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EMISSIONS OF HYDROCARBONS AND NITROGEN OXIDES IN THE GÖTEBORG AREA 1979

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18 Sammanfattning av projektet/rapporten (ange gärna målsättning, metod, teknik resultat m m)

Emissions of hydrocarbons and nitrogen oxides from traffic, industry and energy production have been estimated in Göteborg area in 1979. The traffic is due to about 50% of the emissions.

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EMISSIONS OF HYDROCARBONS AND NITROGEN OXIDES IN THE GÖTEBORG AREA 1979

Abstract

An inventory of nitrogen oxides and hydrocarbon emissions was made for the Göteborg area in 1979.

To some extent emissions from specific sources were known. In all other cases emissions were estimated from data on solvent use, petrol use etc. and emission factors.

The results show a yearly nitrogen oxide emission of approximately 22.000 tons (as NO_2) and a yearly hydrocarbon emission of approximately 37.000 tons. Further, the diurnal variation of emissions was estimated for a summer and a winter week-day. The variation pattern shows clearly the high contribution from the traffic.

EMISSIONS OF HYDROCARBONS AND NITROGEN OXIDES IN THE GÖTEBORG AREA 1979

INTRODUCTION

During 1980, two model studies were undertaken in the Göteborg area on the local formation of photochemical oxidants. These studies were an application of the so called EKMA model and a more detailed study carried out by the University of Oslo (Ivar Isakssen)(1). The EKMA study was part of an OECD project on photochemical oxidants.

For both models it was necessary to know the emissions of the precursors, i.e. hydrocarbons and nitrogen oxides. An emission inventory was therefore undertaken representing the emission situation during 1978-79.

METHODS

Area

The area surveyed includes the city of Göteborg and the four closest suburbs surrounding Göteborg. The size of the area is 675 km^2 and the population was 524,000 on 31 December 1977 (Figure 1). The emissions were estimated as a whole, without any area subdivisions.

Inventory of hydrocarbon emissions from stationary sources

The conception of hydrocarbons includes not only pure hydrocarbon compounds but also other types of volatile organic compounds (eg. alcohols, aldehyds and chlorinated hydrocarbons).

The hydrocarbon emissions from stationary sources were determined with one or more of the following methods:

