Implications of the Observed Effect of Air Pollution on Birth Weight

*Louise Williams, †M. Anne Spence, and †Susan C. Tideman

Department of Anthropology, University of California, Los Angeles, California: and †Neuropsychiatric Institute, MR Unit, Los Angeles, California

ABSTRACT: The purpose of this study was to ascertain whether air pollution in the Los Angeles Basin is affecting birth weight. The data base for the study consisted of daily air pollutant averages from the Air Pollution Control District of Los Angeles County, California, obstetric records of births at the University of California at Los Angeles Hospital for the year 1973, and smoking information on each gravida. The effect of total pollution level was significantly negatively associated with birth weight after removing the effects of other variables significantly associated with birth weight. Infants born to nonsmoking women who lived in the more polluted areas of the city weigh an average of 314 grams less than infants born to women living in the less polluted areas.

The constituents of polluted air occur naturally in small quantities in nonpolluted air and are not harmful. Moderate to heavy levels of air pollution affect the health of biological organisms, decrease property values, and generally make daily life less comfortable. High concentrations of most pollutants are toxic.

Studies of the effects of moderate levels of these substances recorded in polluted air have focused on direct health effects such as respiratory illnesses, mortality, hospital admissions, etc. Recent evidence indicates that the correlation between air pollution and mortality is significant (Lave and Seskin, 1970; Kitagawa and Hauser, 1973). The purpose of this study is to ascertain whether air pollution levels are correlated with a reduction of birth weight, which is one measure of the maturity of a neonate and is predictive of a neonate's relative probability of survival (Karn and Penrose, 1951; Yerushalmy, 1970; Armstrong, 1972).

* Present address: World Fertility Survey, International Statistical Institute, 35–37 Grosvenor Gardens, London, SW1W OBS, U. K.

The proposition to be tested is that infants born to women who live in polluted urban environments weigh less than infants born to women who live in nonpolluted urban environments. This hypothesis is already supported by several observations:

1. Women who smoke one pack of cigarettes a day have infants who weigh 100–300 grams less than nonsmoking mothers (Rush and Kass, 1972).
2. Carboxyhemoglobin (COHb) levels from 6 to 10 per cent measured on women who are smoking one pack of cigarettes a day are thought to be the primary causal components in the observed weight reduction of infants born to these women (Younoszai et al., 1968; Longo, 1976).
3. Carbon monoxide levels of 300 parts per million are often recorded in the Los Angeles Basin (APCD Annual Report, 1972). These levels and durations of CO in ambient air produce COHb levels equal to those recorded on persons smoking one pack of cigarettes a day. In addition, persons living in Los Angeles have been observed to have significant COHb concentrations in their blood (Stewart et al., 1973).
4. The reproductive success of experimental animals has been impaired in atmospheres containing not only CO, but also NO_2 and O_3 at levels simulating those recorded in the Los Angeles Basin (Hueter et al., 1966; Lewis et al., 1967).

5. Human neonatal, infant, and adult mortality rates are higher in urban polluted atmospheres than in nonpolluted atmospheres (Lave and Seskin, 1970; Kitagawa and Hauser, 1973).
6. Median birth weights are inversely related to population density, but this reduction in weight has not yet been directly correlated with elevated pollution levels (Unger, 1957).

The region from which the data were obtained to test this proposition was the Los Angeles Basin, California. Because of the combination of meteorology, geographic location, climate, sunlight, and heavy automobile traffic, the Los Angeles Basin has been plagued by air pollution. Air pollution zones, each monitored by a recording station, have been established, and elevated levels of carbon monoxide (CO), nitrogen dioxide (NO_2), and ozone (O_3) which are known to be toxic are often recorded (APCD Annual Report, 1972).

MATERIALS AND METHODS

The data were derived principally from three sources. The first source was the hospital records from the University of California at Los Angeles (UCLA) Department of Obstetrics and Gynecology and UCLA Department of Medical Records of all births for the calendar year 1973. Each record contained over a hundred measured characteristics such as age, parity, antenatal care information, delivery complications (if any), past history of illness, etc., on the gravida and her infant.

The second major source of data was the daily readings from the Air Pollution Control District (APCD) of Los Angeles County. Carbon monoxide, nitrogen dioxide, and ozone readings were collected from Stations 1, 69, 71, 74, 76, and 83 because these are the areas from which UCLA draws the greatest proportion of its hospital population (Figure 1). Daily averages, computed from the 24 hourly means, were extracted from the records beginning April 1, 1973 through December 31, 1973, and nine-month and three-month moving averages of each pollutant for each monitoring station were computed.

