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Frontier Analysis in Air Pollution
Abstract
Compounds that undergo chemical reactions in the atmosphere and result in particulate organic and inorganic compounds. They also act as secondary source for organic carbon as they emit gases and particles of atmospheric conditions. All other particles are primary emissions source for black carbon. The latter two vapors in the atmosphere and background or biogenic contributions. The former two, secondary contributions that come from gas-to-particle conversion of gases and vapors, secondary contributions that are formed by high temperature processes. Organic carbon, however, results from primary source. Black carbon is attributed to primary emissions (primarily combustion sources) as it is molecular identity, and secondary when the molecular identity is lost from the source to the compound or particles. Some contributions of particles are defined as primary when compounds retain their molecular identity, and secondary when the molecular identity is lost from the source to the compound or particles.
between the amount of organic and black carbon emitted by motor vehicles. The measurements
particles in the tunnel, the measurements inside the tunnel can be used to develop a relationship
samples were collected outside the tunnel. Since motor vehicles is the only source emitting
district of San Francisco Bay Area. Thirteen samples were taken inside the tunnel and hence
The freeway serves as a major commuter route linking the San Francisco Bay Area to the business
The Caldecott Tunnel is located east of Berkeley, California on Highway 24.

**RELATIONSHIP BETWEEN ORGANIC CARBON AND BLACK CARBON**

The primary contribution of motor vehicles to organic carbon at the two sites
then applied at the two sites in order to estimate the amount of background organic carbon and
the tunnel data and those on the samples collected at Durene and Lomax. Further analyses is
Black and Organic carbon emitted by motor vehicles. Different regression models are used on
Regressions analyses is used on the samples collected at the Caldecott Tunnel to relate

emission profiles.
also collected at the Caldecott Tunnel, Berkeley, CA. In 1995 and used to develop motor vehicle
procedures. Organic and inorganic particles and carbon monoxide (CO) concentrations were
Global Geochemistry Corp. (GGC) following standard quality control / quality assurance
Lomax were selected for analysis. All particulate data at Durene and Lomax were collected at
Airport. One set of 35 samples collected at Durene and one set of 20 samples collected at
near the Pacific Coast located near to a major freeway near the Los Angeles International
located about 35 km inland to the east of downtown Los Angeles, and in Lomax, a sampling site
almost the particles were randomly collected in 1995 at Durene, CA, a suburban residential site
a pollution source (motor vehicles) in this case, in the same year, were necessary. Samples of
For the analyses presented in this paper, carbon concentrations collected at different sites
This method of comparing the regression model results with the 
background data of OC and BC taken outside the tunnel, 
also shows background data of OC and BC taken outside the tunnel. 
The regression model having an $R^2$ of 94.6%, which is also a good 
equation in the tunnel data of OC and BC, gives 
the first term corresponds to background or biogenic organic carbon. 
APPLYING THIS REGRESSION 
relation is expressed as:

\[ [O] = [BC] + [OC] \]

The derivation of the model is found in Appendix A. In terms of a regression model, this 
carbon source contributes to the concentration of particulate organics in the atmosphere.

Another model was tested assuming the gas-to-particle conversion on the black above 3.13%.

This is an over-prediction since ambient data suggest an ambient concentration at 
and is equal to 94.6%. The expression in (1) suggests that the background OC in the tunnel is 
the relatively small sample size the adjusted (shrunken) $R^2$-squared, $R^2_{adj}$ was also calculated

As shown in Figure 1, the model explains the data very well and the resulting $R^2$ is 94.55%. 

\[ [O] = 13.17 + 0.96[BC] \]

points in the tunnel, the following regression model was obtained:

at the source thus a linear regression model would represent this relationship. From the literature
only. Traditionally, it was believed that the ozone to black carbon ratio (OC/BC) is constant.

BC concentration was the independent variable since it can be attributed to primary sources
(OC) to black carbon (BC). The OC concentration was set as the dependent variable with the 
regression analysis was used to analyze the data in the tunnel and relate organic carbon

taken outside the tunnel represent the background carbon found in the area.
A high percentage of the OC found at the site, which is contrary to what is expected. The surface model had most of the sample points below the line and suggested that motor vehicles contribute a similar amount was performed for the Dunvegan data. Dunvegan is a residential area and the

\( \text{OC} = 3.11 \text{[BC]}_{3.3} \)

was run through the combined data (Tunnel and Lenaux). The following model was obtained. When a regression model predicts the ambient data much better than the linear model, it is clear from this figure that the surface reaction

Tunnel data and a logarithmic scale for BC. Figure 2 shows the two regression models with the Lenaux and considerations as source emissions. Figure 2 shows the two regression models with the Lenaux and highway, almost all of his carbon is emitted from motor vehicles and the measurements can be compared. Both models were tested on the Lenaux data. Since this site is next to a major concentrations in the Dunvegan are very high (up to 100 \( \text{[NO]}_{3} \)) while ambient

significant.

