NILU
OPPDRAGSRAPPORT NR 15 /80
REFERENCE: 21980
DATE: JULY 1980

USE OF THE "EKMA MODEL" TO PREDICT THE EFFECT OF EMISSION CONTROL ON AMBIENT OZONE LEVELS

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ISBN - 82 - 7247 - 173 - 6

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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 two urban/industrial areas in Norway as a result of future 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.

Four assumptions have been made for the future levels of transported ozone, both in the surface layer and aloft: 20% increase, no change, 20% decrease, and 50% decrease.

Three assumptions for the future levels of emission control have been considered: a) present situation, b) 20% reduction of non-methane hydrocarbons (NMHC) and no reduction of nitrogen oxides (NO_x), c) 50% reduction of both NMHC and NO_x.

The calculations were carried out for Oslo ($60^{o}N$) and southern Telemark ($59^{o}N$) for 17 August 1977 and 7 June 1979, respectively.

The results of the model calculations can briefly be summarized as follows:

For a given level of emission control:

- 20% increase of the transported ozone caused 5-8% increase in the maximum downwind ozone concentration.
- 20% decrease of the transported ozone caused 3-7% decrease in the maximum downwind ozone concentration.
- 50% decrease of the transported ozone caused 10-18% decrease in the maximum downwind ozone concentration.

For a given level of the transported ozone:

- 20% reduction of NMHC and no reduction of NO_x caused 11-13% decrease in the maximum downwind ozone concentration.
- 50% reduction of both NMHC and NO_x casued 27-35% decrease in the maximum downwind ozone concentration.

The relative effect of change of the transported ozone was highest for the strongest emission control, and the relative effect of emission control was highest for the lowest level of transported ozone.

It should be emphasized that the results should be interpreted with considerable care. Many of the area-specific input parameters to the model are uncertain, and a detailed sensitivity analysis has not been carried out. Furthermore, ozone episodes in Norway are often due to mesoscale formation and transport, or to transport from distant sources. In such cases there seems 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 may be necessary to estimate the emission controls for these episodes.

USE OF THE "EKMA MODEL" TO PREDICT THE EFFECT OF EMISSION CONTROL ON AMBIENT OZONE LEVELS

1 INTRODUCTION

The "EKMA Model" (Empirical Kinetic Modeling Approach) 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 a small number of polluted areas.

The EKMA Model is described in detail in the literature (EPA, 1977 and 1978), and the computer program has been made available on magnetic tape together with a detailed User's Manual (Whitten & Hogo, 1978).

At the Workshop on Oxidant Control Strategies held at the OECD, Paris, 15-16 November 1979, it was agreed that the participating countries would use the EKMA Model according to the procedure described by the EPA and adapt it to their local conditions for at least one urban area.

This report contains the Norwegian contribution to the use of the EKMA Model in the OECD exercise.

The assumptions for the future changes in transported ozone and precursor emissions have been specified by the Workshop:

Transported ozone:

1) 20% increase
2) No change
3) 20% decrease
4) 50% decrease

Emissions of non-methane hydrocarbons (NMHC) and oxides of nitrogen (NO_x):

a) Present situation
b) 20% reduction of NMHC,
   no reduction of NO_x
c) 50% reduction of both NMHC and NO_x

2 MODEL CALCULATIONS

The EKMA Model was used according to the EPA specifications (EPA, 1977). Two areas in Norway, Oslo and southern Telemark, were examined. For each area one date was selected when local formation of ozone was believed to be a major cause of the recorded levels. The two days chosen (Schjoldager, 1979; Schjoldager & Stige, 1980) were:

17 August 1977 for Oslo.
7 June 1979 for southern Telemark.

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, or not directly influenced by, 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 ratios were estimated from emission inventories. For Oslo these figures can be considered reasonably reliable (Grønskei, 1978). For southern Telemark the NMHC emissions, and hence the NMHC/NO_x ratio, are uncertain.

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, 17 August 1977

The following input data were used:

Latitude:	60.0°N
Longitude:	10.8°E
Time zone:	-1
Design value for ozone:	97 ppb
Transported ozone, surface layer and aloft:	34 ppb
Mixing height:	300 m at 0800 h. 1100 m at 1400 h.
NMHC/NO_x ratio:	9

Four isopleth runs were carried out, based on the four assumptions for the transported ozone, both in the surface layer and aloft. The four runs are illustrated in Appendix A. The resulting maximum ozone concentrations are given in Tables 1 and 2 for the

three levels of emission control. Table 1 gives the ozone concentrations in ppb, while Table 2 gives the changes as percent of the design value of 97 ppb.