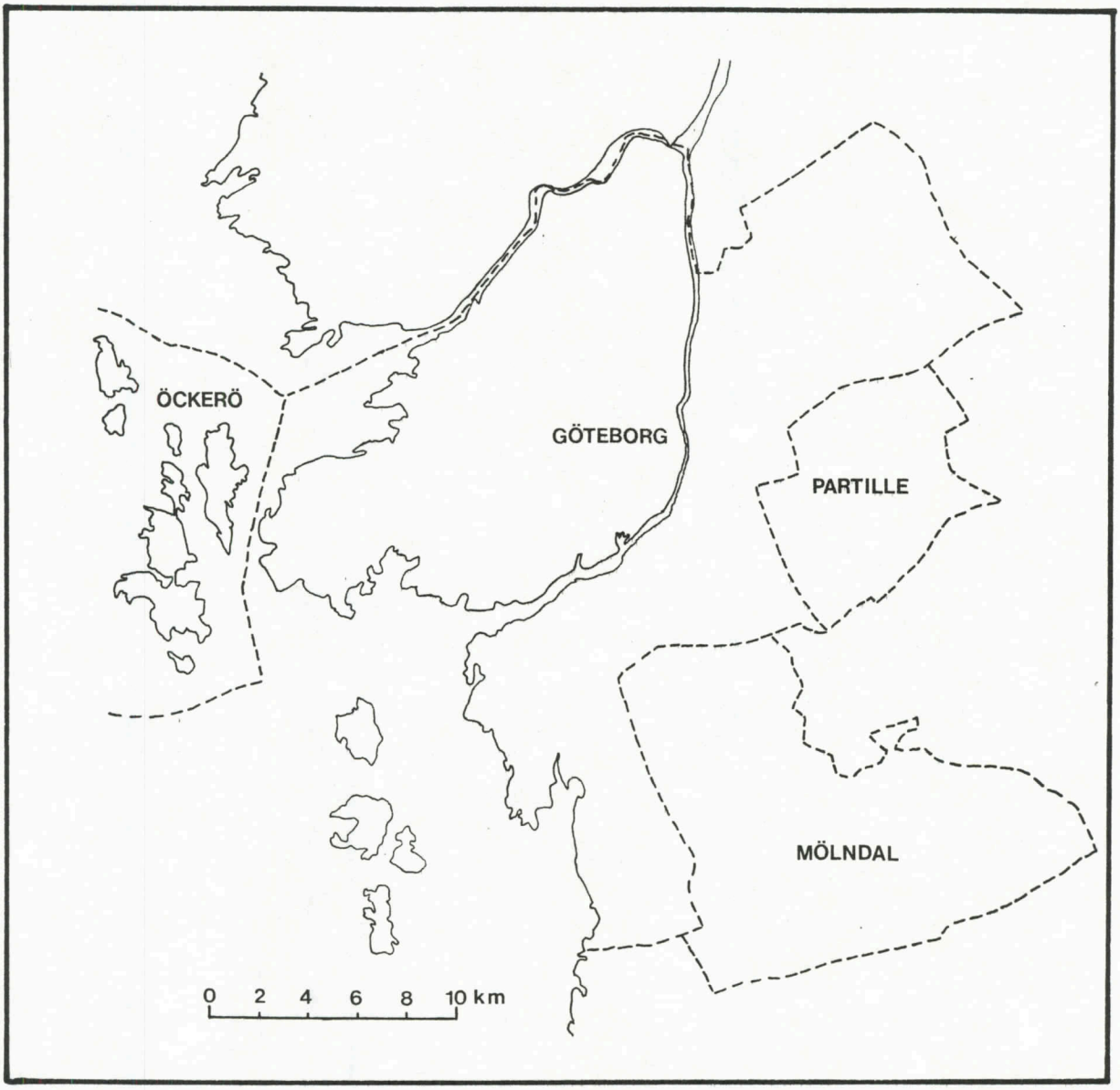

Figure 1. The area for which emissions were estimated

1) Information from the regional environmental protection board

2) Direct enquiries to different companies by means of a questionnaire

3) Use of emission factors or available emission monitoring statistics for Sweden

4) Use of statistics of goods transports (for example, solvent deliveries) to different types of technical activity

All known sources were studied. The questionnaire was sent to about 160 companies, of which about 80% responded.

In addition to the well-defines sources, the emissions from "diffuse " activities such as house painting and household consumption of paint, solvents etc. were estimated. These estimates on fugitive emissions were made on the basis of statistic of, among other things, solvent consumption.

Estimation of emissions of nitrogen oxides from stationary sources

The emissions of nitrogen oxides were estimated mainly by using emission factors and the official statistics of the local deliveries of fuel oils. Also, for the city of Göteborg a compilation of all plants with an oil consumption of more than 400 m^3/yr was used.

The emission factors are presented in the table below. All figures are given i kg NO_2/ton burnt oil or its equivalent.

Göteborg	NO_2 kg/ton
Oil refineries	10
Plants using heavy oil (quantities over 400 m^3/yr)	7
Plants using heavy oil (quantities below 400 m^3/yr)	5
Large furnaces fired with light oils	5
Small " " " " "	3
Remaining areas	
Furnaces fired with heavy oil	7
" " " light oil	3

Estimation of the emissions of hydrocarbons and nitrogen oxides from traffic

The estimation of the emission from cars, trucks and buses was made from statistics on the total yearly distance covered (mileage by all vehicles registered in the area concerned. It is assumed that the total traffic volume within the city is about the same as the total mileage of the cars registered within the area.