Each woman in the study was assigned the station number of the nearest air pollution monitoring station to her residence. The averages were then incorporated into each woman's record such that the nine-month average covered the gestation period and the three-month averages specified the mean level for each trimester of the pregnancy.

The third major source of data was smoking information. A systematic sample of 1,500 gravidae was selected, and letters explaining the research were sent to these women. The women were requested to complete and mail a postcard which contained two questions on smoking habits during their most recent pregnancy. The first question was whether a gravida had smoked; the second requested the number of cigarettes per day, if she had smoked.

Five hundred thirty-three women received their letters and responded (henceforth, these are called the respondents). Six hundred twenty-nine women apparently received their letters but did not respond (henceforth, these are called the nonrespondents). Three hundred thirty-eight women did not receive their letters, which were returned marked "addressee unknown" or "fictitious address." These women were not analyzed further since the study design required that women reside in Los Angeles throughout their pregnancies, and these women were probably transients.

The combination of these three data sources (air pollution averages, hospital records, and smoking history) provided the data base for this study.

Respondents and nonrespondents were found to be virtually identical with respect to all of the measured characteristics. Ref-

FIG. 1.—Map of monito
APCD).

erence can be made to
details of the char
groups. Methods and
only for nonsmoking
otherwise stated, sinc
pollution effects are s

RESU

Since monitoring
terized by different
gravidae were groupe
of residence. Analysis
and Massey, 1969; Du
revealed a significant
birth weight among zo
weights of infants bor
spondents are shown

acted from the records beginning .973 through December 31, 1973, -month and three-month moving of each pollutant for each moni- ation were computed.

voman in the study was assigned n number of the nearest air pol- onitoring station to her residence. ages were then incorporated into man's record such that the nine- average covered the gestation d the three-month averages spec- mean level for each trimester of nancy.

hird major source of data was information. A systematic sample gravidae was selected, and letters g the research were sent to these The women were requested to and mail a postcard which con- wo questions on smoking habits heir most recent pregnancy. The stion was whether a gravida had the second requested the number ttes per day, if she had smoked. hundred thirty-three women re- neir letters and responded (hence- hese are called the respondents). dred twenty-nine women appar- eived their letters but did not re- henceforth, these are called the ondents). Three hundred thirty- omen did not receive their letters, vere returned marked "addressee n" or "fictitious address." These were not analyzed further since y design required that women re- Los Angeles throughout their cies, and these women were prob- nsients.

combination of these three data (air pollution averages, hospital and smoking history) provided a base for this study.

ondents and nonrespondents were be virtually identical with respect the measured characteristics. Ref-

