industrial hygienist, either extremely small quantities of materials must be determined or else provision must be made for sampling a large volume of air. The more toxic gases and vapors are of hygienic importance when found to be present in amounts even less than 1 ml. per cubic meter of air (1 p.p.m.), and many dusts and fumes are of interest in amounts of less than 1 mg. per cubic meter of air. Methods of analysis based upon microchemical technique, especially colorimetry, are frequently preferred because they can utilize a very small sample and thus involve less time and difficulties in sampling. Modes of expressing concentrations of atmospheric contaminants are discussed in Chapter VI (page 150).

GASES AND VAPORS

I. Methods Giving Quantitative Results in the Field

A. EVALUATING THE INTENSITY OF ODOR AND IRRITATION

Perhaps the most useful of all methods of detecting and estimating gases and vapors in the air is by their odors and irritant effects. Only a relatively few toxic ones are without either of these characteristics, notable among which is carbon monoxide. Many well-informed persons are inclined to scoff at the idea of considering odor and irritation as qualitative guides, much less quantitative ones, but that is either because they have never cultivated and educated the sense of smell or because for them that sense is physiologically substandard. The particular power of odors to quicken memory of associations has long been recognized. For instance, the odor of acetamide instantly calls up for most people the association of mice because it was first met as a constituent of mouse urine; the odor of nitrobenzene is associated with shoe polish because it once was widely used as an ingredient of shoe polish; and there are many others.

There have been various attempts to describe and classify the odor sensations. Henning,[2] in one of the best, recognizes six classes as follows: spicy, flowery, fruity, resinous (turpentine), foul and scorched. To further divide or add to these classes is a very difficult problem and, even though the memory of an odor may extend over many years, we seem to lack the proper descriptive adjectives. However, regardless of the quality of an odor, Gamble[3] has shown that in conformity with Weber's law the sense reaction to odors is proportional to the logarithm of the stimulus, that is, the intensity of sense reaction increases in arithmetical progression as the stimulus increases in geometrical progression. Katz and Allison[4] devised the odor and irritation scales shown in Tables 1 and 2, which with slight modification have since proved convenient for other investigators.

Odors are best determined by the first and second inhalations, as succeeding

[2] Hans Henning, *Der Geruch*. Leipzig, 1924.
[3] Eleanor A. M. Gamble, *Am. J. Psychol.*, **10**, 82 (1898).
[4] S. H. Katz and V. C. Allison, *U. S. Bur. Mines Tech. Paper* No. **267**, 1920.

TABLE 1

Scale of Odor Intensities

Degree	Intensity	Description
0	No odor	No detectable odor
1	Very faint	Minimum, but positively perceptible odor
2	Faint	Weak odor, readily perceptible
3	Easily noticeable	Moderate intensity
4	Strong	Cogent, forcible odor
5	Very strong	Intense effect, may irritate

TABLE 2

Irritant Scale (Nasal Irritation and Eye Irritation)

Degree	Intensity	Description
0	No irritation	Not detectable
1	Faint	Just perceptible, not painful
2	Moderate	Moderate irritation, midway between 1 and 3
3	Strong	Discomforting, painful, but may be endured
4	Intolerable	Exceedingly painful, cannot be endured voluntarily

inhalations may tend to fatigue the sense of smell. Nasal irritation, throat irritation, and eye irritation, however, frequently increase with time, at least for the first several seconds and sometimes minutes. During the first attempts to evaluate odor and irritation, a subject may have considerable difficulty in making estimations that conform to the pattern of a representative group, but most persons overcome this difficulty rapidly so that with a group of six persons the deviation of individuals from the average is rarely more than one degree on the scale. As has been pointed out, however, some individuals are handicapped by having an impaired sense of smell; likewise, temporary impairment of anyone's sense of smell may result from various causes. Additional published data[5–8] on odor intensities are inadequate, therefore the problem more or less resolves itself into a matter of individual education, and industrial hygienists find it advantageous to note and record the quality and intensity of odors wherever an evaluated atmospheric contaminant is either encountered or prepared.

The graphs reproduced here are portrayals of data collected from experiments in synthetic atmospheres, where 4 to 7 investigators kept independent notes. Each point on the graph is an average of the individual results. Figure 1, prepared from data collected by the United States Bureau of Mines[6] showing the relation between odor intensity and concentrations of allyl mercaptan and ethyl mercaptan,

[5] *International Critical Tables*, Vol. 1 (1926).
[6] S. H. Katz and E. J. Talbot, *U. S. Bur. Mines Tech. Paper* No. **480**, 1930.
[7] A. C. Fieldner, R. R. Sayers, W. P. Yant, S. H. Katz, J. B. Shohan, and R. D. Leitch. *U. S. Bur. Mines Monograph* No. **4**, 1931.
[8] A. C. Fieldner, W. P. Yant, and W. P. Patty, *U. S. Bur. Mines Rept. Invest.* No. **2978**, 1929.