug/m3 de SO2 (Valor Límite Horario)
200 ug/m3 de NOx (Valor Límite Horario del NO2)
10000 ug/m3 de CO (Valor Límite Octohorario)
50 ug/m3 de PM (Valor Límite Diario de PM10)
5 ug/m3 de Benceno (Valor Límite Anual)

calculando para ello los Índices de Calidad de Aire Parciales de cada contaminante

Para calcular cada Índice de Calidad de Aire (ICA) Parcial se realiza lo siguiente:

El ICA va de 0 a 150:
- El valor de cero se correponde con el cero de concentración del contaminante
- El valor de cien se correponde con el valor límite de concentración del contaminante

Así, para cada contaminante se deduce un factor que multiplicado por su concentración nos da cada ICA parcial.

Una vez tenemos cada ICA parcial se escoge el mayor, que se corresponde con el ICA TOTAL (o sea, se selecciona el ICA parcial del contaminante que más empeora la Calidad del Aire)

Una vez obtenemos el ICA Total, se valora según:

ICA Total <=50, La Calidad del Aire es BUENA
ICA Total entre 50 y 100, ADMISIBLE
ICA Total entre 100 y 150, MALA
ICA Total> 150, MUY MALA.

También señalar que, al realizar los cálculos de las Concentraciones de SO2, NOx y PM10 se ha considerado conveniente sumar a los valores obtenidos según la aplicación del Submodelo, el valor promedio obtenido en las estaciones EMEP Españolas durante 2003 (contaminación residual).

Por último indicar que los resultados obtenidos de la aplicación de este sencillo modelo son SOLO INDICATIVOS y deben ser tomados como un ejercicio didáctico de aproximación a algunos conceptos habituales en Calidad del Aire.

La realidad es mucho más compleja.

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ANEXO

Guidance Report on preliminary assessment under EC air quality directives

Technical report No 11
The Framework Directive on ambient air quality assessment and management (96/62/EC)1 was adopted by the European Council in September 1996.

Themes: Air pollution

A joint report by the EEA and the European Commission, DGXI

Publish date: 28 May 1998

- EEA (European Environment Agency)

Guidance Report on preliminary assessment under EC air quality directives

Annex 5.1 URBAN DISPERSION MODELS

This annex documents simple models for first estimation or screening.

An urban area contains thousands, or even millions, of individual sources. The application of a diffusion model to each source is impractical. Consequently most of the small sources are combined into larger area sources of strength Q_a (mass per unit time per unit area), and it is assumed that the emissions from the ground surface are uniform over that particular area.

Diffusion from the largest point sources can be calculated individually and the resulting concentrations at a receptor point can be added to the contribution from the area sources.

A. AREA SOURCE MODEL

In order to estimate by hand calculations the 1hr average air concentration at an arbitrary receptor point (0) due to area source emissions, a modified expression of the ATDL urban diffusion model (Hanna, 1972; Gifford and Hanna, 1973) may be used:

$$C = \frac{(2/\pi)^{1/2}}{uc(1-d)}\left\{(\Delta x/2)^{1-d} Q_{a0} + \sum_{i=1}^{n} Q_{ai}(\Delta x/2)^{1-d}\left[(2i+1)^{1-d} - (2i-1)^{1-d}\right]\right\} \quad (A.1)$$

where

C, the concentration (micrograms m^{-3})

0, denotes the location of the receptor point

n, is the number of grid blocks (of size Δx), necessary to reach the upwind edge of the urban area, starting from the receptor point.

Q_{ai}, for i=0,1,2,...,n, are source strengths (microgram sec^{-1} m^{-2}), constant over a distance Δx.

u, is the wind speed, assumed constant within the mixing layer.

c,d are the Brookhaven National Laboratory parameter values, (Smith, 1968), as listed in Table 1.

