CHAPTER 2.

AIR POLLUTION EFFECTS

AIR POLLUTION EFFECTS

- Any competent engineer begins any engineering task by asking, among other things, “Why are we doing this at all?”
- We control air pollution because it causes harmful effects on ***human health, property, aesthetics, and the global climate.***
- This brief chapter reviews what we know about these effects on human health and property and on visibility.
- We will consider the effects on human health first.

TABLE 2.1

Air pollutants believed dangerous to human health and currently regulated in the United States

Pollutants regulated by National Ambient Air Quality Standards (NAAQS) as described in *40CFR50* (as of July 1, 1998). These are called *criteria pollutants* because before the standards were issued, documents called Air Quality Criteria were issued.

- Sulfur oxides
- Fine particulate matter
- Carbon monoxide
- Ozone
- Nitrogen dioxide
- Lead

Pollutants regulated by National Emission Standards for Hazardous Air Pollutants (NESHAP) as described in *40CFR61* (as of July 1, 1998). These are called *hazardous air pollutants* or *air toxics*.

- Asbestos
- Benzene
- Beryllium
- Coke oven emissions
- Inorganic arsenic
- Mercury
- Radionuclides
- Vinyl chloride

The Clean Air Amendments of 1990 expanded this list to 189 chemicals. The regulations for those in addition to the above 8 are currently in the regulatory pipeline (see Chapter 15).

2.1 EFFECTS ON HUMAN HEALTH

1. “There is poison in everything and no thing is without poison. It is the *dose* that makes it harmful or not.”
2. The same is true of air pollution. To make any meaningful statements about air pollution effects on human health, we must consider the dosages people receive, that is,

$$\text{Dosage} = \int (\text{concentration in air breathed})\, d(\text{time}) \qquad (2.1)$$

3. Current interest in air pollution and health is mostly directed at long-term, low- concentration exposures (which lead to chronic effects).

4. Short-term, high-concentration exposures (which lead to acute effects) occur only in industrial accidents or air pollution emergency episodes; the latter occurred occasionally in the past, but are now very rare in countries with modern pollution control regulations.

Figure 2.1 de Nevers

To determine what dosage is harmful, we wish to construct a dose-response curve **(Figure 2.1).**

Dose-response relationships:

- Threshold type
- No-threshold type

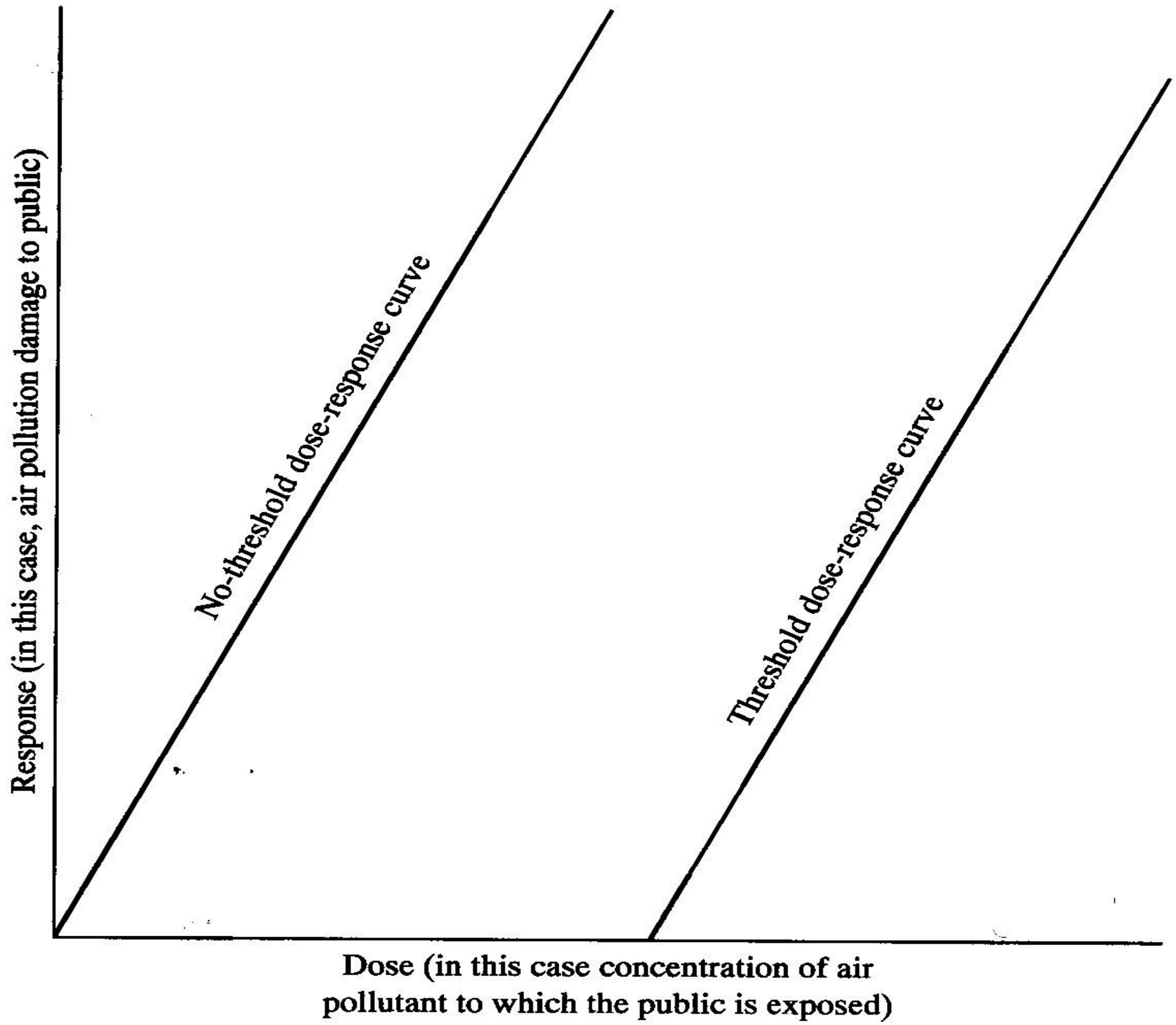


FIGURE 2.1
Threshold and no-threshold dose-response curves. The straight lines are an admission of ignorance; we generally do not know the true shapes of these curves.