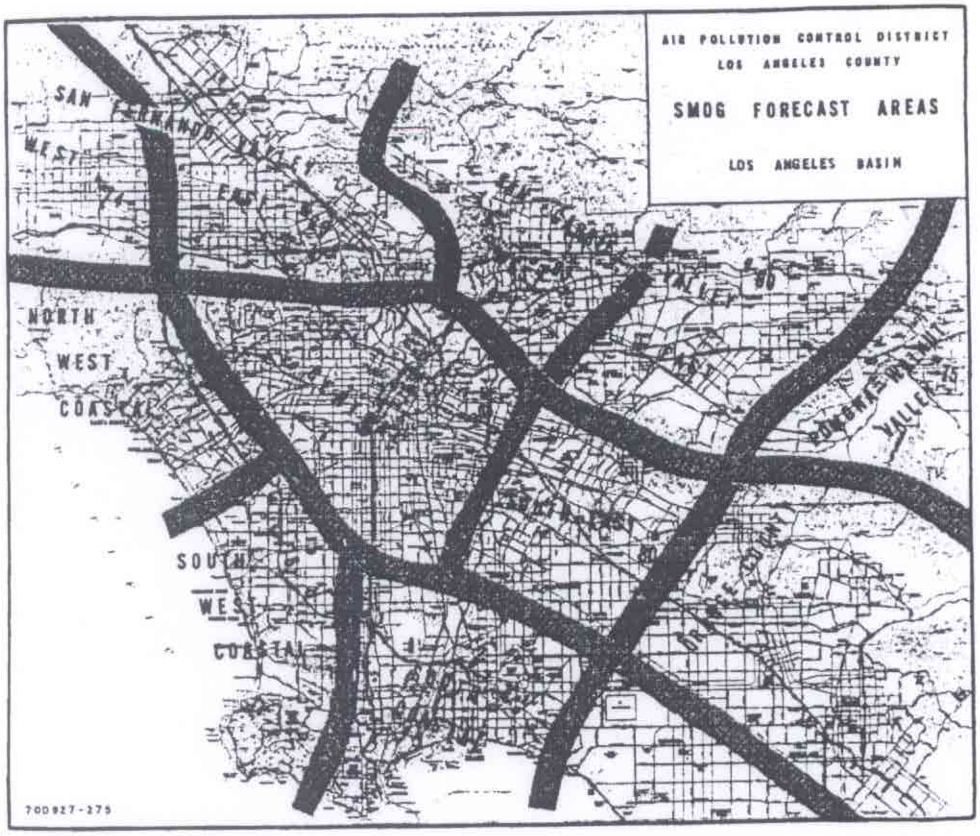

FIG. 1.—Map of monitoring areas of Air Pollution Control District County of Los Angeles (courtesy of APCD).

erence can be made to Williams (1975) for details of the characteristics of both groups. Methods and results are specified only for nonsmoking respondents, unless otherwise stated, since in their case the air pollution effects are seen directly.

RESULTS

Since monitoring zones are characterized by different pollution levels, the gravidae were grouped by monitoring zone of residence. Analysis of variance (Dixon and Massey, 1969; Dunn and Clark, 1974) revealed a significant difference in mean birth weight among zones. The mean birth weights of infants born to nonsmoking respondents are shown in Table 1 by monitoring zones, which are listed in order of decreasing total levels of pollution. Note

TABLE 1

MEAN BIRTH WEIGHT DIFFERENCES BY MONITORING STATION ZONES FOR NONSMOKING RESPONDENTS ONLY

Monitoring Stations*	Mean Weight†	Group Size
83	3.193 ± 0.672	12
69	3.327 ± 0.708	57
1	3.348 ± 0.491	138
74	3.494 ± 0.466	24
71	3.589 ± 0.421	134
76	3.488 ± 0.570	37
Light Pollution	3.647 ± 0.459	22
Total	3.453 ± 0.508	424

* Monitoring station areas are listed in order of decreasing total levels of pollution.

† F-value = 4.167, $p < 0.001$. Birth weights of less than 1 kg were omitted to normalize the birth weight distribution. Birth weight is in kg. Standard deviations follow the means.

that as the pollution level decreases, birth weight increases.

In Table 2, monitoring zone areas are grouped on the basis of the clustering of similar annual pollution levels. (The basis for this grouping will be detailed later.) The birth weight differences between heavy and light pollution areas and between intermediate and light pollution areas is significant, and the trend is in the hypothesized direction for nonsmoking respondents as well as for nonsmoking respondents pooled with nonrespondents (see Table 3). For infants of nonsmoking respondents, there is a 314 gram difference in mean birth weight between light and heavy pollution areas, a difference that is statistically significant. For infants of nonsmoking respondents pooled with nonrespondents, there is a 237 gram difference, which is significant. The difference for infants of nonrespondents alone is 177 grams.

Given these statistical findings, it was necessary to determine whether the observed differences and trend were due to differences in pollution level or to some other factor. The factors to be determined were conceptually divided into: (1) variables external to the infant, e.g., the pollution constituents and concentrations; (2) intermediate variables which are rela-

TABLE 2

DISTRIBUTION OF MEAN BIRTH WEIGHT IN THREE POLLUTION LEVEL AREAS OF THE LOS ANGELES BASIN*

Respondents	Heavy (Stations 1, 69, 83)	Intermediate (Stations 71, 74, 76)	Light (Surrounding Areas)	Total	F-Value†	Probability F Exceeded
Respondents (Smokers Excluded)	3.333 ± 0.567 (207)	3.555 ± 0.458 (195)	3.647 ± 0.459 (22)	3.453 ± 0.515 (424)	11.25	$p << 0.001$
Nonrespondents	3.333 ± 0.563 (273)	3.381 ± 0.537 (325)	3.510 ± 0.481 (28)	3.366 ± 0.547 (626)	1.58	$p = 0.21$
Both groups combined	3.333 ± 0.565 (480)	3.447 ± 0.516 (520)	3.570 ± 0.472 (50)	3.401 ± 0.537 (1,050)	8.24	$p << 0.001$

* Birth weights of less than 1 kg were omitted to normalize the birth weight distribution. Birth weight is in kg. Standard deviations follow the means. Group size is in parentheses.

† F-values are computed from Model I ANOVA and are included to show the difference in the means since the intermediate pollution group was not exposed to average pollution levels halfway between the two groups.

