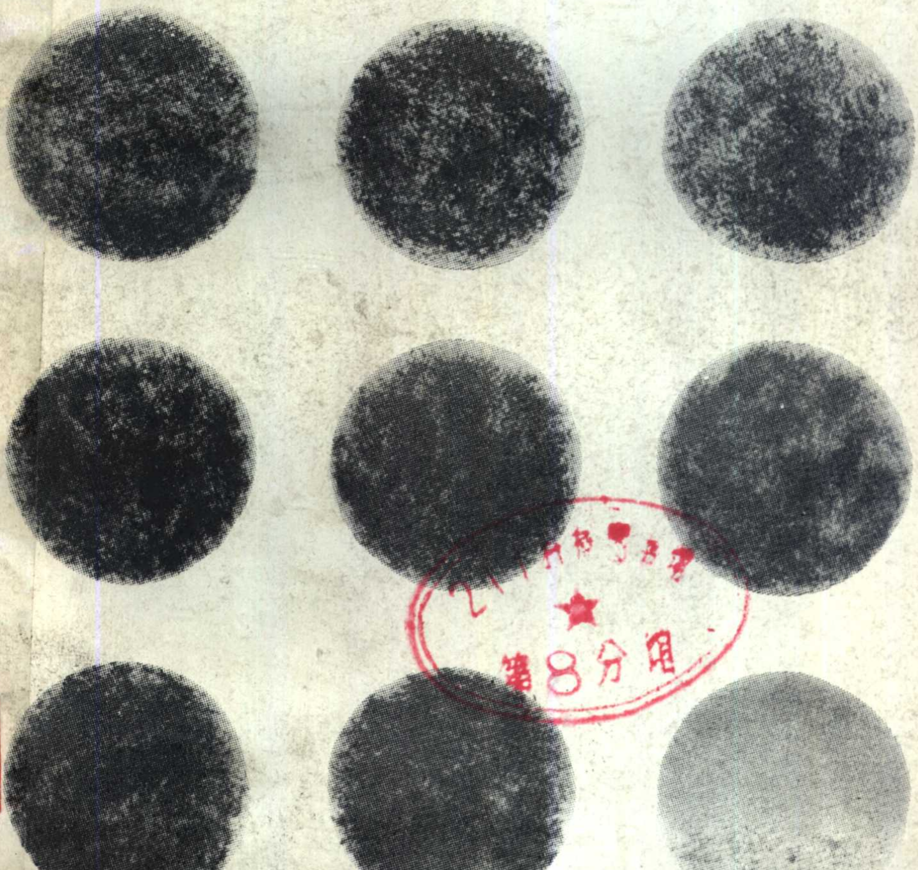
UNDERSTANDING & CONTROLLING AIR POLLUTION



UNDERSTANDING & CONTROLLING AIR POLLUTION

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PREFACE

The use of the word *ecology* has increased rapidly in the past few years--and for good reason. Only a few years ago man found it necessary to exploit the frontier areas so they could become usable farms and cities. The same exploitation must be stopped to regain a proper ecological balance. Every member of the society is affected because all forms of pollution are interrelated. Those of us concerned with solving air pollution problems must not do so by creating water pollution or some other form of pollution. Likewise, other forms of pollution must cease becoming air pollution problems.

Specialists are needed in all aspects of pollution control. *Generalists* who have knowledge of environmental problems are also needed to safeguard against specialist solving of one pollution problem which in turn creates another. Beware of *temporary* improvements that make people believe the problem is solved and needs no further concern, as happened in 1969-70 when air quality in some areas was improved by reductions in massive open burning and control of other extreme emissions. Pollution is *not* under control now, yet it can be and will be, but only as quickly and as efficiently as we want it.

It is important that the specialists and generalists communicate effectively with all segments of the society. A few poets and professional writers (trained in communication) declare that the world is absolutely out of control and it cannot be saved. Scientists (notoriously poor communicators) predict that by the end of this century we can prevent further deterioration and can reverse the process in the direction of melioration. Part of communication is listening, reading, and evaluating to decide which information is correct--the poet's or the scientist's or some combination. If the data being communicated can be checked to ascertain validity before making a decision, the evaluator should assume that responsibility. It is my fervent hope that this volume will assist its user to make these evaluations and thereby aid in solving one aspect of the pollution problem.

Howard E. Hesketh
Carbondale, Illinois

September 1972

ACKNOWLEDGEMENTS

Quite frequently the works of the student are merely extensions of ideas received from an influential teacher. The teacher in reference is Dr. Seymour Calvert, who founded the Center for Air Environment Studies at The Pennsylvania State University and who was one of my teachers. I greatly appreciate the influence of this man.