Table A.1. Brookhaven National Laboratory parameter values a, b, c and d in equation (A.1) and in the formulas for the dispersion parameters, $\sigma_y = ax^b$ and $\sigma_z = cx^d$

atmospheric conditions	**insolation**	**wind speed**	**a**	**b**	**c**	**d**
very unstable	strong-moderate	2	0.40	0.91	0.40	0.91
unstable	strong-moderate	2-3	0.36	0.86	0.33	0.86
neutral	moderate-slight	3-4	0.32	0.80	0.22	0.80
estimated Pasquill D	moderate-slight or night	4	0.32	0.75	0.15	0.75
stable	night	2-4	0.31	0.71	0.06	0.71

Note that these values represent one choice; alternative datasets exist. Note also the dependence of the dispersion parameters on averaging time (see end of this annex).

Basic assumptions

- The pollutants are assumed to be uniformly mixed in a layer, whose height is proportional to the vertical dispersion parameter $\sigma_z(x)$, where x is the total distance from the urban area.

Simpler approach

When the distribution of emissions is quite smooth, as it is often the case in residential urban areas, the calculated concentration (C) at any receptor point is usually proportional to the emissions Q_{ao} in the grid square in which the receptor is located. In this case it is sufficient to use the following simpler relation:

$$C = A\frac{Q_{ao}}{u}$$

$$= (2/\pi)^{1/2}\frac{\left[\Delta x(2N+1)/2\right]^{1-d}}{c(1-d)}\frac{Q_{ao}}{u} \quad \text{(A.2)}$$

the expression $\Delta x(2N+1)/2$ denotes the distance to the edge of city.

The following values for the dimensionless factor A are suggested:

atmospheric conditions	**A**
neutral or average	200
stable	600
unstable	50

Note, however, that A is slightly dependent on Δx.

Additional contribution from other sources

The urban area source model can give the average concentration over a broad area. In a street canyon or adjacent to a highway in an urban area, there is an additional contribution to the concentration from local sources. In this case the total concentration C_t is the sum of the spatial average C (calculated from equation (A.1)) and the local C_l component. Finally, the concentrations resulting at a receptor point from large point sources, C_p, can also be added to the spatial average concentration C.

B. ELEVATED POINT SOURCES

In order to estimate the contribution from an elevated point source C_p, (Fig. 1) of strength Q, the following Gaussian relation can be used:

$$C = \frac{Q}{2\pi\sigma_y\sigma_z u}e^{-y^2/2\sigma_y^2}\left[e^{-(z-h)^2/2\sigma_z^2} + e^{-(z+h)^2/2\sigma_z^2}\right] \quad \text{(A.3)}$$

where

C is the concentration (micrograms m^{-3});

Q is the source strength (micrograms sec^{-1});

u is the wind speed at the plume height;

y refers to the horizontal direction at right angles to the plume axis with y equal to zero on the axis;

z is the height above the ground;

σ_y, σ_z are standard deviations of the concentration distribution C, in the y and z direction and are calculated from table A.1;

h is the effective plume height (stack height plus plume rise). The plume rise can be calculated by using the appropriate formulas, summarised in table A.2