Emission factors were taken from tests made at the Motor Vehicle Exhaust Laboratory of the Swedish Environment Protection Board. Since exhaust control regulations have been introduced on different occasions during the last decade, different emission factors must be employed.

Factors are available both for country road driving and for city driving. The traffic within the area concerned is assumed to be 40% road driving and 60% city driving. Moreover, an "aging factor" for the emission of hydrocarbons was introduced for cars older than 3 years. For cars between 3 and 6 years old, the aging factor is 15% and for cars of 6 years or older it is 30%.

From these assumptions, a mean emission factor was calculated for each year model. The resulting emission factors are presented in table 1.

Table 1

Emission factors for hydrocarbons and nitrogen oxides from traffic in Göteborg 1979

		Emission factors (g/km)	
	year model	hydro-carbons	nitrogen oxides
Passenger cars:			
Gasoline fueled	- 1968	4.7	2.1
	1969 - 1970	4.3	2.1
	1971 - 1972	3.2	2.1
	1973 - 1975	2.8	2.1
	1976 - 1979	2.1	1.9
Diesel fueled	all	1.66	0.93
Trucks and buses:			
Gasoline fueled	- 1972	10.4	5.0
	1973 - 1975	9.2	5.0
	1976 - 1979	8.0	5.0
Diesel fueled low weight		4.0	4.0
Diesel fueled heavy weight		6.8	22.0

Furthermore, the emission data were adjusted for "cold starts". Test data from the Motor Vehicle Exhaust Laboratory have shown that the emission of hydrocarbons during the first 6 minutes at 20°C is 1.8 times greater, and at 0°C it is 2.65 times greater, than with a warm engine. For NO_x the emission is increased by a factor 1.3 at 20°C, whereas no increase occurs at 0°C. It was assumed that 10% of the total mileage within Göteborg is cold starts and that the cold starts are made at 0°C during the winter months and at 20°C during the summer months.

RESULTS

Yearly emissions of hydrocarbons from stationary sources

The yearly emissions from different types of stationary sources are presented in table 2. The inventory also includes the composition of the organics in the cases where these were well defined. The composition is shown in table 3.

Emissions of nitrogen oxides from stationary sources

The results from the inventory of emissions of nitrogen oxides is presented in table 4 below. The total emission is about 11,000 ton/yr (calculated as NO_2).

Emissions of hydrocarbons and nitrogen oxides from traffic

Table 5 presents the results from the calculated emissions of hydrocarbons and nitrogen oxides. In order to assess the plausability of the calculations made, a rough estimate of the emissions of hydrocarbons were made from the total figure of delivered

quantities of fuel to the area concerned. This estimate gave a total hydrocarbon emission of 12 000 tons/yr. The figure is probably somewhat too low, since a substantial part of the traffic is caused by cars coming into the area from the suburbs, having obtained their gasoline outside the area. Similar discrepancies have been observed in other inventories of this type.

Table 2.

Emissions of hydrocarbons from stationary sources in the Göteborg area 1979

Type of activity	Method of estimation/ source acc. to page 3	Emissions of hydrocarbons tons/yr
Refineries (incl. oil handling)	1	11 000 - 15 000 *
Engineering industry (incl. ship building and car industry)	1,2,3,4	3 500 - 4 000
Dye stuff manufacture	2,3	70 - 100
Printing industry	2,3	700 - 1 000
Chemical industry (incl. plastic manufacture and wood working industry)	1,2,3,4	500 - 700
Car repairs and servicing	2,4	125 - 150
Asphalt works	2,3	∿100
Gas stations	3,4	∿500
Laboratories	2	10 - 20
Schools, hospitals		?
Waste incineration plants	3	∿3
Oil-fired heating plants	3	∿400
Laundries	2,3,4	200 - 300
Bakeries	3	∿700
Fugitive emissions from households, building sites and the like	4	∿1 100
		18 800 - 23 900

* After completion of this report new data on hydrocarbon emissions have been presented by the oil refineries and the local harbour authorities.
The new data indicate a lower emission-level than the figures given here.