Table 1: Oslo, 17 August 1977.
Calculated maximum 1-hour ozone concentration (ppb) for four assumptions of transported ozone and three levels of emission control.

Emissions	Transported ozone, surface layer and aloft			
	+20%	No change	-20%	-50%
a. Present situation	102	97	92	86
b. 20% reduction of NMHC No reduction of NO_x	90	86	80	75
c. 50% reduction of NMHC and NO_x	73	68	63	56

Table 2: Oslo, 17 August 1977.
Change of maximum 1-hour ozone concentration (%) relative to the design value of 97 ppb.

Emissions	Transported ozone, surface layer and aloft.			
	+20%	No change	-20%	-50%
a. Present situation	+5	0	-5	-11
b. 20% reduction of NMHC No reduction of NO_x	-7	-11	-18	-23
c. 50% reduction of NMHC and NO_x	-25	-30	-35	-42

2.2 Southern Telemark, 7 June 1979

The following input data were used:

Latitude: 59.1°N
Longitude: 9.6°E
Time zone: -1

Design value for ozone: 199 ppb
Transported ozone, surface layer and aloft: 72 ppb

Mixing height : 400 m at 0800 h
1300 m at 1400 h

$NMHC/NO_x$ ratio : 6

The four isopleth runs were carried out, and the three levels of emission control were considered in the same way as previously described. The runs are illustrated in Appendix B. The resulting 1-hour maximum ozone concentrations are given in Tables 3 and 4 as absolute concentrations and relative change, respectively.

Table 3: Southern Telemark, 7 June 1979. Calculated maximum 1-hour ozone concentration (ppb) for four assumptions of transported ozone and three levels of emission control.

Emissions	Transported ozone, surface layer and aloft			
	+20%	No change	-20%	-50%
a. Present situation	210	199	194	180
b. 20% reduction of NMHC No reduction of NO_x	187	177	169	160
c. 50% reduction of NMHC and NO_x	154	143	135	120

Table 4: Southern Telemark, 7 June 1979.
Change of maximum 1-hour ozone concentration (%) relative to the design value of 199 ppb.

Emissions	Transported ozone, surface layer and aloft.			
	+20%	No change	-20%	-50%
a. Present situation	+ 6	0	- 3	-10
b. 20% reduction of NMHC No reduction of NO_x	- 6	-11	-15	-20
c. 50% reduction of NMHC and NO_x	-23	-28	-32	-40

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 perhaps not surprising because the same model was used, and many of the input parameters were the same. The design value for ozone, the absolute level of transported ozone and the NMHC/NO_x ratio were, however, quite different.

In summary, the model calculations showed the following:

For a given level of emission control:

- 20% increase of the transported ozone caused 5-8% increase in the maximum downwind ozone concentration.
- 20% decrease of the transported ozone caused 3-7% decrease in the maximum downwind ozone concentration.
- 50% decrease of the transported ozone caused 10-18% decrease in the maximum downwind ozone concentration.

For a given level of the transported ozone:

- 20% reduction of NMHC and no reduction of NO_x caused 11-13% decrease in the maximum downwind ozone concentration.
- 50% reduction of both NMHC and NO_x caused 27-35% decrease in the maximum downwind ozone concentration.

The relative effect of changes of the transported ozone was highest for the strongest emission control, and the relative effect of emission control was highest for the lowest level of transported ozone.

When both the transported ozone level and the NMHC emission were reduced by 20% (no reduction of the NO_x emission), the maximum downwind ozone concentration decreased by 15-18%.

When both the transported ozone level and the NMHC and NO_x emissions were reduced by 50%, the maximum downwind ozone concentration decreased by 40-42%.

It should be emphasized that due to various aspects of the EKMA Model, the results should be interpreted with considerable 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 theoretical calculations. The hydrocarbon composition has not been experimentally determined, and especially for southern Telemark there may be deviations from the typical "urban mixture".

