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ESTIMATES OF THE EFFECT OF LOCAL PRECURSOR CONTROL ON THE AMBIENT OZONE CONCENTRATION IN OSLO

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SUMMARY

The Empirical Kinetic Modeling Approach ("EKMA Model"), developed by the U.S. Environmental Protection Agency, has been used to predict changes in the ambient ozone levels downwind of Oslo, Norway, as a result of changes in precursor emissions and ozone transport.

The work is a part of an OECD study evaluating various strategies for emission control of photochemical air pollutant precursors.

Two assumptions have been made for the future levels of transported ozone, both in the surface layer and aloft: no change and 20% decrease.

The following assumptions have been made for future reductions of emissions of non-methane hydrocarbons (NMHC) and oxides of nitrogen (NO_x):

NMHC control: 0% (present situation), 20%, 40%, 60%
NO_x control: 0%, 20%, 40%

With all the combinations of these reductions, a total of 12 emission control levels has been considered.

The calculations were carried out for Oslo ($60^{o}N$) for 14 May 1980 and 6 June 1980.

The results of the model calculations can briefly be summarized as follows, for no change of transported ozone:

- 20% reduction of NMHC caused 15-20% decrease of ozone concentration.
- 40% reduction of NMHC caused 30-45% decrease of ozone concentration.
- 60% reduction of NMHC caused 40-50% decrease of ozone concentration.

- 20% reduction of NO_x caused 4-8% increase of ozone concentration.
- 40% reduction of NO_x caused 1-10% increase of ozone concentration.
- 20% reduction of both NMHC and NO_x caused 5-10% decrease of ozone concentration.
- 40% reduction of both NMHC and NO_x caused ca. 15% decrease of ozone concentration.

For the input data used, the NMHC is the limiting component of the ozone formation. A reduction of NO_x emissions only gave an increase of the ozone concentration, because of the change to a NMHC/NO_x ratio which is more conducive to ozone formation. For the same reason it turned out that NMHC reduction alone was more efficient than a combined reduction of NMHC and NO_x.

Ozone episodes in Norway are frequently due to mesoscale or large-scale formation and transport. In such cases there are often similar ozone concentration levels upwind and downwind of the local source areas. Models for larger spatial and temporal scales than the EKMA Model are necessary to estimate the effect of emission controls for such episodes.

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1 INTRODUCTION

At the meeting of the OECD Air Management Policy Group in January 1982, it was agreed that some countries should use photochemical oxidant models to calculate the effect of local precursor control on the ambient ozone concentration. The work should be carried out as a part of the OECD project: "Development of Photochemical Oxidant Strategies within an Urban Airshed".

This report contains the Norwegian contribution to this exercise. The calculations are carried out for Oslo for two different days, in a similar way as for two cases in 1977 and 1979, reported to the OECD earlier (Schjoldager, 1980).

The photochemical oxidant model used is the "EKMA Model", which is a photochemical box model for predicting the changes in maximum ozone concentration downwind of an urban area, as a result of various changes of factors influencing the ozone level, such as precursor emissions, transported ozone, mixing height, etc. The EKMA Model has been developed by the U.S. Environmental Protection Agency (EPA) and is offered as a tool for studying photochemical oxidant abatement strategies.

The model is of "intermediate complexity", i.e., it is more sophisticated than the simple rollback procedures, but less complex than the detailed photochemical dispersion models which have been developed for some polluted areas.

The EKMA Model is described in detail elsewhere (EPA, 1977 and 1978; Whitten & Hogo, 1978). The computer code used was named "OZIPP, version 2, April 1981".

The reductions of emissions have been chosen as follows; for non-methane hydrocarbons (NMHC) and oxides of nitrogen (NO_x):

NMHC reduction: 0% (present situation), 20%, 40%, 60%
NO_x reduction: 0%, 20%, 40%

With all the combinations of these reductions, 12 emission levels are considered, as shown in Table 1.

Table 1: Combinations of NMHC and NO_x emission reductions.