Table 3.

Emissions of hydrocarbons from stationary sources divided into different types of compounds. The table does not include refineries, gas stations, fugitive emissions and stationary combustion.

Compound	Emission tons/yr
Aliphatic hydrocarbons	1 200
Aromatic hydrocarbons	1 900
Alcohols	1 200 (∿700 from bakeries)
Esters	400
Aldehydes and ketones	250
Terpenes	30

Table 4

Emissions of nitrogen oxides (calculated as NO_2) from stationary sources in the Göteborg area 1978

Source	NO_x tons/yr
Oil refineries	3 300
Engine testing	100
Incinerators	100
Domestic heating	7 600
	11 100

Table 5

Emissions of hydrocarbons and nitrogen oxides from traffic within the Göteborg area calculated from statistics on mileage and emission factors

	Emissions of hydrocarbons tons/yr	Emissions of nitrogen oxides tons/yr
Passenger cars		
gasoline	9 300	5 100
diesel	200	100
Trucks and buses		
gasoline	2 700	1 300
diesel	1 800	4 400
Light and heavy motor cycles and motorized machinery	1 000	
Boats	200	100
	15 200	11 000

Compilation of the emission data from the Göteborg area

When summarizing the above data on emissions of hydrocarbons and nitrogen oxides in the Göteborg area, the total yearly emission of hydrocarbons is 37 000 tons/yr and the total NO_x emission is 22 000 tons/yr (table 6). If these emissions are converted to kg/capita (inhabitant), the hydrocarbon emission is about 68 kg and the NO_x emission about 42 kg.

Table 6

Total yearly emission of hydrocarbons and nitrogen oxides in the Göteborg area 1979

Source	Emissions (tons/yr)	
	Hydrocarbons	Nitrogen oxides
Stationary combustion	400	7 700
Process emissions - industry	18 400	3 400[1)]
Traffic	15 200	11 000
Miscellaneous	2 600	
	36 600	22 100

[1)] Refers to refineries and engine testing

Hourly emissions of hydrocarbons and nitrogen oxides

Using traffic statistics, combustion statistics of large plants for domestic heating and hours of operation for industries emitting hydrocarbons and nitrogen oxides, the hourly emissions for a typical working day were calculated. The calculation was made for one day in February and one day in August. The result is shown in Figure 2 and 3.

The hour-by hour variation patterns clearly show a strong dependence on the daily traffic rythm. The emission during daytime is about four times higher than during the night. The emissions of nitrogen oxides are during the summer throughout lower - due to less space heating.