TABLE 3

SIGNIFICANCE OF LINEAR CONTRASTS FOR DIFFERENCES IN MEAN BIRTH WEIGHT AMONG THREE POLLUTION LEVEL AREAS OF THE LOS ANGELES BASIN*

Respondents	Heavy Pollution Contrasted to Intermediate	Intermediate Pollution Contrasted to Light	Heavy Pollution Contrasted to Light
Respondents (Smokers excluded)	−4.38 ($p << 0.001$)	−0.53 ($p = 0.59$)	−2.52 ($p < 0.01$)
Nonrespondents	−1.06 ($p = 0.29$)	−1.19 ($p = 0.23$)	−1.63 ($p = 0.10$)
Both groups Combined	−3.36 ($p << 0.001$)	−1.42 ($p = 0.16$)	−2.86 ($p < 0.004$)

* Each cell contains the t-value and the probability that the t-value is exceeded for the particular contrast.

tively more internal, e.g
ables such as age, pari
variables internal to the
tation length, sex, birth

EXTERNAL VAR

Several modes of int
pollution constituents o
and birth weight were
cause of the complex ch
poral nature of pollutants
ses included that one, sev
pollutants affect birth w
or more trimesters, or
limited to particular sea
irrespective of the partic
the fetus.

Data from the nonsmo
were tested by stepwise r
relationship between eac
ants, CO, NO_2, and O_3,
of the infants (Dixon an
Dunn and Clark, 1974).
month average pollution
ployed, only CO had a
nificant negative regres
which accounted for 1 pe
variance of birth weight.
were analyzed using the a
trimester, all three pollu
nificant negative regre
and, summed, they acco
cent of the variance.

All three pollutants we
effect of seasonal variatio
trations. Regression anal
veal any relationship b
fluctuations in pollution
and birth weight. Also, w
infants were divided into
season of birth, mean birt
groups did not vary, valid
seasonal effect on birth w

INTERMEDIATE VARIABLES
VARIABLES

The three pollutants
and the total averaged ove

on areas, a difference that is significant. For infants of ·espondents pooled with non-

EE POLLUTION
ASIN*

Total	F-Value	Probability F Exceeded
453 ± 0.515 (424)	11.25	$p << 0.001$
366 ± 0.547 (626)	1.58	$p = 0.21$
401 ± 0.537 (1,050)	8.24	$p << 0.001$

h weight is in kg. Standard deviations follow the means since the intermediate pollution group was

there is a 237 gram differ- is significant. The difference f nonrespondents alone is 177

se statistical findings, it was determine whether the ob- ences and trend were due to n pollution level or to some The factors to be determined itually divided into: (1) vari- al to the infant, e.g., the pol-

IEAN BIRTH WEIGHT AMONG
NGELES BASIN*

ermediate 'ollution ontrasted o Light	Heavy Pollution Contrasted to Light
−0.53 (= 0.59)	−2.52 ($p < 0.01$)
−1.19 (= 0.23)	−1.63 ($p = 0.10$)
−1.42 (= 0.16)	−2.86 ($p < 0.004$)

articular contrast.

ituents and concentrations; (2) : variables which are rela-

tively more internal, e.g., maternal variables such as age, parity, etc.; and (3) variables internal to the infant, e.g., gestation length, sex, birth weight.

EXTERNAL VARIABLES

Several modes of interaction between pollution constituents or concentrations and birth weight were hypothesized because of the complex chemical and temporal nature of pollutants. These hypotheses included that one, several, or all of the pollutants affect birth weight during one or more trimesters, or the effects were limited to particular seasons of the year irrespective of the particular trimester of the fetus.

Data from the nonsmoking respondents were tested by stepwise regression for the relationship between each of the pollutants, CO, NO_2, and O_3, and birth weight of the infants (Dixon and Massey, 1969; Dunn and Clark, 1974). When the nine-month average pollution levels were employed, only CO had a statistically significant negative regression coefficient, which accounted for 1 per cent of the total variance of birth weight. When the data were analyzed using the averages for each trimester, all three pollutants had a significant negative regression coefficient and, summed, they accounted for 3 per cent of the variance.

All three pollutants were tested for the effect of seasonal variation in their concentrations. Regression analysis failed to reveal any relationship between seasonal fluctuations in pollution concentrations and birth weight. Also, when respondents' infants were divided into four groups by season of birth, mean birth weights among groups did not vary, validating the lack of seasonal effect on birth weight.