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 mentioned that ozone episodes in Norway are often due to mesoscale formation and transport, or to transport from distant sources. 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 may be necessary to estimate the emission controls for these episodes.

Furthermore, it is of interest to compare the results from the EKMA Model with results from other photochemical models. A comparison of that kind has recently been carried out, based on data from England (Hov & Derwent, 1980).

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APPENDIX A

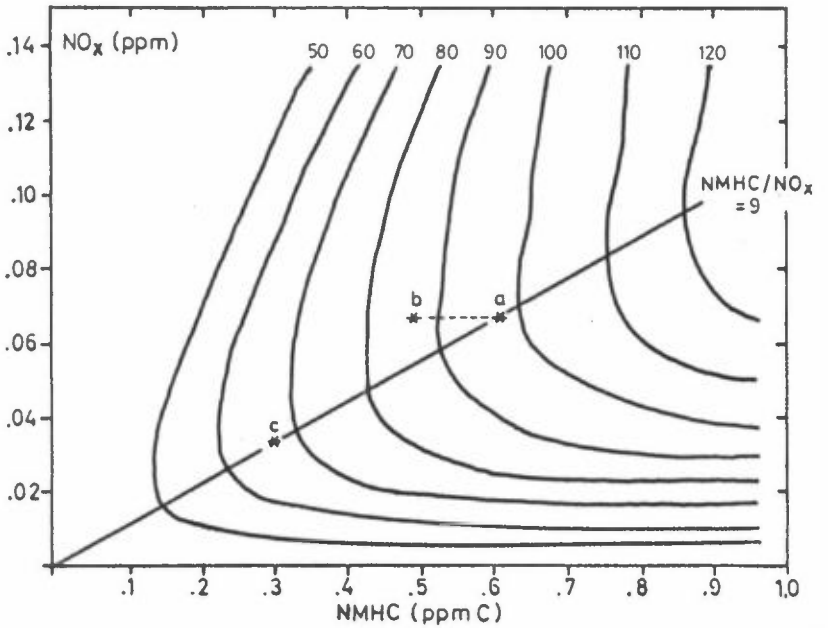
OZONE ISOPLETH DIAGRAMS FOR OSLO, 17. AUGUST 1977

Design value for ozone: 97 ppb

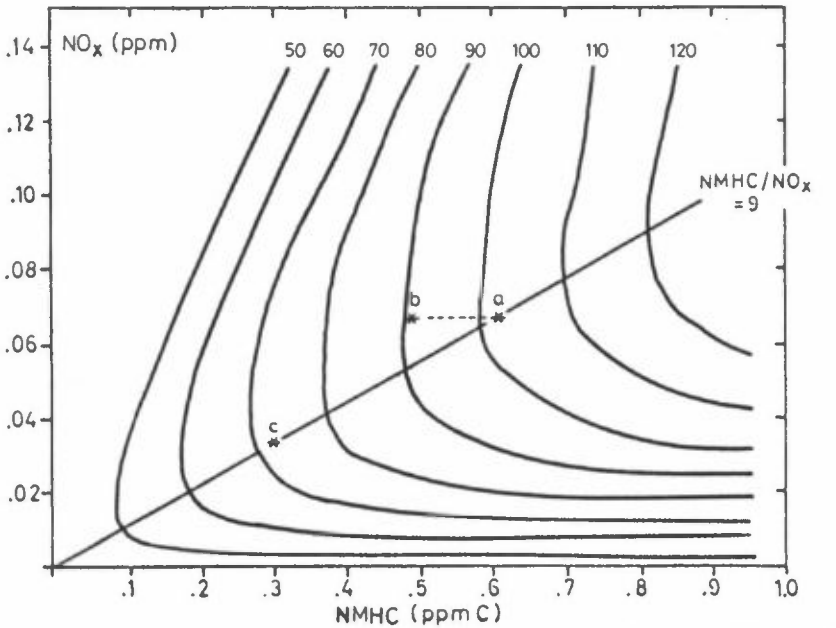
Levels of emission control:

a) Present situation
b) 20% reduction of NMHC and no reduction of NO_x
c) 50% reduction of both NMHC and NO_x.