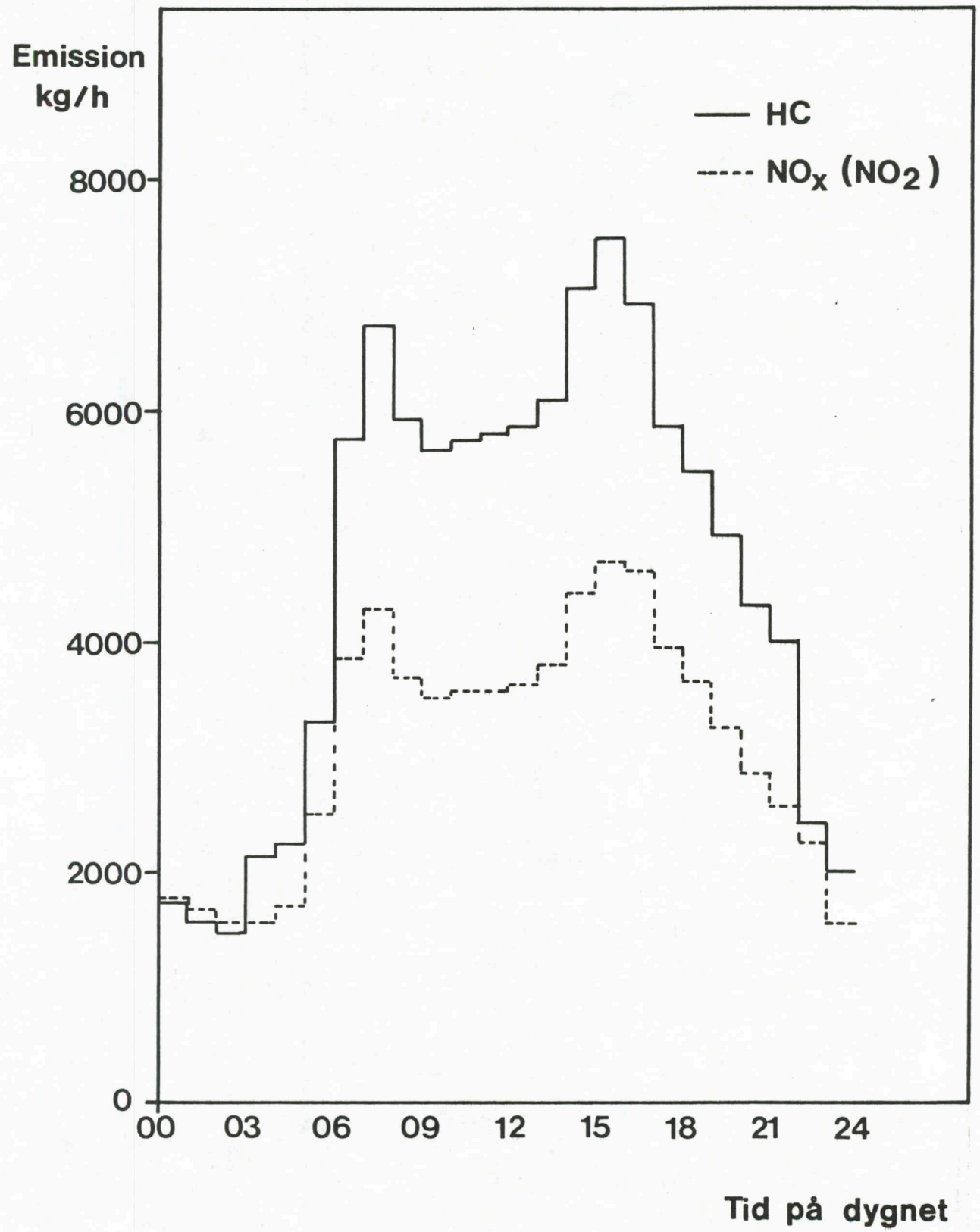

Figure 2. 24-hour variation in hydrocarbons and nitrogen oxides in the Göteborg area for one week-day in February, 1979.