INTERMEDIATE VARIABLES AND INTERNAL VARIABLES

The three pollutants were combined and the total averaged over twelve months for each monitoring station so that a measure expressing relative differences in levels of total pollution among monitoring zones could be specified. This pollution level variable is included with the analysis of the intermediate and internal variables. The average for the monitoring station with the highest annual level in this sample, Station 83, was set to Level 10, and each lesser station assigned the relative proportion compared to 83, times 10, so that the range was index values from 1 to 10. The women residing in areas on the periphery of Los Angeles were classified as having exposure to negligible amounts of pollution and served as the control group. These annual averages, referred to as total pollution level, plus the relative pollution concentration of the stations are listed in Table 4.

TABLE 4

ANNUAL AVERAGE OF COMBINED POLLUTION CONCENTRATIONS FOR EACH MONITORING STATION, APRIL 1972—MARCH 1973, MEAN OF DAILY AVERAGE READINGS, CO, NO_2, AND O_3

Station	Average	Index*
83	4.81	10.00
69	4.80	9.98
1	4.66	9.69
74	4.00	8.32
71	3.96	8.23
76	3.93	8.17
None	...	1.00

* Index = Station average / 4.81 × 10.

Of the 121 intermediate and internal variables recorded for each gravida and her infant, only nine were found to be significantly associated with birth weight of the infant. These variables, along with total pollution level, are listed in the matrix of simple correlations shown in Table 5. The nine variables are defined as follows:

1. *Socioeconomic status (SES)* is the patient status of the gravida. Patients were divided into five groups: clinic nonregistered, clinic registered, county registered, private part-time; and private full-time patients. Socio-

economic status was regrouped into three groups: (1) clinic nonregistered, (2) clinic and county registered, and (3) part- and full-time private. Eighty per cent of the study population were registered clinic and county patients.

2. *Maternal age* is years completed at the time of birth of the infant.
3. *Parity* is defined as the number of pregnancies a woman has had, excluding her current pregnancy.
4. *Antenatal care* is the total amount of antenatal care a gravida received, measured in weeks.
5. *Prepregnant weight* is the weight before becoming pregnant.
6. *Weight gain* is the difference between the weight at the time of delivery and the prepregnant weight.
7. *Sex* is sex of the infant.
8. *Gestation length* is measured in weeks.
9. *Smoking* is the number of cigarettes smoked per day. Patients were divided into five groups ranging from zero cigarettes per day to more than one pack a day.

It is evident from Table 5 that all of the above variables except socioeconomic status are significantly correlated with birth weight. In addition, socioeconomic status and sex of the infant are significantly correlated with pollution level as well as with birth weight. Therefore, regression analysis was undertaken to determine the extent of the independent effects on birth weight of the nine variables listed above and the extent of the interaction among the variables. The computations reveal that socioeconomic status, maternal age, and antenatal care are not significantly associated with birth weight, the positive effect of parity is still significant after controlling for maternal age, and the interaction effects between sex of infant and pollution level and between socioeconomic status and pollution level are nonsignificant for respondents (Table 6).

A multilinear regression model including only variables significantly associated with birth weight was fitted on the data for respondents.

After controlling for the significant ef-

TABLE 5

SIMPLE CORRELATION MATRIX OF SELECTED VARIABLES FOR RESPONDENTS

Variable Name	SES	Maternal Age	Parity	Antenatal Care	Pre-pregnant Weight	Weight Gain	Sex	Gestation Length	Birth Weight	Total Pollution Level	Birth Weight
Socioeconomic status	...	...	...	...	...	...	...	...	...	...	...
Maternal age	0.15*	...	...	...	...	...	...	...	...	...	...
Parity	−0.01	0.55*	...	...	...	...	...	...	...	...	...
Antenatal care	0.25*	0.01	−0.07	...	...	...	...	...	...	...	...
Prepregnant weight	−0.07	0.15*	0.19*	0.01	...	...	...	...	...	...	...
Weight gain	−0.04	−0.12*	−0.20*	0.14*	−0.05	...	...	...	...	...	...
Sex	−0.03	0.07	0.04	−0.03	−0.08	−0.02	...	...	...	...	...
Gestation length	0.00	−0.03	−0.06	0.19*	0.13*	0.14*	−0.08	...	...	...	...
Smoking quantity	−0.03	−0.09†	0.02	−0.04	0.00	−0.04	−0.05	−0.01	...	...	...
Total pollution level	−0.13*	−0.06	0.05	−0.06	−0.03	−0.05	0.15*	0.00	−0.05	...	...
Birth weight	−0.03	0.10†	0.11†	0.13*	0.33*	0.19*	−0.16*	0.46*	−0.10†	−0.12*	...