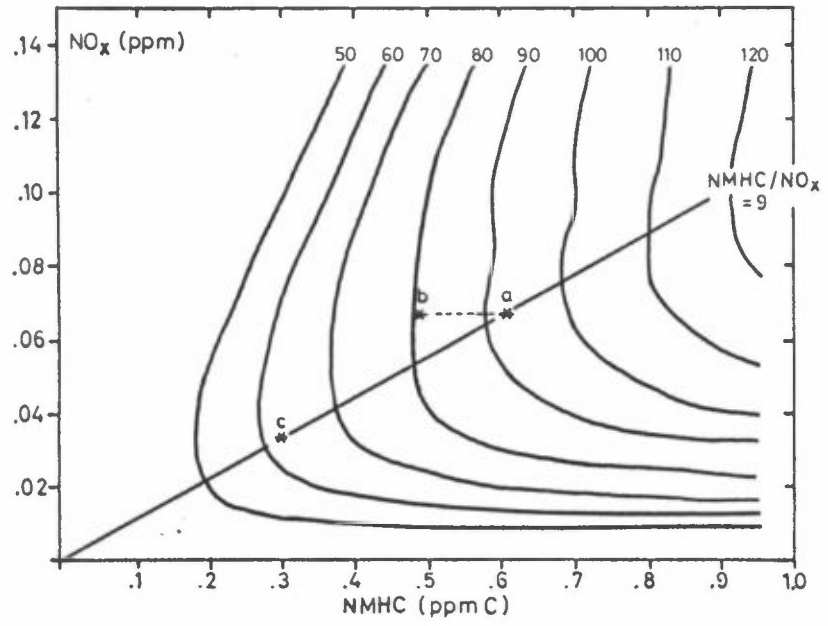
Transported ozone 34 ppb (present level)



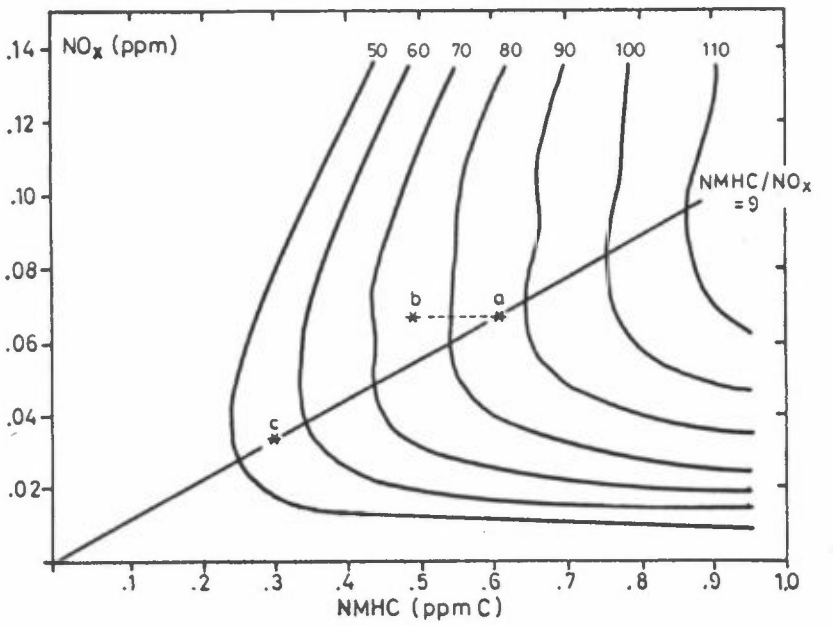
Transported ozone 41 ppb (+ 20%)



Transported ozone 27 ppb (- 20%)



Transported ozone 17 ppb (-50%)



