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Project Summary

Historical Emission and Ozone Trends in the Houston Area

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An analysis of historical trend data for hydrocarbons, nitrogen oxides, and ozone in the Houston region from 1974 to 1978 is conducted in order to check the EKMA ozone model and to obtain a better understanding of the Houston ozone problem. In addition to historical trend analyses, the study includes a detailed investigation of seasonal/diurnal/meteorological patterns in ambient ozone data at two Houston monitoring sites (Mae Drive and Aldine).

Historical emission trends are compiled for 26 NMHC source categories, for 15 NO_x source categories, for each year from 1974 to 1978, and for five sub-areas of the Houston region. It is found that estimated NMHC emissions in the Houston region decreased 17% from 1974 to 1976 but then increased 12% from 1976 to 1978, so that there was only a slight net decrease over the 4-year period. Estimated NO_x emissions increased by 18% over the 4 years. These emission trend estimates involve significant uncertainties. Ambient precursor data indicate an even more pessimistic picture of historical trends (i.e. moderate increases in NMHC and substantial increases in NO_x from 1974 to 1978).

The historical emission trends are entered into the EKMA isopleth model to predict historical ozone trends; the predicted trends are then compared to actual ozone trends. Predicted ozone trends change very little from 1974 to 1978 (except for a slight increase from 1976 to 1977). For most sites/indices, actual ozone trends show little net change from 1974 to 1978, although there are significant fluctuations within the 4-year period. Most of the discrepancies between predicted and actual trends can be explained by the large error bounds in the analysis (e.g. uncertainty in the emission trend estimates and meteorological variance in the actual ozone trends). It is concluded that historical emission changes in the Houston region were not large enough from 1974 to 1978 to provide a definitive test of the EKMA isopleth method.

Although this study of historical trends in Houston is unable to provide a definitive test of the EKMA method, it does provide a better understanding of the emission and air quality effects being produced by control programs and source growth in the Houston region. In particular, this study explains an apparent paradox noted by previous researchers—the lack of an ozone decrease from 1974 to 1978 in light of expected sizeable reductions in hydrocarbon emissions. There is no paradox; hydrocarbon emissions did not decrease significantly from 1974 to 1978 because rapid source growth negated the effects of controls and because many of the controls were installed prior to the 1974-1978 period.

This Project Summary was developed by EPA's Environmental Sciences Research Laboratory, Research Triangle

Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Empirical Kinetic Modeling Approach (EKMA) has recently been proposed by EPA as a method for evaluating ozone control strategies. Before the EKMA method is accepted as a reliable technique for control strategy analysis, it should be subjected to validation studies. The purpose of this report is to test the EKMA method using historical trend data for the Houston area. Specifically, nonmethane hydrocarbon (NMHC) and nitrogen oxide (NO_x) emission trends in Houston are estimated for the years 1974 to 1978; these emission trends are entered in the EKMA method to predict historical ozone trends; the predicted ozone trends are then compared to actual ozone trends as a test of the EKMA method.

The historical trend data presented herein are not only of interest with respect to testing EKMA but also by themselves. By conducting a detailed analysis of precursor (NMHC and NO_x) emission trends, we can show how emissions for individual source categories have changed due to controls and source growth, and how total emissions have responded to trends for individual source categories. By examining trends in ambient NMHC and NO_x data, we can check our emission trend estimates with an independent measure of precursor trends. By analyzing historical ozone trends, we can investigate whether or not the ozone trends make sense in light of precursor changes and meteorological fluctuations. Thus, this study is useful not only as a means to validate EKMA, but also as a means to understand the air quality effects actually being produced by control programs and source growth in the Houston region.

There are two basic reasons why Houston was selected for the study region. First, as evidenced by the Houston Area Oxidants Study sponsored by the Chamber of Commerce and by several Houston programs sponsored by EPA, a great deal of interest currently exists in the Houston ozone problem. Second, substantial changes in historical precursor emissions are required for an adequate test of the EKMA method; previous investigators in Texas have suggested that large reductions in NMHC emissions, on the order of 20 to 35%, have occurred in the Houston area since 1974.

Figures 1 and 2 illustrate some of the important characteristics of the study area. In the study, actual ozone trends are determined from data at two Houston monitoring stations, Mae Drive and Aldine. The investigation covers the years 1974 to 1978 at Mae Drive and 1975 to 1978 at Aldine. These are the only years for which complete smog season ozone data are available at the two locations.

Emission trends are compiled herein for 26 NMHC source categories and 15 NO_x source categories on a year by year basis from 1974 to 1978. The emission trend study region consists of Brazoria, Galveston, and Harris counties. Emission trends are determined for the entire study region and individually for five sub-areas of the region: Brazoria County, Galveston County, Ship Channel area of Harris County, Houston city area of Harris County, and remainder of Harris County. Because our analyses of ambient ozone data indicate that sources within Harris County are mainly responsible for ozone episodes at Mae Drive and Aldine, emission changes for Harris County only are used in the isopleth validation tests.