2.1 EFFECTS ON HUMAN HEALTH

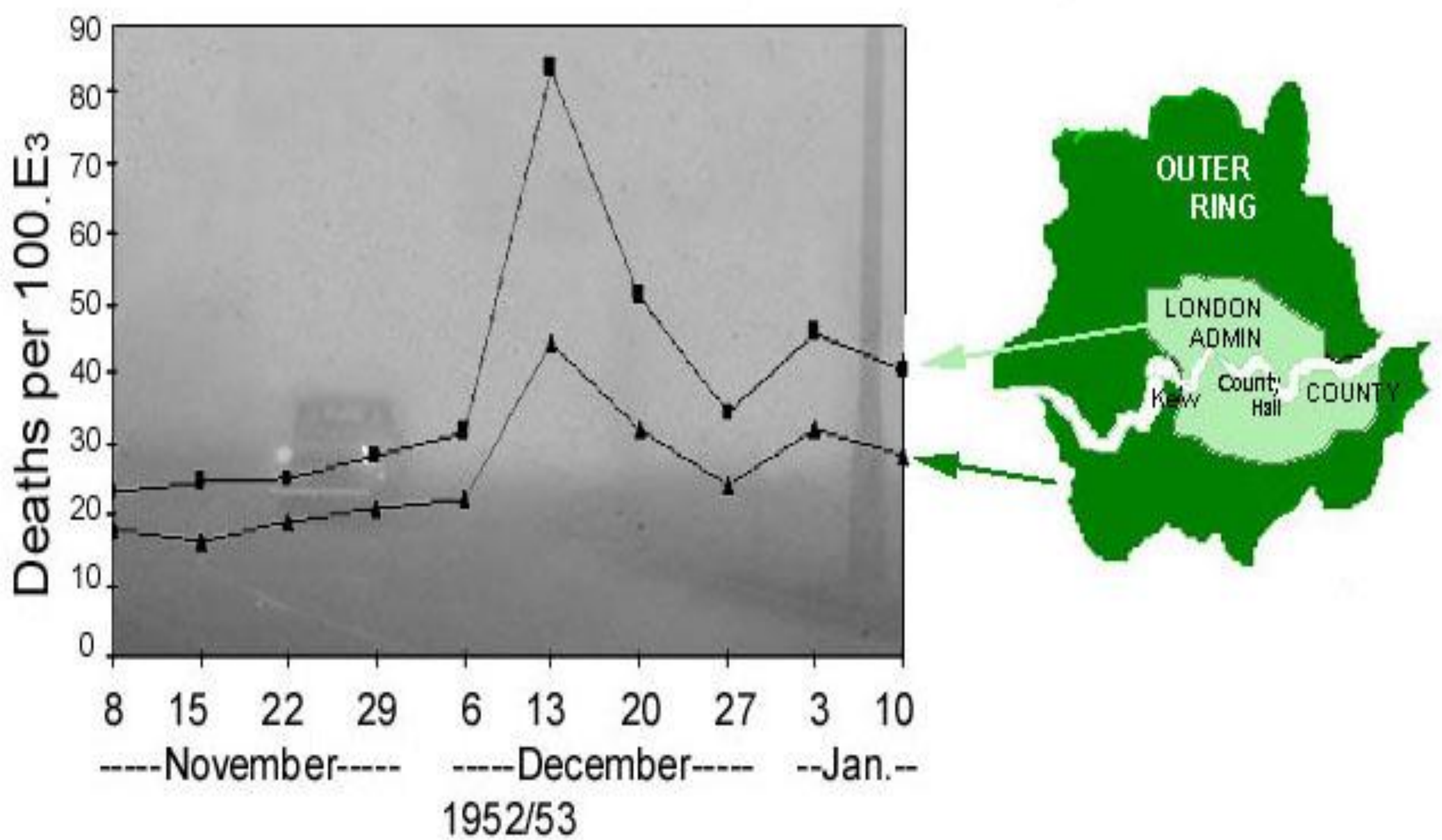
1. **Figure 2.1** is a dose-response curve for a hypothetical homogeneous population exposed to a single hypothetical pollutant for a specific time period.

2. We know most about dose-response curves from pharmacology, where experimental subjects are regularly given carefully measured doses of experimental pharmaceuticals and their responses are measured.

3. Synergism, the effect of two pollutants together being greater than the sum of the separate effects of the two, may occur; that is believed to be the case with sulfur oxides and fine particles, and perhaps some other pollutant combinations as well.

London Smog 1952:
Example on Lethal Synergism between SOx & smoke

Death rates in London Administrative County and the Outer Ring



2.1 EFFECTS ON HUMAN HEALTH

- From theory and experiment, we know that for pharmaceuticals, the most common *dose-response curve* is the no-threshold curve, which passes through the origin.

- However, in industrial hygiene it has been observed that there is so ***threshold value*** that *"represents conditions under which me concentration of pollutants called the it is believed that nearly all workers may be repeatedly exposed day after day, without adverse effect".*

HEALTH EFFECTS ASSESSMENT

- To establish dose-response curve for a pollutant, we have three possible way:
  1. Animal experiments: expose animals to the pollutant of concern under controlled conditions and observe effects; extrapolate results to humans.
  2. Short-term laboratory exposure experiments with humans:
     - Ample published data show that exposure of healthy young adults to air pollutant concentrations much higher than those ever measured in the ambient air produce no measurable, irreversible short-term or long-term effects.
     - Because we are interested in the effects of long-term exposure and also in sensitive members of society (children, asthmatics, and the very old), short-term laboratory tests on healthy young adults will not provide the data we need.
     - Such tests are useful for finding physiological mechanisms of air pollution damage.
  3. Epidemiological studies of human populations: only way we can ultimately settle health-effect questions is through sophisticated epidemiology; observe effects in populations of similar characteristics except for exposure to the pollutant of concern.