APPENDIX B

OZONE ISOPLETH DIAGRAMS FOR SOUTHERN TELEMARK, 7. JUNE 1979

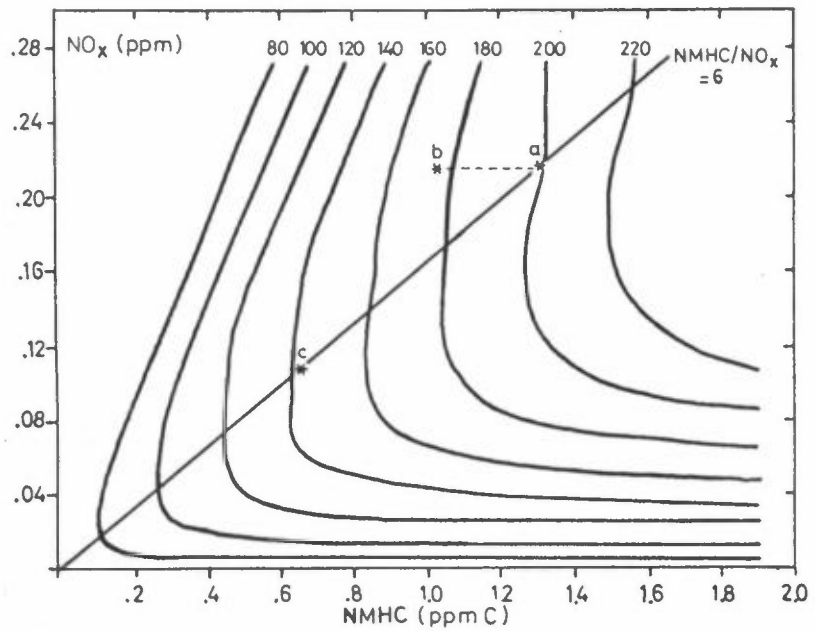
Design value for ozone: 199 ppb.

Levels of emission control:

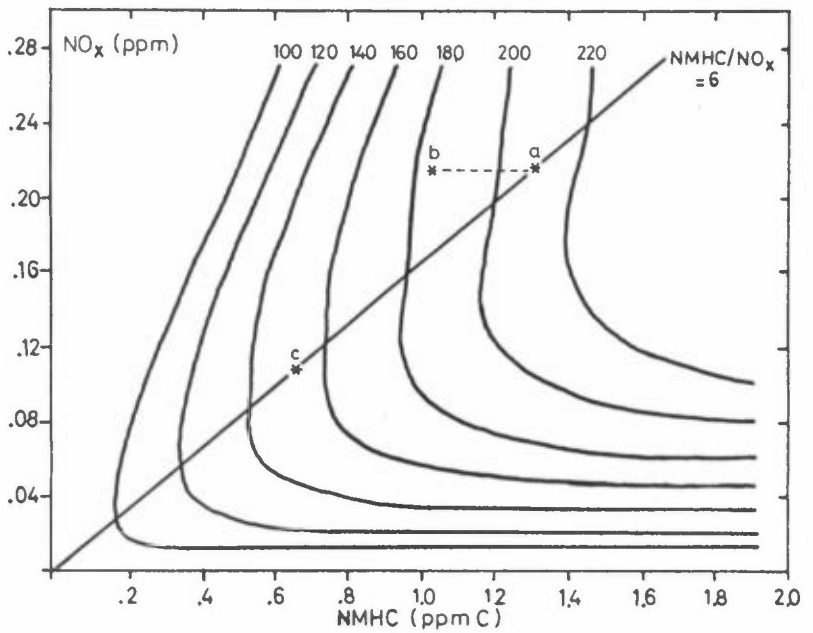
a) Present situation
b) 20% reduction of NMHC and no reduction of NO_x
c) 50% reduction of both NMHC and NO_x

SOUTHERN TELEMARK, 7 JUNE 1979

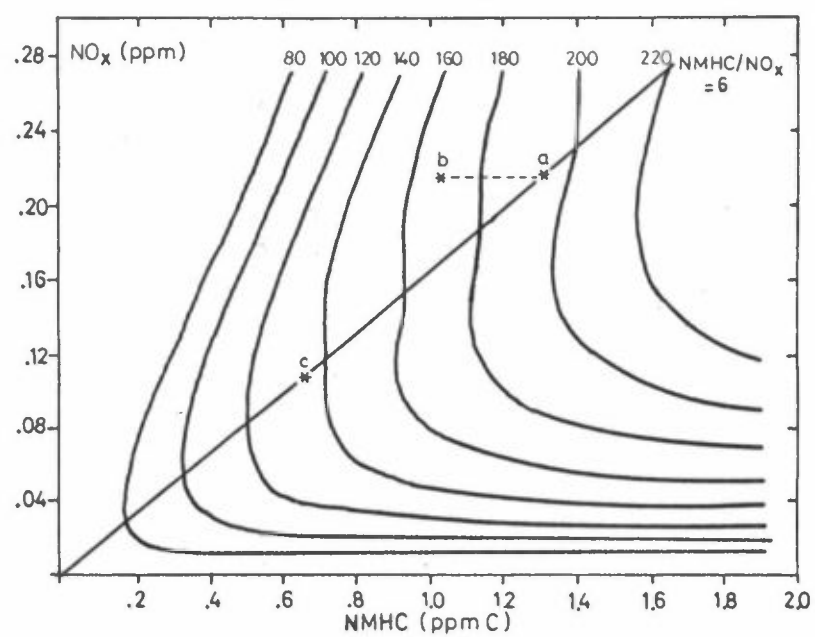
Transported ozone 72 ppb (present level)