I also acknowledge the assistance provided by the Southern Illinois University which enabled me to prepare this work. Special thanks go to my students who helped proof read and correct the manuscript.

H.E.H.

TABLE OF MOST COMMONLY USED SYMBOLS

(NOTE: Not all symbols are listed here and some symbols have several meanings; check context as necessary.)

A^o	= Angstroms = 10^{-8} cm or 10^{-4} μ
a	= Acceleration = ft/sec^2 or cm/sec^2
C_D	= Drag coefficient, dimensionless
$C_{(x,y,z)}$	= Concentration downwind from source at position x, y, z, g/m^3
$\mathcal{C}$	= Cunningham correction factor (Eq. 9.7), dimensionless
cfm	= cubic feet per minute
D_{AB}	= Molar diffusivity of a gas A in gas B, lb moles/(ft hr)
D_{PM}	= Diffusivity of particle P through continuous medium M, cm^2/sec
D	= Diameter
d	= Particle diameter, microns
d'	= Particle diameter, not in microns
$\bar{d}$	= Arithmetic mean diameter
d	= Differential operator
d_{50}	= Mean particle diameter which occurs at frequency probability of 50% (Note context to determine whether geometric or arithmetic mean is implied)
E	= Overall collection efficiency, %
E_O	= Collection efficiency for specified size particle; or electrical field strength
exp	= Signifies e (natural log base) to the exponent indicated by the quantity in brackets after exp

esu	= Electrostatic units
g	= Gravitational acceleration, ft/sec^2 or dynes/cm^2
g_c	= Gravitational acceleration constant, 32.174 ft $lb_m/(lb_f\ sec^2)$ or 980.7 dynes/cm^2
H	= Effective plume height (H' + ΔH), meters
H'	= Stack height, meters
ΔH	= Rise of plume above the stack (positive, negative, or zero), meters
h	= Height of uniformly mixed inversion layer, meters
ID	= Inside diameter
K	= Boltzman constant = 1.38×10^{-16} g cm^2/(sec^2 molecule $^\circ$K) or may be (per small particle) or 1.38×10^{-23} joules/$^\circ$K)
$^\circ$K	= Absolute temperature in degrees Kelvin, $^\circ$C+273.16
K'	= Pettyjohn shape factor (Eq. 7.6), dimensionless
K_o	= Dielectric constant of a vacuum, 8.8×10^{-12} coulombs^2/(joule m)
L	= Temperature lapse rate = $-\frac{\partial T}{\partial Z}$
L_a	= Adiabatic lapse rate = -1°C/1000m or -5.4°F/1000 ft
lb_f	= Pound force
lb_m	= Pound mass (see g and g_c)
ℓn	= Natural logarithm
M	= Molecular weight (also can mean 1,000)
$\overline{M}$	= Average molecular weight of phase (see Eq. 11.29)

m	= Meter or mass
N_{Re}	= Reynolds' number* = $\frac{Dv\rho}{\mu}$, dimensionless (see also Re)
N_{Sc}	= Schmidt number* = $\frac{\mu}{\rho\ D_{PM}}$ or $\frac{\mu}{M\ D_{AB}}$, dimensionless
N_c	= Σ no. of calms
N_e	= Σ principal wind direction frequencies
N_o	= Σ secondary wind direction frequencies
n	= Sum of numerical values (frequency); or a number
n_e	= Frequency for any one particular principal wind direction
n_o	= Frequency for any one particular secondary wind direction
P	= Total pressure (See Appendix C)
P°	= Vapor pressure of pure substance at some given temperature
p	= Partial pressure
ppm	= Parts by volume per million parts total volume (for ideal gases: vol ratio = mole ratio = pressure ratio)
ppb	= Parts per billion
psia	= Pounds per square inch absolute = psig + atmospheric pressure in psi
psig	= Pounds per square inch gauge
Q	= Source strength when pollution is released, g/sec; or volumetric flow rate, ft^3/min
R	= Ideal gas law constant (See Appendix C)
°R	= Degree Rankine = °F + 459.49

* ρ and μ refer to the fluid phases

Re	= Drop Reynolds' number = $\frac{d(v_p - v_g)\rho g}{\mu_g}$, dimensionless (see also N_{Re})
τ or r	= Particle radius or reaction rate
SC	= Standard conditions, 60°F and 1 atmosphere unless otherwise noted
STP	= Standard temperature and pressure, 32°F and 1 atmosphere
T	= Absolute temperature, °R or °K
$\bar{u}$	= Mean wind speed, meters/sec
v	= Velocity, ft/sec
v_a	= Velocity of air
v_g	= Velocity of gas
v_p	= Velocity of particle
v_S	= Stokes' terminal settling velocity (Eq. 9.6) cm/sec
X_S	= Stokes' stopping distance (Eq. 9.11), cm
x	= Distance downwind from source, meters; or abscissa of graphs
y	= Distance horizontally from plume centerline, meters; or ordinate of graphs
z	= Height above ground, meters