TABLE 2.3
Comparison of air quality standards and industrial exposure standards

Substance	Permitted ambient concentrations (NAAQS)[a]	Permitted industrial concentrations (TWA and STEL)[a]
Sulfur dioxide	80 μg/m^3 (0.03 ppm),[b] annual average, 365 μg/m^3 (0.14 ppm), 24-h average.[c]	2 ppm, 8-h average. 5 ppm, 15-min peak.
Ozone	0.08 ppm (157 μg/m^3), 8-h average.	0.1 ppm, 8-h average.
Nitrogen dioxide (NO_2)	0.053 ppm (100 μg/m^3), annual average.	3 ppm, 8-h average. 5 ppm, 15-min peak.
Carbon monoxide	9 ppm (10 mg/m^3), 8-h average. 35 ppm (40 mg/m^3), 1-h average.	25 ppm, 8-h average.
Inhalable particles (PM_{10})[d]	50 μg/m^3, annual average. 150 μg/m^3 24-h average.	Standards exist for specific kinds of particle, but not for PM_{10}.
Fine particles ($PM_{2.5}$)	25 μg/m^3, annual average. 65 μg/m^3, 24-h average.	Standards exist for specific kinds of particle, but not for $PM_{2.5}$.
Lead	1.5 μg/m^3, quarterly average.	50 μg/m^3, 8-h average.
Asbestos	No NAAQS.	A special standard, in number of fibers per cc, exists.
Benzene	No NAAQS.	10 ppm, 8-h average.
Beryllium	No NAAQS.	2 μg/m^3, 8-h average. 10 μg/m^3, 15 min peak.
Coke oven emissions	No NAAQS.	No standard for these as a group, standards for individual components.
Inorganic arsenic	No NAAQS.	10 μg/m^3, 8-h average.
Mercury	No NAAQS.	25 μg/m^3, 8-h average plus a lower standard for alkyl mercury compounds.
Radionuclides	No NAAQS.	No comparable standard.
Vinyl chloride	No NAAQS.	5 ppm, 8-h average.

[a] The NAAQS (National Ambient Air Quality Standards) are current EPA values. The TWA (time-weighted average) and STEL (short-term exposure limit) values are current ACGIH (American Conference of Governmental Industrial Hygienists) values.

2.1.4 REGULATIONS TO PROTECT HUMAN HEALTH

- From Table 2.3, we see that the permitted industrial concentrations are generally much higher than the permitted ambient air concentrations.
- This difference reflects two facts:
  - *we are exposed to ambient air 168 hours a week but are on the job only 40 hours a week; and*
  - *the working population does not contain the most susceptible members of the population (infants, asthmatics, and very old people).*
- In addition, people who are especially susceptible to irritation by a certain pollutant will quit a job where the concentration of that pollutant is insufficient to bother average people; unlike ambient air quality standards, industrial standards are not intended to protect everyone.

2.2 AIR POLLUTION EFFECTS ON PROPERTY

- In the early history of air pollution control, a great deal of attention was paid to air pollution damage to property.
- Today we pay little attention to it. The reason for this change is that 50 years ago, there were pollutants that caused visible damage to plants and animals.
- The owners of these plants and animals sued the emitters for damages and thus contributed to the early development of air pollution science and engineering.
- Today there are few such sources because we have imposed strict controls on them to protect human health.

2.2 AIR POLLUTION EFFECTS ON PROPERTY

- Metals corrode faster in the polluted environments of our cities than they do in cleaner environments.
- Paints do not last as long in polluted environments as in clean ones; tires and other rubber goods fail due to ozone cracking, caused by atmospheric ozone, if they are not made with antioxidant additives (which most now have).
- Many green plants are harmed by air pollutants (**Figure 2.8** is a summary of the effects of nitrogen dioxide on plants).
  - As expected, the damage depends on the concentration and the duration of exposure.
  - Like humans, plants can survive short-term exposures to high concentrations of NO_2 without measurable ill effect;
  - the longer the exposure time, the lower the concentration needed to produce damage.