		NMHC reductions (%)			
		0	20	40	60
NO_x reductions (%)	0	a	b	c	d
	20	e	f	g	h
	40	i	j	k	l

Two assumptions were made for the changes of transported ozone to the urban area, upwind and aloft: no change, and a reduction of 20%.

2 MODEL CALCULATIONS

The EKMA Model was run for Oslo, Norway, according to the EPA specifications (EPA, 1977), for two cases when local formation of ozone was believed to be a major cause of the recorded levels. The two days chosen were 14 May 1980 and 6 June 1980 (Schjoldager et al., 1981).

Area-specific ozone isopleths were generated based on available input data. The "design values" for ozone were based on maximum 1-hour ambient surface measurements downwind of the source areas.

The transported ozone, both in the surface layer and aloft, was based on average 1100-1300 h ambient surface measurements upwind of the source areas.

The mixing heights were estimated using a procedure developed in England (Smith & Hunt, 1978), by which the mixing height is expressed as a function of local time, month, cloud cover, and wind speed. In the EKMA calculations the mixing height was assumed not to increase after 1400 h.

The $NMHC/NO_x$ ratio was set equal to 4. The ratio was estimated from emission inventories (OECD, 1982).

For all the other input parameters to the EKMA Model, the "default values" of the computer program (Whitten & Hogo, 1978) were employed.

2.1 Oslo, 14 May 1980

The following input data were used:

Latitude: $60.0^{\circ}N$
Longitude: $10.8^{\circ}E$
Time zone: -2 (Daylight savings time)
Design value for ozone: 143 ppb
Transported ozone,
surface layer and aloft: 68 ppb
Mixing height: 350 m at 0800 h.
1300 m at 1400 h.
$NMHC/NO_x$ ratio: 4

Two isopleth runs were carried out, based on the two assumptions for the transported ozone, both in the surface layer and aloft. The runs are illustrated in Appendix A. The resulting maximum ozone concentrations are given in Tables 2 and 3 for the 12 levels of emission control. Table 2 gives the ozone concentrations in ppb, while Table 3 gives the changes as percent of the design value of 143 ppb.

Table 2: Oslo, 14 May 1980.
Calculated maximum 1-hour ozone concentrations (ppb).

1. Transported ozone 68 ppb (present level)					
		NMHC reduction (%)			
		0	20	40	60
NO_x reduction %	0	143	112	77	<70
	20	155	130	100	<70
	40	158	142	119	89

2. Transported ozone 54 ppb (-20%)					
		NMHC reduction (%)			
		0	20	40	60
NO_x reduction (%)	0	134	100	67	<60
	20	145	120	87	<60
	40	150	132	106	74

Table 3: Oslo, 14 May 1980
Change of maximum 1-hour concentration (%), relative to the design value of 143 ppb.

1. Transported ozone 68 ppb (present level).					
		NMHC reduction (%)			
		0	20	40	60
NO_x reduction (%)	0	0	-22	-46	<-51
	20	+8	- 9	-30	<-51
	40	+10	- 1	-17	-38

2. Transported ozone 54 ppb (-20%).					
		NMHC reduction (%)			
		0	20	40	60
NO_x reduction (%)	0	-6	-30	-53	<-58
	20	+1	-16	-39	<-58
	40	+5	- 8	-26	-48

For some cases, the concentrations are found to be less than 70 ppb and 60 ppb, respectively. This is because the upwind ozone concentration probably gives the lower limit of the downwind concentration in the model calculations.

2.2 Oslo, 6 June 1980

The following input data were used:

Latitude:
Longitude:
Time zone:
} Same as for 14 May 1980

Design value for ozone: 135 ppb
Transported ozone,
surface layer and aloft: 81 ppb
Mixing height: Same as for 14 May 1980
NMHC/NO_x ratio:

The two isopleth runs were carried out, and the 12 levels of emission control were considered in the same way as previously described. The runs are illustrated in Appendix A. The resulting 1-hour maximum ozone concentrations are given in Tables 4 and 5 as absolute concentrations and relative change, respectively.