Conclusions

The objectives of this study are (1) to gain a fundamental understanding of ozone phenomena at Mae Drive and Aldine by examining temporal ozone patterns and ozone/wind relationships; (2) to determine historical trends in NMHC and NO_x emissions in Houston resolved on a yearly basis, for various

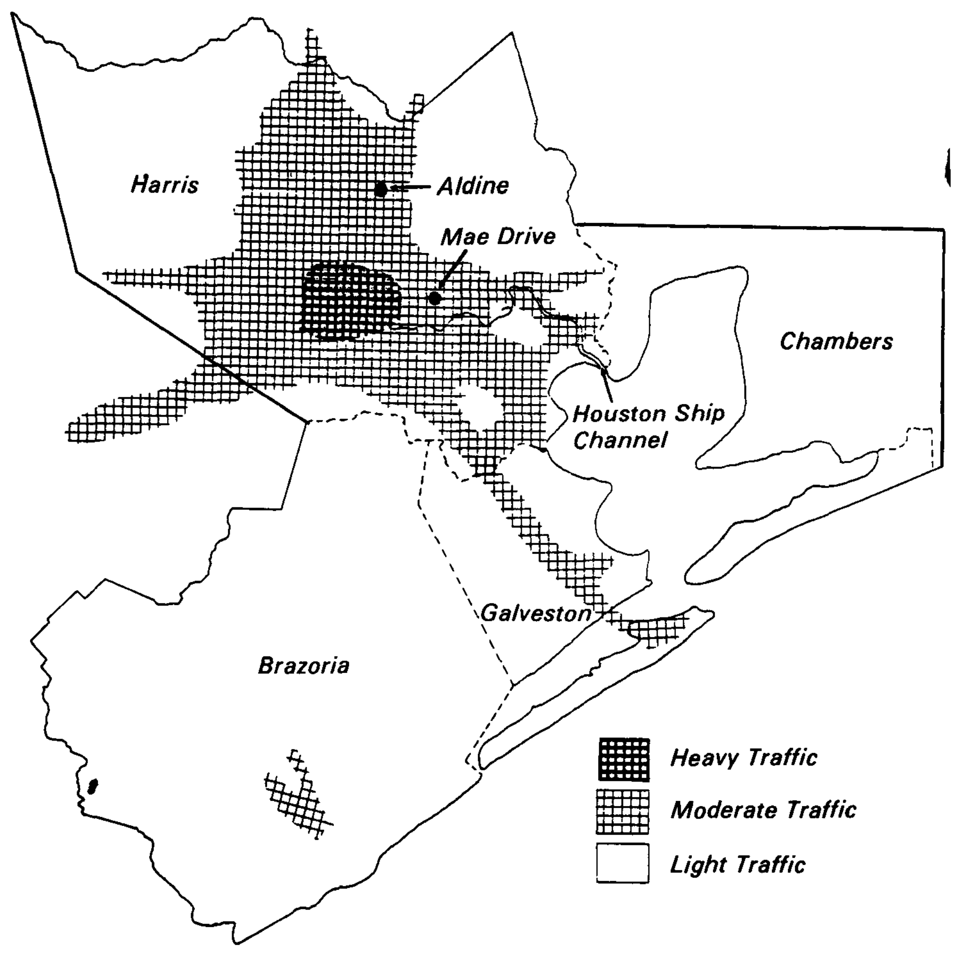

Figure 1. *Approximate spatial distribution of traffic density in the Houston area.*

sub-areas, and for all major source categories; (3) to characterize historical ozone trends at Mae Drive and Aldine; and (4) to test the EKMA isopleth model by comparing predictions of historical ozone trends with actual ozone trends. The following sections summarize our findings and conclusions with respect to each of the above four objectives.

Phenomenological Analysis of Ozone and Wind Data

As expected, ozone levels tend to be higher at Aldine (located as a downwind receptor site for Houston air pollutants) than at Mae Drive (located near the major source areas). For both locations, the seven months-April-October-comprise a distinct "smog season" that is conducive to elevated ozone concentrations.

The most salient characteristic of the ozone/wind relationship at both Mae Drive and Aldine during the smog season is the association of high ozone with calm winds. Another important feature of the ozone/wind relationship at both locations is the association of high ozone with transport from either the Houston City area or the Ship Channel area.

The daily ozone maximum is most likely to occur from 12 AM to 4 PM at Mae Drive and 1 PM to 5 PM at Aldine. Assuming that solar irradiation effectively begins at 8:00 AM, the mean irradiation times up to the ozone peak during the smog season are 6¼ hours at Mae Drive and 6¾ hours at Aldine. On days of extreme ozone, the mean irradiation time is approximately 7 hours at both locations.