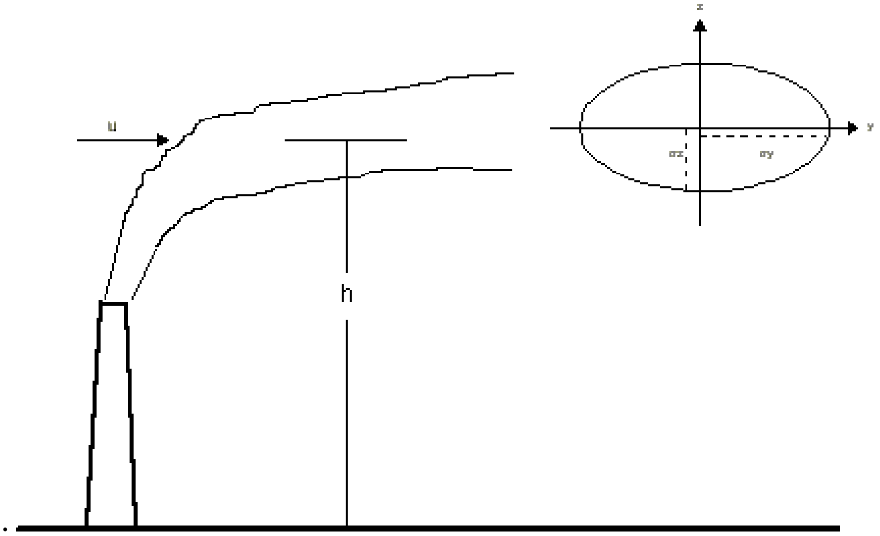

Figure A.1 Diagram of plume, illustrating concepts important in the Gaussian plume formula.

Table A.2. Plume rise formulas according to the plume characteristics and atmospheric conditions

plume type	1	atmospheric conditions	formulas
bent-over	buoyant	stable strong wind	$h = 2.6\left(\frac{F_0}{us}\right)^{1/3}$
		neutral, unstable	$h = 1.6F_0^{1/3}u^{-1}x^{2/3}$
	jet	strong wind neutral	$h = 3D\left(\frac{w_0}{u} - 1\right)$
vertical	jet	low wind stable	$h = 2.44\left(\frac{M}{s}\right)^{1/4}$
	buoyant		$h = 5.3F_0^{1/4}s^{-3/8}$

where

F_o is the buoyancy flux , $F = \frac{g}{T_p}(T_p - T_e)V$;

M is the momentum flux, M=wV;

s is the atmospheric stability, $s = \frac{g}{T_e}\left(\frac{\delta T_e}{\delta z} + 0.01^\circ C / m\right)$;

V is the plume volume flux ($V=wR^2$ for vertical plume and $V=uR^2$ for bent over plume);

w is the plume vertical speed;

x is distance from the stack;

D is the stack diameter;

T is the temperature.

Subscripts p and e denote plume and environment.

Note that alternative formulations for the plume rise exist.

Limitations

Although the Gaussian plume formula in general is appropriate to calculate the dispersion of elevated continuous major point sources, it has been demonstrated that it can lead to misleading results in special cases, such as in inhomogeneous terrain. For other simple models which could be used, see for instance Kretzschmar et al.,1994; Kretzschmar and Cosemans, 1996.

Longer averaging times

The diffusion parameters σ_y , σ_z are directly related to the standard deviations of the turbulent velocity fluctuations. Thus, as averaging time increases, the turbulent velocity fluctuations increase and hence σ_y , σ_z increase. Gifford suggests accounting for the effects of sampling time trough the empirical formula:

$$\frac{\sigma_{yd}}{\sigma_{ye}} = \left(\frac{T_{sd}}{T_{se}}\right)^q \quad \text{(A.4)}$$

where,

d and e represent two different averaging times, and q is in the range 0.25 to 0.3 for $1hr<T_{sd}<100hr$ and equals approximately 0.2 for $3min<T_{sd}<1hr$.

The standard dispersion parameters given in table A.1, represent a sampling time T_{se} of about 10 min.

Extension to longer averaging times is made by solving the above equations for a variety of wind directions and then weighting each result by the frequency with which the wind blows from that direction.

C. STREET CANYON SUBMODEL

Consider the street canyon in figure A.2, where the important variables are defined. Depending on the wind direction, at roof level, the following relations can be used.

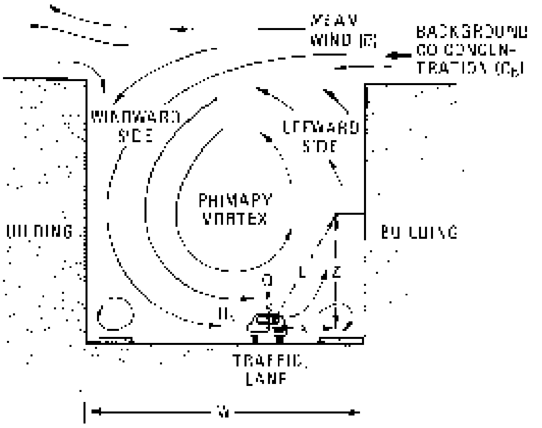

Figure A.2 Schematic of cross-street air circulation in a street canyon. [From Johnson et al, 1977)