Table 4: Oslo, 6 June 1980
Calculated maximum 1-hour ozone concentrations (ppb).

1. Transported ozone 81 ppb (present level).					
		NMHC reduction (%)			
		0	20	40	60
NO_x reduction (%)	0	135	115	96	<80
	20	140	126	106	86
	40	136	127	113	96

2. Transported ozone 65 ppb (-20%).					
		NMHC reduction (%)			
		0	20	40	60
NO_x reduction (%)	0	123	103	79	<70
	20	128	112	93	70
	40	128	117	103	83

Table 5: Oslo, 6 June 1980
Change of maximum 1-hour concentration (%), relative to the design value of 135 ppb.

1. Transported ozone 81 ppb (present level.					
		NMHC reduction (%)			
		0	20	40	60
NO_x reduction (%)	0	0	-15	-29	<-41
	20	+4	- 7	-21	-36
	40	+1	- 6	-16	-29

2. Transported ozone 65 ppb (-20%).					
		NMHC reduction (%)			
		0	20	40	60
NO_x reduction (%)	0	-9	-24	-41	<-48
	20	-5	-17	-31	-48
	40	-5	-13	-24	-39

2.3 Discussion of the results

The relative change of ozone concentrations for the various options of emission control and transported ozone showed strong similarities for the two cases discussed in Sections 2.1 and 2.2. This is not surprising because the same model was used, and most of the input parameters were the same.

The effect of emission reductions was however, greater for 14 May than for 6 June. This can be understood from the differences between the maximum and transported ozone concentrations which were 75 ppb for 14 May, and 54 ppb for 6 June. The net local ozone generation was thus greater for the first of the days, and hence the effect of local emission reductions would be greater.

An important point is that for the low NMHC/NO_x ratio used, the NMHC is the limiting component of the ozone formation. A reduction of NO_x emissions thus gives an increase of the ozone concentration, as seen from the cases e) and i) of the previous tables.

For the same reason it is seen that a NMHC reduction alone is more efficient than a combined reduction of NMHC and NO_x. Based on these model calculations, a reduction of the NO_x emission cannot be recommended.

For the present level of transported ozone, the calculations showed the following:

- 20% reduction of NMHC caused 15-22% decrease of ozone concentration.
- 40% reduction of NMHC caused 29-46% decrease of ozone concentration.
- 60% reduction of NMHC caused 41-51% decrease of ozone concentration.
- 20% reduction of NO_x caused 4-8% increase of ozone concentration.
- 40% reduction of NO_x caused 1-10% increase of ozone concentration.
- 20% reduction of both NMHC and NO_x caused 7-9% decrease of ozone concentration.
- 40% reduction of both NMHC and NO_x caused 16-17% decrease of ozone concentration.

When the transported ozone concentration was reduced by 20%, the downwind ozone concentration decreased by 5-10% for a given level of emission control.

The results should be interpreted with great care. Many of the area-specific input parameters to the model are uncertain, and a detailed sensitivity analysis has not been carried out. The mixing height data were solely based on model calculations. The hydrocarbon composition has not been experimentally determined.

The distance from the source areas to the downwind measurement sites was only ca 15 km. Therefore, the 10-hour simulation period is long compared to the typical transport time to the sites where the ozone "design values" have been recorded.

It should also be emphasized that ozone episodes in Norway are often due to mesoscale or large-scale formation and transport. In such cases, there seem to be similar ozone concentration levels upwind and downwind of the local source areas. Models for larger spatial and temporal scales than the EKMA Model are necessary to estimate the effect of emission controls for these episodes.