* $p < 0.01$
† $p < 0.05$

TABLE 6

RESPONDENTS: STEPWISE MULTIPLE REGRESSION SUMMARY TABLE*

Variable Name	Multiple R	Multiple R^2	F-Value	Mean	Standard Deviation
Gestation length	0.461	0.213	131.188	6.351†	0.134
Prepregnant weight	0.535	0.286	49.961	11.217†	0.989
Weight gain	0.555	0.308	15.571	5.143†	1.167
Parity	0.567	0.321	9.383	1.570	1.959
Total pollution level	0.577	0.333	8.324	8.525	2.009
Sex	0.590	0.348	11.390	1.461	0.499
Smoking quantity	0.599	0.359	7.919	0.426	0.943
Socioeconomic status	0.600	0.360	0.937	2.119	0.377
Antenatal care	0.601	0.361	0.720	3.869†	1.296
Maternal age	0.602	0.362	0.556	25.306	5.279
Socioeconomic status × pollution level	0.602	0.363	0.764	17.954	5.036
Sex × pollution level	0.602	0.363	0.001	12.307	5.185

* Multiple R = 0.602; multiple R^2 = 0.363; constant = −6.957.
† These variables were transformed to the square root of their values in order to normalize the distributions before computing the regression.

fects of parity, prepregnant weight, weight gain, smoking quantity of the gravida, and sex and gestation length of the infant, the effect of pollution level is still significant (standardized regression coefficient = 0.134, $p < 0.01$; see Table 7).

TABLE 7

RESPONDENTS: MULTILINEAR REGRESSION SUMMARY TABLE*

Variable Name	Regression Coefficient	Standard Error	Standardized Regression Coefficient	t-Value
Parity	0.035	0.010	0.135	3.541†
Prepregnant weight	0.125	0.019	0.244	6.449†
Weight gain	0.070	0.016	0.162	4.288†
Sex	−0.136	0.038	−0.133	−3.571†
Gestation length	1.519	0.141	0.402	10.741†
Smoking quantity	−0.056	0.020	−0.103	−2.814‡
Total pollution level	−0.034	0.009	−0.134	−3.600†

* Multiple R = 0.599; multiple R^2 = 0.359; constant = −7.513.
† Two-tailed t-value exceeded, $p < 0.001$.
‡ Two-tailed t-value exceeded, $p < 0.005$.

in a study such as this. First, a major problem is the possibility of overlooking variables that may be contributing to the observed effect. A second problem related to the first is that this is a retrospective pilot study to ascertain whether there is an effect, so the selected sample is small and is further reduced because relatively few women responded to the questionnaire. And, third, although the birth records from UCLA were randomly selected, perhaps women who deliver at UCLA are not a random sample of all those who deliver in Los Angeles. A discussion of these three problem areas follows:

DISCUSSION

The results reported above show that there is a reduction in birth weight due to the total level of pollution to which the gravida is exposed and that this reduction is independent of the effects of other variables tested.

Final interpretation of this result must include a consideration of three difficulties

UNMEASURED VARIABLES

It seems evident that only the measured variables in this population are making major contributions to the observed effect. Ethnicity, socioeconomic status, and level of antenatal care are the three most important variables related to residence and therefore to exposure to pollution.

The ethnic composition of this population was 39 per cent white, 51 per cent Spanish American, and about 4.5 per cent, each, Oriental and Black gravidae. Birth weight is not significantly different among ethnic groups, and whites and Spanish Americans reside in all the monitoring zones. Neither of these two factors accounts for the mean difference (Williams, 1975).

Socioeconomic status is measured by the patient class, available from hospital records. While this may be an inadequate measure of socioeconomic status, the impact is minimized because 80 per cent of the sample are clinic patients. They come from all monitoring station areas, and therefore socioeconomic status is relatively homogeneous and in effect controls for socioeconomic status across station areas. This distribution in the sample meant, however, that we could not adequately assess a possible interrelation between socioeconomic status and pollution level.

The level of antenatal care significantly differentiates birth weight in this sample, but it does not correlate with residence and so it is not contributing to the differences in birth weight among areas of residence.

SMALL SAMPLE

The sample size is limited because so few women responded to the smoking survey. However, combining respondents with nonrespondents increases sample size and does not alter the findings.

RANDOM SAMPLE

The effect in terms of a woman's choice of hospital must be considered, since UCLA is one of the major teaching hospitals in the area and attracts women at risk in terms of low birth weight offspring or other health problems. One might expect women from areas farther from UCLA to deliver infants of lower birth weight. However, the study population is a healthy one by recognized medical criteria (Williams, 1975). The sample does indeed seem to be random on several levels.