OC attributed to 23 dependence on BC mass, and the linear term was not satisfactory

were included in the regression model, and most of the data variance was explained by the reaction of convert into OC particles by combustion on BC particles (r=2.73 term). When both terms emissions of OC (as would be represented by a linear term) as well as emission of gas that BC controls the formation of OC. A key question is whether there are direct particulate predict the background measurements taken outside the tunnel. The latter model suggests that both regression models fit the ambient data well. Though the surface reaction model can

model nicely explains these data.
A deterministic parameter approach was applied in this study, and a model approach similar to the methods for estimating pollution functions: deterministic parameter and nonparametric and stochastic parameter and nonparametric. Parameter and nonparametric refer to whether a stochastic parameter and nonparametric relationship is preserved or not. A deterministic approach makes no assumptions about the relationship. Since the development of data envelopment analysis, the efficient frontier analysis has been applied to several business problems. Smith describes the four basic groups that cover the methods for estimating pollution functions: deterministic parameter and nonparametric and stochastic parameter and nonparametric.

Separating primary and other source contributions.
When the background amount was subjected, 37.2% of OC was attributed to primary secondary aerosols. Background and many emissions contributed 64% of OC at this site. Concentration because of transport from the coastal area and products of photochemical reaction is higher at the residential site. Since OC is an inland residential site it receives a higher amount of background OC. Next, we can calculate the amount of background OC at the lower front and the new front.

\[
OC = 2.1 + 1.46(\text{BC})_{22}
\]

The next front is the same as the lower front. Figure 4 gives the lower front and the.

\[
[OC] = 1.43(\text{BC})_{22}
\]

The concentration of the front is.

The equation for the lower front gives the primary contribution to organic carbon in terms of black carbon. The

\[
1 \equiv 1
\]

Subject to

\[
I \equiv 1
\]
that contributes to the concentration of particular organics in the atmosphere. The findings
called for. Regression analyses provided insight on the measures of gas-to-particle conversion
applied at two different sites, and the motor vehicle contribution to organic carbon was
developed. A relationship that can attribute organic carbon to motor vehicles. Thus this relationship was
in this study, carbonaceous concentrations taken at the Calculott Tunnel were used to

CONCLUSIONS

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emissions, screen the basin average is over a 20 x 50 mile grid in the South Coast Air Basin
higher than the emission inventory estimate of 37% since the site is dominated by primary
average for 1982-1984 is shown in the Table. Both estimates (tree gas and further analysis) are
53.3% ± 18.7% but not statistically different from it. For comparison the Los Angeles basin
Lancam in 1983 was 45% ± 21% (Table 1). This estimate is lower than the further estimate of
using the internal OC/CO ratio, the motor vehicle contribution to organic carbon at
motor vehicles.

0.75, which is very close to the Calculott Tunnel, further suggesting the use of CO as a tracer for
vehicle emissions. Furthermore, the correlation coefficient between the two variables at Durance is
coefficient between BC and CO is 0.80 indicating that CO can be used as a tracer of motor
the Calculott Tunnel, the concentrations of BC and CO were compared. The correlation
calculated using carbon monoxide (CO) as a tracer for motor vehicles. Using the data collected at
in order to compare the results from the further analysis, similar contributions were
emissions while background was responsible for 26.9%.
pollution control as carbon containing aerosol is the most abundant particulate air pollutant to the ambient carbon concentrations is an important step in environmental management and air
the two sites. The estimation of the biogenic carbon and the contribution of pollution sources
results. Further analysis was also used to calculate background or biogenic organic carbon at
analysis can be used as a method for estimating the organic carbon contribution of different pollution
ratio analysis and emission inventories and found to be similar. This suggests that further
The results obtained from this analysis were compared to contributions obtained from recent
Black Carbon surface and result in Organic Carbon particulate matter. Further analysis was
suggest that motor vehicles emit Black Carbon and Organic Carbon vapors that react on the

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California

received the Best Paper in Environment Award, IFORMS, May 7, 1997, San Diego,
School of Business Administration, Miami University, Summer Research Program. This paper
spedes:
(A.1) \[ \text{OC} = (\text{OC}_{\text{existing}} + (36\gamma^2 / \varepsilon \rho^2) \text{BC}_\theta \text{z}) \]

mass of OC is related to the mass of BC by 1

Keeping in mind that no new BC can be generated in the atmosphere by chemical reactions, the

where $\rho$ is the black carbon density. By substituting (A.2) in (A.3) and integrating

(A.3) \[ \int_{0}^{6} \frac{\delta}{\kappa} \text{BC} \]

where $\kappa$ is the particle diameter. The black carbon mass is given by

(A.2) \[ \frac{\delta}{\kappa} \text{BC} \]

atmospheric conditions. The surface is given by

species ! (\text{gas}^2) on the surface of a black carbon particle, which is nearly constant at

where $\alpha$ is the surface area (cm$^2$) of a black carbon particle and $\Omega$ is the surface reaction of

(A.1) \[ \frac{\delta}{\kappa} = \text{OC} / \Omega \]

d surface as follows

The mass of organic carbon, OC, increases by surface reaction on the black carbon

contributions to the concentration of particulate organics in the atmosphere

Deviations of model assuming ideal gas to particle conversion on the black carbon surface

Appendix A