Wind direction normal to the street axis

If the wind direction is nearly normal to the street, the equations for the concentration C_l in the street canyon are:

- lee side, $$C_1 = \frac{KNq / 3.6}{(u+0.5)\left[\left(x^2+z^2\right)^{1/2}+2\right]} \quad (A.5)$$
- windward side, $$C_1 = \frac{KNq / 3.6}{W(u+0.5)} \quad (A.6)$$

where,

C_l	is the concentration (µg/m^3);
N	is the traffic flow (vehicles/hr);
q	is the emission factor (g/km);
u	is the wind speed at roof level (m/sec);
W	is the street width(m);
x and z	are horizontal distance and height (both in m) of the receptor point relative to the traffic lane;
K	is a dimensionless "best fit" constant (K ≈ 7 is suggested).

Wind direction parallel to the street axis

If the wind direction is nearly parallel to the street axis, the equations for the concentration C_l in the street canyon are:

$$C_1 = \frac{1}{2}\left[C_1(\text{winward}) + C_1(\text{lee})\right] \quad (A.7)$$

Limitation: The model as such is not suitable for calculation of NO_2 concentrations, which are mainly determined by chemical reaction of NO with ozone.

D. HIGHWAY SUBMODEL

The excess concentration C_l contributed by a major highway in an urban area is important for a distance less than 300m downwind of the highway. Consider the highway in figure A.3, the concentration at some distance x from the highway can be estimated from the relation:

$$C_1 = \frac{Q.F(\varphi)}{u[h + \sigma_z(x)]} \quad (A.8)$$

where

C is the concentration (µg/m^3);

Q is the line source strength (µg/s/m);

h is the effective height of emissions due to initial dispersion (2-3m);

φ is the angle between the wind direction and the highway;

σ_z is the vertical dispersion parameter.

F(φ) Function of φ ; for φ around 90 degrees, F(φ) is close to 1.

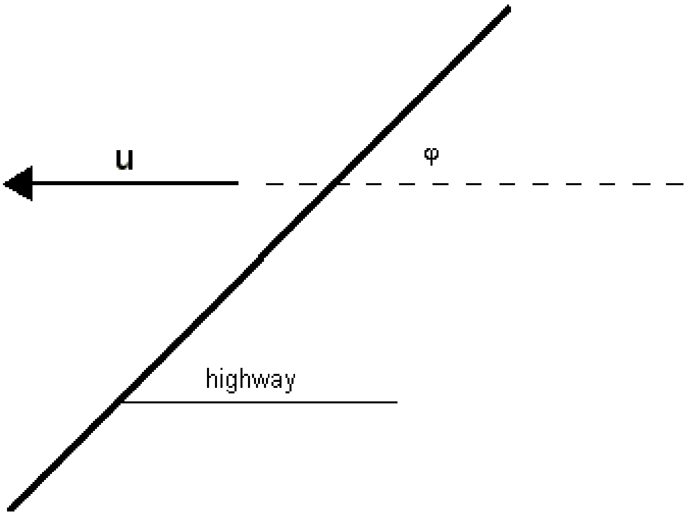

Figure A.3 Infinite line source pattern.

Limitation: This formula cannot be used to calculate concentrations on the highway, or in case the wind blows in the direction of the highway .

Meteorological data and emissions

All the models in this annex are best suitable for estimation of long term average concentrations. They should not be used for short term high percentile values, which are highly dependent on critical meteorological conditions.

For long term average concentrations, calculations can be made with average meteorological conditions. For wind speed, the annual average can be used. For wind direction, the most frequent direction can be taken. For point sources, neutral atmospheric conditions should be selected.

Appropriate choices must also be made for emission estimates, to make sure that they reflect typical conditions.

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