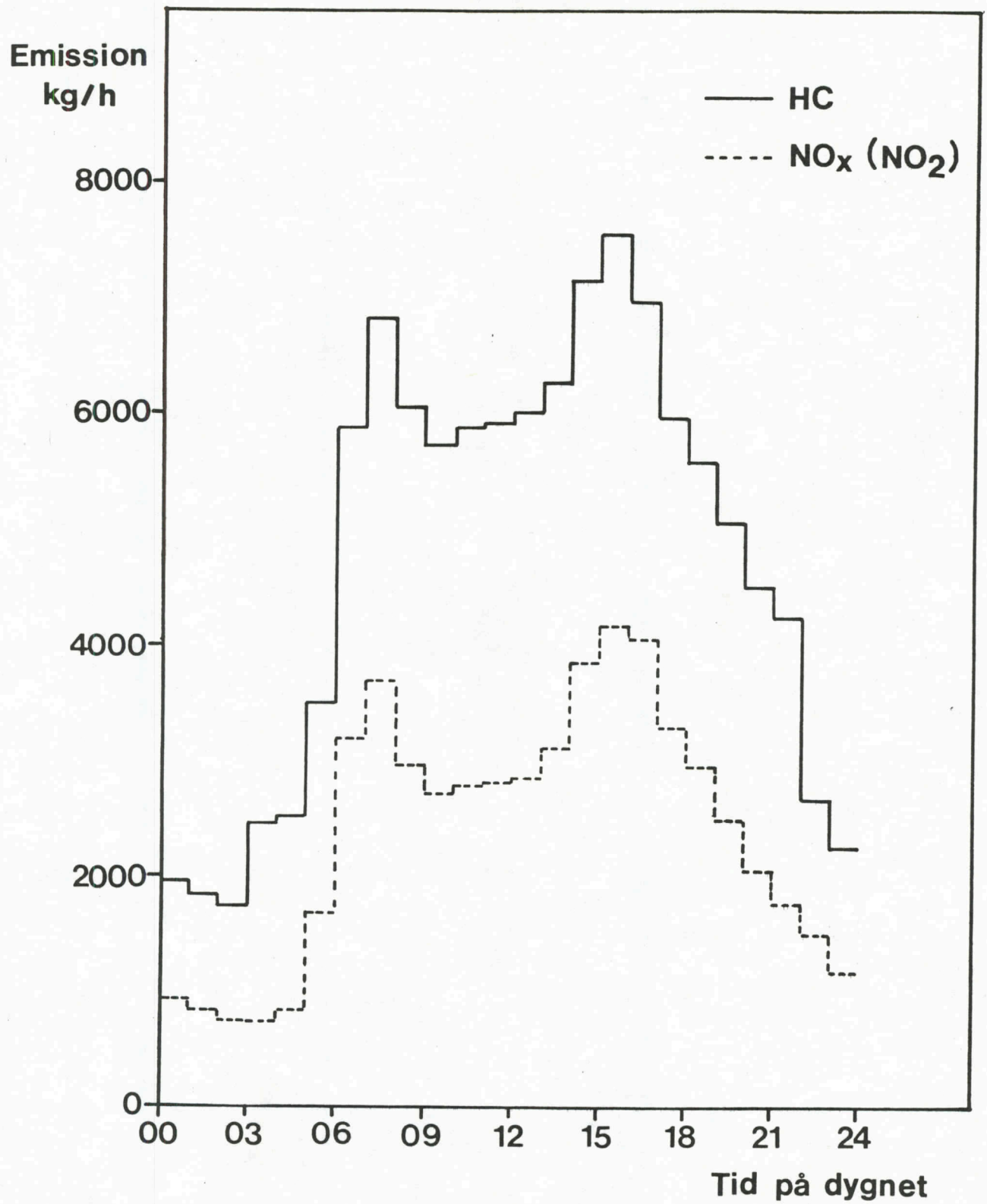

Figure 3. 24-hour variation in hydrocarbons and nitrogen oxides in the Göteborg area for one week-day in August, 1979.

Emission inventories are always more useless based on assumptions. It is difficult to cover all significant sources and moreover the basis for the emission estimates is often "incomplete"

Emissions from stationary sources are in most cases easier to estimate than those from mobile sources. So many factors affect the many individual sources that a "mean" value of the emissions is almost impossible to determine without very extensive statistics.

Througout it is easier to estimate emissions of nitrogen oxides than emissions of hydrocarbons. For nitrogen oxides the sources are more easily defined and the statistical basis for the estimates is generally easier available. The complexity and great variety of the sources of hydrocarbons make a complete estimate almost impossible. All this will in most cases lead to an underestimate of the emission. This investigation will therefore probably represent a lower limit for the hydrocarbon emission. As an example, if the total Swedish emission of solvents calculated from consumption data is proportioned for the area according to the population, our emission of solvents are underestimated with 20-30%.

The results from the hourly based inventory (Fig. 2 and 3) clearly show that yearly data are insufficient for judgements of atmosphere concentrations and porssible environmental effects. For example, for more detailed studies on the production of photochemical oxidants the hourly data are necessary.

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