GREEK LETTERS

α = Any number value

$\bar{\alpha}$ = Arithmetic average or mean of

α' = Deviation from the mean

∂ = Partial differential operator

η = Effective efficiency, fraction

μ = Micron = 10^{-3} mm; or viscosity

μ_a = Viscosity of air = 1.8×10^{-4} g/(cm sec) = 1.8×10^{-4} poise = 1.21×10^{-5} lbm/(sec ft) or = 3.76×10^{-7} lb_f sec/ft^2 at SC

μ_g = Viscosity of gas

π = 3.1416

ρ = Density, lb/ft^3 or g/cm^3

ρ_a = Density of air = 1.2×10^{-3} g/cm^3 = 7.50×10^{-2} lb/ft^3 at SC

ρ_g = Density of gas

Σ = Summation

σ = Standard deviation

σ_y = Horizontal (cross wind) deviation, meters

σ_z = Vertical deviation, meters

T = Surface tension = $(0.04)(641 - °K)^{1.28}$ dyne/cm for water near normal SC

T_{zu} = Downward shear stress momentum in down wind direction acting on the wind in the z plane

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CHAPTER I

AIR POLLUTION AND SOCIETY

Air pollution can be controlled but society must decide to what level and when it should be controlled. In the first half of this book, it is hoped that the reader will gain an understanding about what air pollution is and what it does. For those concerned with how air pollution can be controlled, Part II of this book will be very useful. The purpose of Chapter I is to orient the reader so that he can understand what efforts are being undertaken and perhaps more importantly, it may help point out what is not being done.

1.1 AWARENESS

Odors are the most common source of air pollution complaints. Most of what we call air pollution could be roughly classified as either smoke or odors.

As early as 1300, a royal decree was issued in London prohibiting the use of low-grade coal for heating because it created excessive smoke and soot. The only known case of capital punishment because of an air pollution violation occurred in the 13th Century when a Londoner violated this order. Sulfur in fuels burns to sulfur dioxide. In 1600 sulfur dioxide was the first chemical to be specifically recognized as an air pollutant. However, it was not until about 1940 when air pollution, as such, became important.

It should be noted that the earth, which had been warming up prior to 1940, is now cooling. Artic winter temperatures have in fact dropped an average of 6°F. It is theorized that this is due to the air pollution in the atmosphere, in particular to the more than 10% increase in the carbon dioxide content since 1900. This cooling effect may even be further intensified due to the changing of the reflectivity of the earth which is being altered by jet contrails. A Boeing 707 burns one ton of fuel every ten minutes, releasing 1.3 tons of water vapor and 3.2 tons of CO_2 plus other gases. Most of the CO_2 is released in the jet airstreams and years are required for this material to enter the lower elevation atmospheric circulation system and thereby become incorporated back into the biological carbon cycle. It is not apparent what effects this continuing activity will have on the earth's life. Visible portion of the jet contrails are condensed water droplets that form ice at high altitudes. This produces 30 to 40 days per year of cirrus cloud cover in areas where there are jet airplane lanes.

Automobile exhaust contributes over 60% of the total air pollution that now exists in the atmosphere. In addition to the direct results of the pollution, it is also possible that particles released with the exhaust, such as lead oxide, super-seed the clouds making them unable to release their rain. This could be an explanation for the high number of droughts which have occurred in various portions of the United States.

Authors of technical papers presented at the 1969 Air Pollution Control Association meeting wrote independent responses which uniformly concluded that increased public awareness of the pollution problem is the single biggest factor in helping to foster solutions to excessive pollution (1). Should the reader desire supplementary basic air pollution information he is referred to the "Air Pollution Primer" (2).

1.2 AIR POLLUTION DEFINED

Air pollution is the presence of foreign matter (either gaseous or particulate or combinations of both) in the air which is detrimental to the health and/or welfare of man. This definition enables us to include not only the direct effects of air pollution on man, but the effects of air pollution which damages materials and reduces the esthetic value of antimate and inanimate matter. Remember that health can also be damaged by mental attitude and this attitude is affected by factors such as esthetic and monetary considerations.

Air pollution would not exist if it were not for the chain which consists of source-transport-receptor. If any one of these links were missing, we would not be affected by pollution.