Historical Emission Trends

Emission trends are determined by three factors: uncontrolled emission levels for various source categories, growth of source activity levels, and the timing and effectiveness of controls. Each of these three factors often involves considerable uncertainty. To help minimize these uncertainties, we have attempted to use the most accurate and up-to-date information available from industrial representatives, consulting firms, trade associations, and local/state/federal agencies. Despite our efforts, certain information gaps persist which lead to significant uncertainties in our emission trend estimates.

Estimated emissions of NMHC in the three-county study region decreased 17% from 1974 to 1976 and increased 12% from 1976 to 1978, so that only a slight NMHC reduction (7%) occurred from 1974 to 1978. The single major source category undergoing a significant reduction in NMHC from 1974 to 1978 was the chemical industry which, despite extremely rapid growth in output, managed to decrease NMHC emissions by 34%. Although some degree of control was installed on all other major NMHC source categories from 1974 to 1978, these controls were insufficient to overcome growth rates; thus, NMHC emissions from motor vehicles, the petroleum industry, and other sources all increased slightly from 1974 to 1978. The two major reasons for the lack of significant NMHC reductions in the Houston region from 1974 to 1978 were rapid source growth and the fact that most of the stationary source controls were already in place by 1974.

The regionwide 7% decrease in NMHC emissions from 1974 to 1978 was composed of a 34% decrease in Brazoria County, a 13% decrease in Galveston County, and a 1% increase in Harris County. Brazoria County experienced a significant decrease in NMHC because the chemical industry (which was controlled during the period) is of great relative importance there.

Estimated emissions of NO_x in the three-county region rose by 18% from 1974 to 1978. The NO_x increase was a product of high growth and the absence of NO_x controls (except for automobiles). The predominant part of the NO_x rise resulted from a 43% increase in chemical industry NO_x over the four years. Increases in NO_x from other sources were as follows from 1974 to 1978: petroleum industry—13%, power plants—15%, motor vehicles—7%, and all other sources—13%. The increase in NO_x emissions from the chemical and petro-

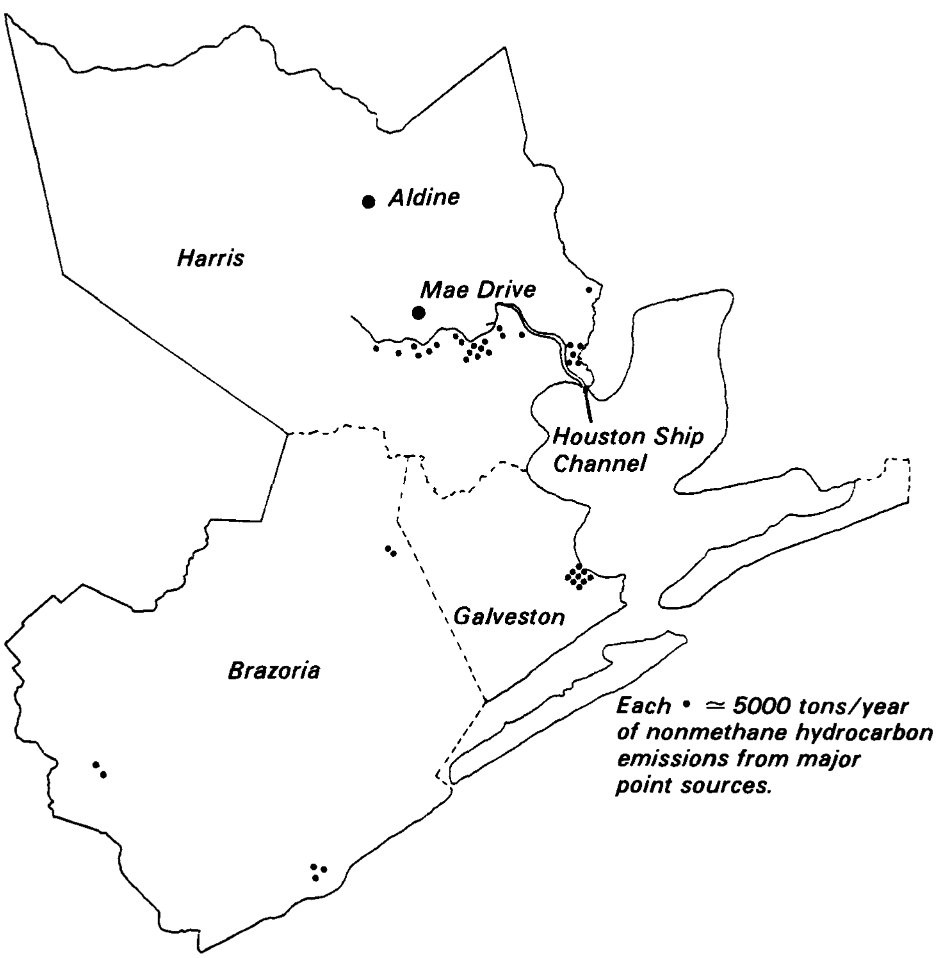

Figure 2. Approximate spatial distribution of hydrocarbon emissions from major point sources in the Houston area.

leum industries would have been substantially greater were it not for a voluntary fuel conservation program that significantly decreased fuel use per pound of product.