Given the limitations on sample size and design of the investigation, the observed effect is most certainly due to differences in total pollution levels among the monitoring zones of the Los Angeles Basin. The difference of 314 grams between heavy and light pollution areas is equivalent to the effect of one pack of cigarettes a day in a smoking gravida and indicates that air pollution may be of significance in the retardation of fetal growth.

IMPLICATIONS

The birth weight is predictive of that infant's probability of survival; lower birth weights are associated with higher infant mortality rates. Any factor that contributes to a reduction in birth weight is of concern because of the predictable relationship of birth weight to mortality. Specifically, the reported infant mortality rates increase from 6.86/1,000 for the 3.501–4.000 kg birth weight class to 8.85/1,000 for the lighter 3.000–3.500 kg class, for U.S. whites (Armstrong, 1972). Assuming a linear relationship between birth weight and mortality, the 500 gram difference between these two classes leads to a 29 per cent increase in mortality. The 314 gram reduction in birth weight attributed to pollution is about three-fifths as great and

predictably could lead to a 17 pe
increase in infant mortality.

This estimate of increased mort
conservative since the data are fo
whites who tend to be of higher so
nomic status and to live in less p
areas of the cities than nonwhites.
rement of 314 grams in the nc
groups could be associated with a
greater loss of life if there is an add
synergistic effect of lower socioec
class and pollution. In addition, th
toring zones included in this study
the most polluted zones in the Los
Basin, and there may be even m
reduction in weight associate
heavier pollution levels.

Until now, the health effects k
be associated with pollution are i
in respiratory illnesses and in ad
tality rates. Since adult mortalit
after childbearing age, there is pre
no selection pressure from p

AIR POLLUTION CONTROL DISTRICT, C
LOS ANGELES. 1972. 1972 Annual
meteorology, air pollution effects, and
ant maxima of Los Angeles County. Co
Angeles APCD, Los Angeles, Calif.
ARMSTRONG, R. J. 1972. A study of infan
from linked records, by birth weight,
gestation, and other variables. U. S. D
of Health, Education, and Welfare,
Health Statistics, Series 20, No. 12. G
Printing Office, Washington, D.C.
DIXON, W. J., and F. J. MASSEY, JR. 1
duction to statistical analysis. 3rd ed.
Hill, New York.
DUNN, O. J., and V. A. CLARK. 197
statistics: Analysis of variance and
John Wiley and Sons, New York.
HUETER, F. G., G. L. CONTNER, K. A. B
R. G. HINNERS. 1966. Biological eff
mospheres contaminated by auto exh
Environ. Hlth. 12:553–560.
KARN, M. N., and L. S. PENROSE. 1
weight and gestation time in relation t
age, parity, and infant survival. Ar
16:147–164.
KITAGAWA, E. M., and P. M. HAUSER.
ferential mortality in the United States
socioeconomic epidemiology. Harv
Press, Cambridge, Mass.
LAVE, L. B., and E. P. SESKIN. 1970. A
and human health. Science 169(3947
LEWIS, T. R., F. G. HUETER, and K.

RANDOM SAMPLE

in terms of a woman's choice must be considered, since ɘ of the major teaching hospi- ea and attracts women at risk low birth weight offspring or problems. One might expect ı areas farther from UCLA to nts of lower birth weight. :he study population is a by recognized medical criteria 975). The sample does indeed ·andom on several levels.

limitations on sample size and e investigation, the observed ıt certainly due to differences ıtion levels among the moni- of the Los Angeles Basin. The f 314 grams between heavy llution areas is equivalent to one pack of cigarettes a day in :ravida and indicates that air ıy be of significance in the re- fetal growth.

IMPLICATIONS

weight is predictive of that ·bability of survival; lower :s are associated with higher lity rates. Any factor that con- reduction in birth weight is of ause of the predictable rela- irth weight to mortality. Spe- reported infant mortality rates :n 6.86/1,000 for the 3.501– th weight class to 8.85/1,000 :er 3.000–3.500 kg class, for (Armstrong, 1972). Assuming tionship between birth weight y, the 500 gram difference be- two classes leads to a 29 per : in mortality. The 314 gram birth weight attributed to pol- out three-fifths as great and

predictably could lead to a 17 per cent increase in infant mortality.

