

Ozone Exposure and Death: Two Studies in the United States and Europe

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Air Resources Board

California Environmental Protection Agency



Thank you, Ms. Witherspoon. Good morning, Madame Chairman and members of the Board.

In previous health updates, we've discussed the relationship between ozone exposure and school absences and asthma in the Children's Health Study, and hospital admissions in Atlanta. Other investigators have studied the relationship between ozone and daily death counts; however, their findings were inconsistent, and interpretation of the evidence was constrained by the limited range of locations, the variability of the methods used, and the imprecision of the estimates.

The focus of today's presentation is on two recently published multi-city studies, which are among the first to have addressed these issues.

U.S. Study

- 95 cities in large urban areas, 1987-2000
- Model adjusted for weather, season, day-of-week, long-term trends
- 10-ppb increase in 1-hour maximum ozone associated with 0.10% increase in non-injury related deaths
 - 95% confidence interval: 0.05% to 0.16%
 - larger increase in death from heart and lung disease
 - larger increase for previous week's ozone
 - similar effect among age groups or when PM is included



Bell et al. (2004) *Journal of the American Medical Association*, Volume 292, pages 2372-2378

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In the first study, Dr. Bell and colleagues developed national approaches for analyzing multi-site data from 95 large U.S. urban communities from 1987 to 2000. These cities account for about 40% of the total U.S. population. For each city, the authors first estimated the death rate associated with exposure to ozone. Then, the city-specific rates were combined to produce a national estimate, taking into account the variation across locations.

The authors controlled for possible confounding effects of the weather by including temperature and dewpoint, and allowed for different baseline death rates by day of the week and adjusted for seasonality and long-term trends.

They found that a 10-parts-per-billion increase in the 1-hour maximum ozone level was associated with a 0.1% increase in the non-injury related death rate. The confidence interval, which reflects the uncertainty in the estimate, is from 0.05 to 0.16%. The rates were similar across age groups and are higher for death from heart and lung disease, and more strongly related to the previous week's ozone. The authors also demonstrated that the ozone effect is independent of particulate matter.

European Study

- 23 cities in 15 countries, 1990-1997
- Model adjusted for weather, season, day-of-week, local events
- 10-ppb increase in 1-hour maximum ozone in summer associated with 0.66% increase in non-injury related deaths
 - 95% confidence interval: 0.34% to 1.04%
 - larger increase in death from heart and lung disease
 - effect independent of SO₂ and PM10, but somewhat confounded by NO₂ and CO



Gryparis et al. (2004) *American Journal of Respiratory Critical Care Medicine*, Volume 170, pages 1080-1087

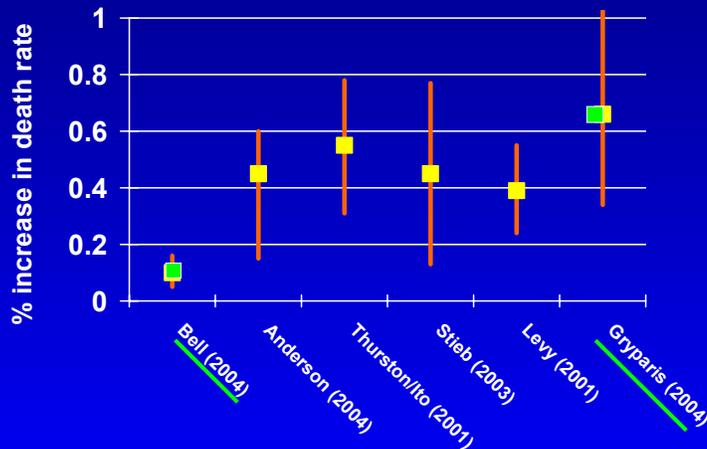
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The second study, which is authored by Dr. Gryparis and colleagues, comes from a major European project that addresses air pollution and health. This project included 23 cities throughout Europe, with a total population of more than 50 million. Similar to the U.S. study, data were initially fitted for each city separately. The results were then combined for an overall estimate. The models also adjusted for potential confounders such as weather.

The authors found that a 10-parts-per-billion increase in summertime 1-hour maximum ozone level was associated with a 0.66% increase in daily deaths, and higher increases for death from heart and lung disease. The confidence interval is from about 0.3 to 1%. No significant effects were observed during the winter season.

The authors found the results to be independent of sulfur dioxide and PM10, but somewhat confounded by nitrogen dioxide and carbon monoxide.