The regionwide 18% increase in NO_x consisted of a 20% rise in Brazoria County, a 7% rise in Galveston County, and a 22% rise in Harris County. The Ship Channel area of Harris County experienced an especially large increase in NO_x (45% over the four years) due to growth in the chemical and petroleum industries.

Trends in ambient precursor data at Mae Drive and Aldine present a more pessimistic picture than our emission trend data. The ambient data indicate that NMHC concentrations increased somewhat (on the order of 7 to 23%) and NO_x concentrations increased substantially (on the order of 16 to 48%) from 1974 to 1978. It should be noted, however, that the ambient trend data (like the emission trend data) also involve significant uncertainties.

Historical Ozone Trends

Complete smog season ozone data are available for 1974-1978 at Mae Drive and 1975-1978 at Aldine. Considering the entire historical record, no overall trends are evident in the ozone data. The only exception is the yearly second maximum hourly concentration at Aldine which displays a significant decrease from 1975 to 1978.

Meteorological normalization of the ambient ozone trends should eliminate weather biases in the trends and should reduce the statistical error bounds on the trends. In a companion study, however, our co-workers encountered several fundamental difficulties with meteorological normalization techniques that precluded their application to the Houston ozone data. Further research into meteorological adjustment procedures is necessary before such procedures can be used in practice.

Stratification of the historical ozone trends by wind direction fails to reveal any consistent patterns at Mae Drive or Aldine. Because of the limited number of data points for given wind directions, the wind-stratified trend data appear to be dominated by large stochastic fluctuations from year to year.

Validation of the EKMA Isopleth Method

In the validation studies, historical emission trends and the standard EKMA isopleth model are used to predict historical ozone trends; these predicted trends are then compared to actual ozone trends. The tests are conducted from 1974 to 1978 at Mae Drive and 1975 to 1978 at Aldine using two ozone air quality indices: the 95th percentile of daily maxima during the smog season, and the yearly second maximum hourly concentration.

Because the emission changes during the study period were rather small, and because NMHC and NO_x emissions underwent rather similar variations from 1975 to 1978, the predicted ozone trends are insensitive to the initial NMHC/NO_x ratio (ratios of 8.5:1, 17:1, and 47:1 are used in the tests). The two major sources of error in the analysis are uncertainties in the emission trend estimates and (especially) statistical errors in the ambient ozone trends caused by yearly weather fluctuations.

Predicted ozone trends show little change from 1974 to 1976, a slight increase from 1976 to 1977, and little change from 1977 to 1978. For both air quality indices at Mae Drive and for the 95th percentile of daily maxima at Aldine, actual ozone trends increase moderately in 1975 and/or 1976 and then decrease somewhat in 1977 and 1978. The net result for these three cases is that the isopleth model underpredicts ozone somewhat in 1975 and/or 1976 but yields fairly good agreement in 1977 and 1978. The discrepancies could easily be explained by potential errors in the emission trends and by meteorological variance in the actual ozone trends. In the fourth case, yearly second maximum ozone at Aldine, actual ozone underwent a substantial decrease from 1975 to 1978, producing a large discrepancy with predicted trends. The large discrepancy might be explained by the very anomalous behavior or this particular air quality index at Aldine (i.e. by an extreme statistical error in this air quality index at Aldine).

Given the rather large error bounds in our analysis, it is difficult to tell if there is any fault with the EKMA model itself. In fact, a major finding of this study is that emission changes in Houston from 1974 to 1978 were not large enough to provide an adequate test of the EKMA model.

Previous investigators in Texas have noted an apparent paradox in the sense that ozone levels increased somewhat at Mae Drive and Aldine from 1974 to 1976, a period in which hydrocarbon emissions were supposedly reduced by about 20 to 35%. Our analysis helps to explain this paradox. For one, the ozone increase from 1974 to 1976 seems to have been a temporary fluctuation (ozone levels came back down in 1977 and 1978). Also, the NMHC emission decrease was not as much as expected (12% in Harris County and 17% in the three-county study region from 1974 to 1976).

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The complete report, entitled "Historical Emission and Ozone Trends in the Houston Area," (Order No. PB 81-184 574; Cost: $12.50, subject to change) will be available only from:
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