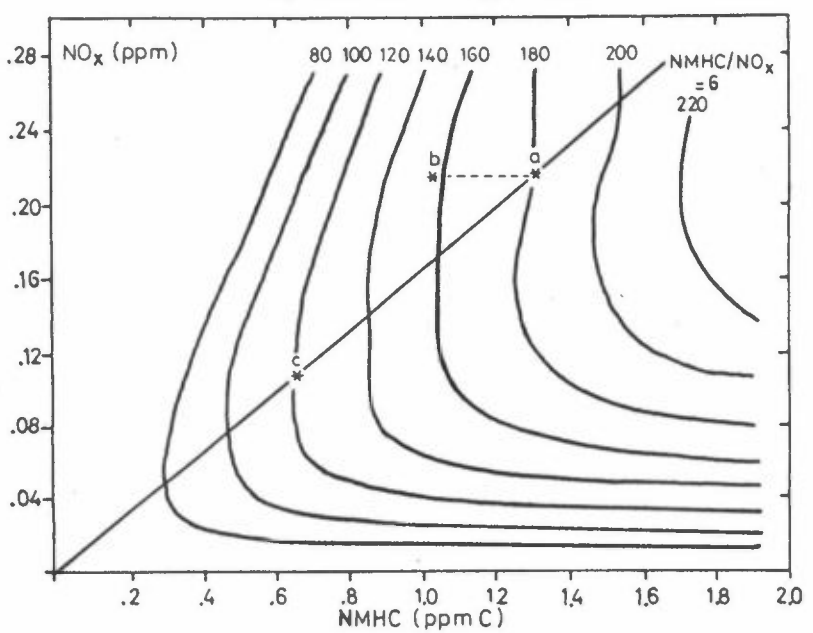
Transported ozone 86 ppb (+ 20%)



Transported ozone 58 ppb (- 20%)



Transported ozone 36 ppb (-50%)



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(NORGES TEKNISK-NATURVITENSKAPELIGE FORSKNINGSRÅD)
POSTBOKS 130, 2001 LILLESTRØM
ELVEGT. 52.
TLF. (02) 71 41 70

RAPPORTTYPE	RAPPORTNR.	ISBN--82-7247-173-6
Oppdragsrapport		
DATO April 1980	ANSV.SIGN. B. Ottar	ANT.SIDER 16
TITTEL Use of the "EKMA Model" to predict the effect of emission control on ambient ozone levels		PROSJEKTLEDER J. Schjoldager NILU PROSJEKT NR 21980
FORFATTER(E) Jørgen Schjoldager		TILGJENGELIGHET ** OPPDRAGSGIVERS REF.
OPPDRAGSGIVER Statens forurensningstilsyn		
3 STIKKORD (á maks.20 anslag) Ozon | Utslippsreduksjoner		Beregninger

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

En fotokjemisk boksmodell, "EKMA Model", utviklet ved Environmental Protection Agency i USA, er bruk til å beregne reduksjon i ozonkonsentrasjon som følge av tenkte endringer i bakgrunnskonsentrasjonen av ozon og utslipp av hydrokarboner og nitrogenoksyder. Beregningene er utført for Oslo, 17 august 1977 og nedre Telemark, 7 juni 1979.

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

The "EKMA Model", developed by the U.S. Environmental Protection Agency, has been used to calculate changes in the ambient ozone lelvels for future assumptions of transported ozone and local emission control. The calculations are carried out for Oslo (60°N), 17 August 1977 and southern Telemark (59°N), 7 June 1979.

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Må bestilles gjennom oppdragsgiver B
Kan ikke utleveres C