This estimate of increased mortality is conservative since the data are for U.S. whites who tend to be of higher socioeconomic status and to live in less polluted areas of the cities than nonwhites. A decrement of 314 grams in the nonwhite groups could be associated with an even greater loss of life if there is an additive or synergistic effect of lower socioeconomic class and pollution. In addition, the monitoring zones included in this study are not the most polluted zones in the Los Angeles Basin, and there may be even more of a reduction in weight associated with heavier pollution levels.

Until now, the health effects known to be associated with pollution are increases in respiratory illnesses and in adult mortality rates. Since adult mortality comes after childbearing age, there is presumably no selection pressure from pollution. However, if pollution is causing a reduction in birth weight, then there is evidence of pollution as an agent of selection; and certain subpopulations living in the less desirable parts of urban centers may suffer relatively more intensive selection due to the effects of pollution.

ACKNOWLEDGMENTS

This research was supported in part by: University of California at Los Angeles, PHS Grants Nos. MCH-927, HD-04612, HD-00345, HD-05615, University of California Academic Senate, and a National Science Foundation Traineeship. Computing assistance was obtained from the Health Science Computing Facility, UCLA, supported by NIH Special Resources Grant RR-3.

The authors thank J. C. Moore, Obstetrics, UCLA, for his assistance in obtaining the data and W. J. Dixon, C. S. Foote, D. Guthrie, M. A. Hill, and G. Rodriguez for their comments.

An earlier version of this paper was presented at the 45th Annual Meeting of the American Association of Physical Anthropologists, 1976.

REFERENCES

AIR POLLUTION CONTROL DISTRICT, COUNTY OF LOS ANGELES. 1972. 1972 Annual report of meteorology, air pollution effects, and contaminant maxima of Los Angeles County. County of Los Angeles APCD, Los Angeles, Calif.

ARMSTRONG, R. J. 1972. A study of infant mortality from linked records, by birth weight, period of gestation, and other variables. U. S. Department of Health, Education, and Welfare, Vital and Health Statistics, Series 20, No. 12. Government Printing Office, Washington, D.C.

DIXON, W. J., and F. J. MASSEY, JR. 1969. Introduction to statistical analysis. 3rd ed. McGRAW-Hill, New York.

DUNN, O. J., and V. A. CLARK. 1974. Applied statistics: Analysis of variance and regression. John Wiley and Sons, New York.

HUETER, F. G., G. L. CONTNER, K. A. BUSCH, and R. G. HINNERS. 1966. Biological effects of atmospheres contaminated by auto exhaust. Arch. Environ. Hlth. **12**:553–560.

KARN, M. N., and L. S. PENROSE. 1951. Birth weight and gestation time in relation to maternal age, parity, and infant survival. Ann. Eugen. **16**:147–164.

KITAGAWA, E. M., and P. M. HAUSER. 1973. Differential mortality in the United States: A study in socioeconomic epidemiology. Harvard Univ. Press, Cambridge, Mass.

LAVE, L. B., and E. P. SESKIN. 1970. Air pollution and human health. Science **169**(3947):723–733.

LEWIS, T. R., F. G. HUETER, and K. A. BUSCH. 1967. Irradiated automobile exhaust; Its effects on the reproduction of mice. Arch. Environ. Hlth. **15**:26–35.

LONGO, L. D. 1976. Carbon monoxide: Effects on oxygenation of the fetus in utero. Science **194**:523–525.

RUSH, D., and E. H. KASS. 1972. Maternal smoking: A reassessment of the association with perinatal mortality. Amer. J. Epidemiol. **96**:183–196.

STEWART, R. D., E. D. BARETTA, L. R. PLATTE, E. B. STEWART, J. G. KALBFLEISCH, B. V. YSERLOO, and A. A. RIMM. 1973. Carboxyhemoglobin concentrations in blood from donors in Chicago, Milwaukee, New York and Los Angeles. Science **182**:1362–1364.

UNGER, J. 1957. Weight at birth and its effects on survival of the newborn; U.S. by geographic divisions and by urban and rural areas, early 1950. Vital Statistics–Special Reports **45**(10):153–218.

WILLIAMS, L. A. 1975. The effect of air pollution on human birth weight. Ph.D. thesis, Department of Anthropology, University of California at Los Angeles.

YERUSHALMY, J. 1970. Relation of birth weight, gestational age, and the rate of intrauterine growth to perinatal mortality. Clin. Obstet. Gynecol. **13**:107–129.

YOUNOSZAI, M. K., A. KACIC, and J. C. HAWORTH. 1968. Cigarette smoking during pregnancy: The effect upon the hematocrit and acid-base balance of the newborn infant. Can. Med. Assoc. J. **99**:197–200.