Comparison of U.S. and European Studies to Other Studies



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To put the results in perspective, we compare the findings from these two studies to other meta-analyses. For ease of comparison, we've converted all results into consistent units. Four meta-analyses have been published between 2001 and 2004. As you can see, the effect estimates from these meta-analyses, shown in yellow, range from 0.39% to 0.55% increase in daily deaths per 10-ppb change in 1-hour maximum ozone -- compared to Bell's estimate of 0.1%, shown in green on the left. 95% confidence intervals are presented in vertical lines. Dr. Bell postulates that the higher values found by other investigators could be due to bias in incorporating only the single-city studies that show positive effects. On the other hand, the modeling techniques employed in the Bell study may over-control for the confounding effects of weather.

Results from the European Study by Dr. Gryparis, shown in green on the right, apply to the summer season only. Since ozone is typically higher in the summer, it is expected that the summer effect would be higher.

The difference in effect estimates between these studies, and between cities within the studies, could be due to differences in the local pollutant mixture, the use of air conditioning, time spent indoors versus outdoors, home structure and differing ventilation rates, open or closed windows, susceptibility of the affected population, and socioeconomic factors. Questions remain on the treatment of weather, season, and other pollutants in the statistical modeling of ozone and death, and the sensitivity of the models used remains to be tested rigorously.

We note that U.S. EPA has funded three independent meta-analyses of the most recent data on short-term exposure to ozone and death. The results are expected to be published in July of this year, and we will report back to the Board after their publication.

Complete references of all papers listed here are located in the ARB staff report "Review of the California Ambient Air Quality Standard for Ozone", on pages B-27 to 28, Vol IV, located in the following link: <ftp://ftp.arb.ca.gov/carbis/research/aaqs/ozone-rs/ozone-final/vol4.pdf>

Health Benefits of Reducing Ozone in California

- Estimate 580 deaths (probable range: 290 to 870) would be avoided annually if the 1-hour standard of 90 ppb is attained
 - low value reflects U.S. study, high value reflects European study, central value reflects other meta-analyses
 - consistent ozone reductions (above 40 ppb) found for SoCAB (1980 to present); basin-specific rates used
 - assumed ozone-related death rate applies to statewide range of ozone levels
 - methodology peer-reviewed by experts in the field
- U.S. EPA obtained similar results for California



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ARB staff used results from the two studies discussed in this update and the four meta-analyses just mentioned to estimate the health benefits of reducing ozone exposure in California. We calculate that annually about 580 deaths would be avoided if the 1-hour standard for ambient ozone of 90 parts per billion were attained statewide.

To determine the range, staff used the U.S. 95-city study for the low-end estimate of 290 deaths, the summer-only European study for the high-end estimate of 870 deaths, and the four meta-analyses of the year-round effect for the central estimate of 580. In this calculation, we estimated the distribution of ozone levels for a situation where the standard was attained Statewide. For the South Coast Air Basin over the past two decades, we found that the control program has reduced high-, moderate- and low-ozone days consistently basinwide, above a base level of 40 parts per billion -- which represents natural background. We assumed this would occur into the future and for other air basins using basin-specific data. In addition, we assumed the ozone-to-daily-death rate applies to the Statewide range of ozone levels, based on the European Study that found the response to be linear even at low levels of ozone. Our methodology has undergone peer review by several experts in the field of air pollution health.

In addition, U.S. EPA published a health benefits study in January 2005. Using a different model, U.S. EPA found a similar central estimate of 560 deaths for California.

Ozone Effects on Health: Summary

- Ozone effects on death supported by scientific literature
- Substantial evidence of health benefits from reduced ozone pollution



In summary, the recent studies covering 95 large cities in the United States and 23 major cities in Europe strongly suggests a link between exposure to ambient ozone and premature death. Research into the biological mechanisms that could help explain the association between ozone exposure and death has just begun and includes a study approved by the Board last December. Some leading hypotheses include activation of inflammatory pathways and reduction in heart rate variability, which is a risk factor for adverse heart-related outcomes.

The two studies discussed today applied sophisticated modeling techniques that account for the variability in the data and the potential confounding factors, which lead to more precise estimates. Together, they add to the substantial body of evidence of the public health benefits from reducing ozone pollution.

Next Steps

- Ozone standard staff report released March 11, 2005
- Recommendations for new state ambient air quality standards for ozone to be considered by the Board in April 2005



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Finally, as you know, the Air Resources Board is responsible for adopting ambient air quality standards for major pollutants at levels that adequately protect the health of the public, including vulnerable populations, such as children and the elderly.

The staff from ARB and the Office of Environmental Health Hazard Assessment recently completed an extensive review of the ambient air quality standard for ozone. Last week, we released a report containing the findings and recommendations for amending the state standard. Although the studies discussed today did not serve as the basis for the recommendations to amend the standard, they were reviewed and discussed in the staff report. The studies were also used for estimating premature death effects as part of the ozone health benefits assessment.

Staff intends to present the recommendations in the report to the Board for your consideration next month.

Thank you for your attention. I will be happy to answer your questions.