2.2 AIR POLLUTION EFFECTS ON PROPERTY

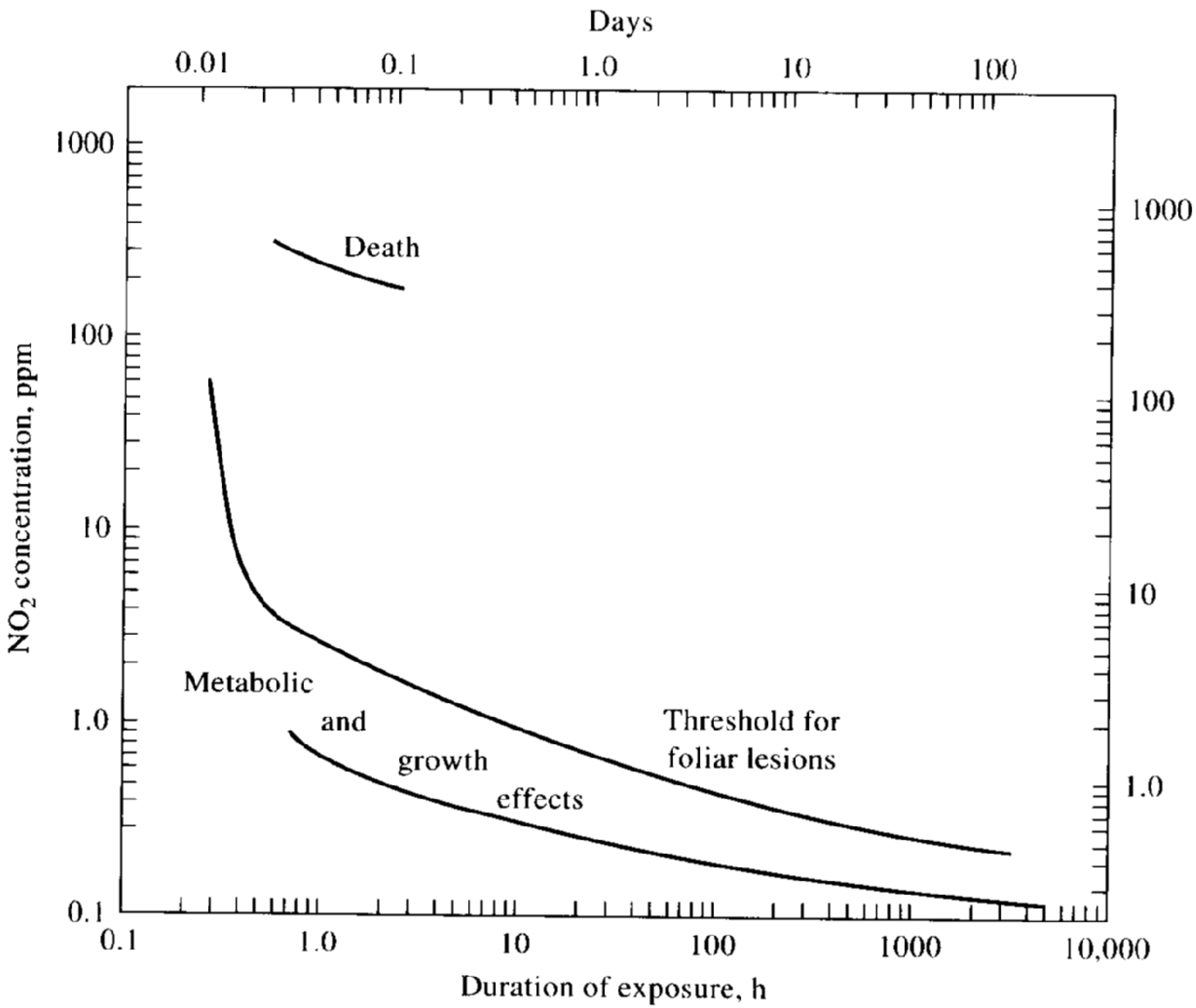


FIGURE 2.8
Threshold curves for the death of plants, foliar lesions, and metabolic or growth effects as related to the nitrogen dioxide concentration and the duration of the exposure [24]. The concentrations shown are much higher than the NAAQS for NO_2, 0.053 ppm annual average. (Reprinted with permission from Springer-Verlag and Professor D. C. MacLean.)

Fig. 2.8 deNev

Effects of Air Pollution on Plants

2.3 AIR POLLUTION EFFECTS ON VISIBILITY

- Most gaseous air pollutants are totally transparent.
- The only common exception is NO_2, which is brown.
- Fluorine, chlorine, bromine, and iodine are also colored, as are some organic vapors, but these are rarely emitted to the atmosphere in significant quantities.
- Some urban smogs appear brown because of the NO_2 they contain.
- Most visible effects of air pollution are caused by the interaction of *light with suspended particles*.