3 REFERENCES

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APPENDIX A

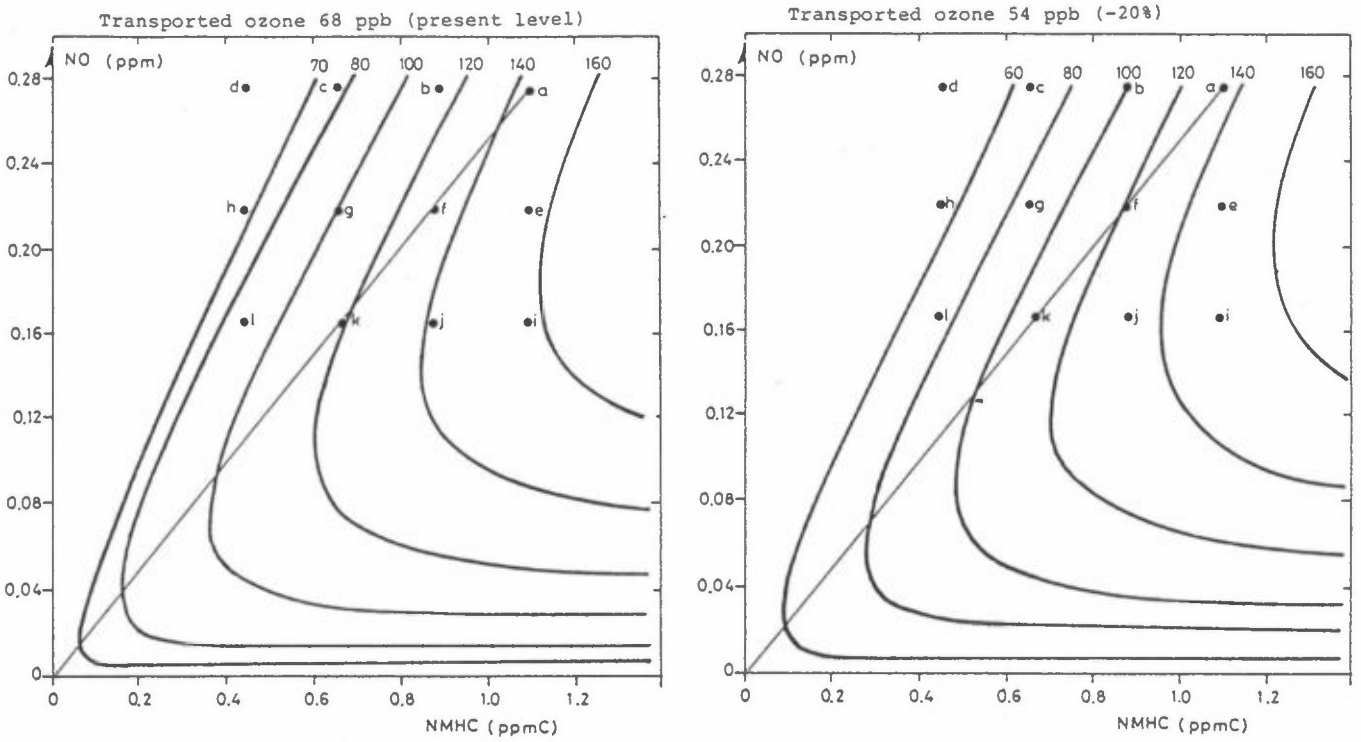
Ozone isopleth diagrams for Oslo

14 May 1980

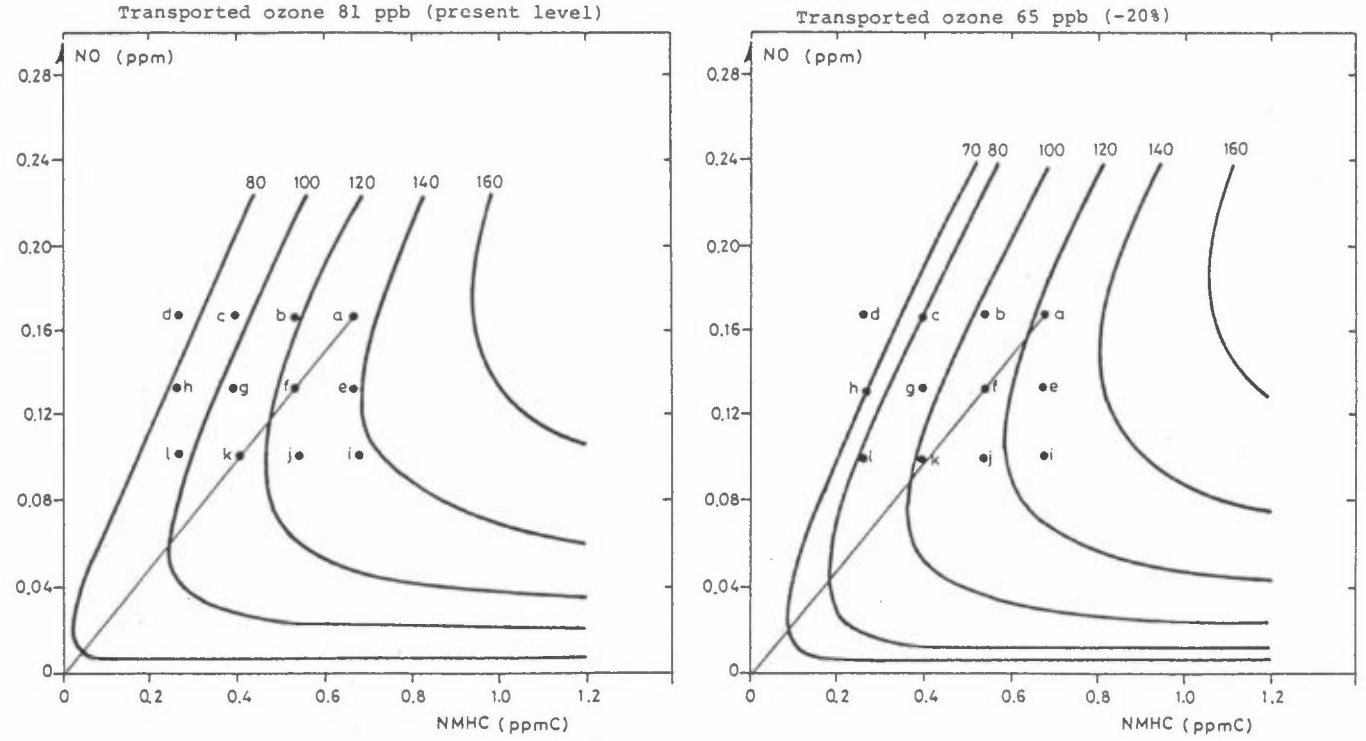
6 June 1980

		NMHC reductions (%)			
		0	20	40	60
NO_x reductions (%)	0	a	b	c	d
	20	e	f	g	h
	40	i	j	k	l

OSLO, 14 MAY 1980



OSLO, 6 JUNE 1980



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3 STIKKORD (á maks. 20 anslag) Ozon	Reduksjon	Modell

REFERAT (maks. 300 anslag, 5-10 linjer)

En enkel, fotokjemisk boksmodell "EKMA Model" er brukt til å beregne reduksjon i ozonkonsentrasjonen i Oslo (målt i Maridalen) som følge av tenkte endringer i bakgrunnskonsentrasjon av ozon og lokale utslipp av hydrokarboner og nitrogenoksyder. Beregningene er gjort for 14.5.1980 og 6.6.1980, da maksimal konsentrasjon ble målt til henholdsvis 286 og 270 $\mu g/m^3$.

TITLE

ABSTRACT (max. 300 characters, 5-10 lines.

The"EKMA Model" (Empirical kinetic Modeling Approach) has been used to calculate changes in the ambient ozone concentration downwind of Oslo (60°N) for various assumptions of local emission control and transported ozone. The calculations were carried out for 14 May and 6 June 1980 when the recorded maximum ozone concentrations were 143 and 135 ppb, respectively.

**Kategorier: Åpen - kan bestilles fra NILU A
Må bestilles gjennom oppdragsgiver B
Kan ikke utleveres C