

Observations on the Impact of Flow Rates on Odor Thresholds

Carol A. Dupraz

Consultant

408 Woodland Hills Rd., White Plains, NY 10603

While reviewing "Odor Thresholds for Chemicals with Established Occupational Health Standards"¹ prior to its publication by the American Industrial Hygiene Association (AIHA), it was difficult to avoid noticing a fairly consistent relationship among several accepted sources of odor threshold data—May,² Dravnieks,³ and Hellman.⁴ Invariably, values reported by May (who used more or less static odorant supply conditions) or Dravnieks (who worked at relatively low odorant flow rates) are substantially higher than those given by Hellman (who employed relatively high odorant flow rates). This observation suggests that the differences in reported odor thresholds might be rationalized to some extent by taking into account odorant mass flow rates.

Considering physiological constraints, it seems reasonable to assume that, regardless of the flow rate at which odorant is supplied in odor-threshold determinations, odorant mass flow rate at the chemically activated olfactory receptors would be limited by respiration rate. Further assuming that odor sensing occurs only on inhalation and that respiration rates for the test subjects would be similar to those widely reported in the literature for subjects at rest, an average inhalation flow rate of perhaps 20 lpm would constitute a limiting factor under normal breathing conditions.

Where experimental procedures employ high volume/high flow presentation methods, it seems less likely that "sniffing" would be necessary to detect odor, so a nominal flow rate of 20 lpm would probably represent the maximum rate at which odorant reaches olfactory sensors. Where low volume/low flow presentation methods are employed, the odorant flow rate would be the limiting factor, regardless of inhalation rate.

Another possible source of variability is the length of time taken by a test subject to respond to (i.e., detect or recognize) the odorant at a given

mass-flow rate. However, this factor is not included in the criteria typically employed in designing (or critically reviewing) odor threshold experiments and may already have been shown of little importance elsewhere.

Examination of odor threshold values from sources accepted after critical review of experiments (Code A data presented in the third table of the AIHA publication) reveal a limited number of odorants with values (typically detection odor thresholds) from three or more different sources where dynamic odorant supply conditions were employed. In particular there are seven odor threshold values for hydrogen sulfide from accepted sources with odorant flow rates ranging from 0.15 lpm to 2830 lpm. As indicated below, Williams,⁵ Nishida,⁶ Adams,⁷ and Katz⁸ report working with odorant flow rates below 20 lpm while Young,⁹ Cederlof,¹⁰ and Wilby¹¹ used flow rates substantially higher than 20 lpm. Reported odor thresholds range from 0.0063 to 0.27 mg/m³, a range of approximately two and half orders of magnitude. As shown in Table 1, with the exception of the 1930 Katz data, corresponding mass flow rates fall within one order of magnitude.

Other available sets of accepted odor thresholds, presented in Table 2, indicate that comparisons in terms of mass flow rate tend to reduce the range of values for a given odorant by one or more orders of magnitude. However, there are exceptions. With *n*-butanol, odor threshold concentrations all fall within a single order of magnitude while calculated mass flow rates range over two orders of magnitude. With isoamyl acetate and methyl mercaptan significant discrepancies in odor threshold values, possibly due to adaptation effects, remain in terms of mass flow rates.

Comparative mass flow rates presented in Table 2 suggest that some variability in odor threshold information from sources accepted

during the critical review reported in "Odor Thresholds for Chemicals with Established Occupational Health Standards" may be the result of differences in the flow rate at which the odorant comes in contact with olfactory sensors. Secondly, although critical review of odor threshold experiments did consider adaptation effects and rejected studies that employed a descending presentation series, no evidence is cited to demonstrate that olfactory fatigue does not result from repeated exposures below odor threshold concen-

trations. Finally, the response time (detection or recognition) may be a characteristic uniquely associated with a test subject and an important source of individual-to-individual variability.

A better understanding of the roles of flow rate, olfactory response time and adaptation effects seems necessary to improve the utility of odor threshold information currently available and to justify determining additional odor thresholds in the future.

Table 1. Mass flow rates from hydrogen sulfide odor threshold values.

Source	Present method	Odorant flow rate (lpm)	Odor threshold mg/m ³	Mass flow rate mg/s x 10 ⁻⁶	
				Q _{odorant}	Q _{inhalation}
Williams	Noseport	0.5	0.27	2.3	na
Nishida	Mask	2	0.74	2.5	na
Adams	Hood	2-5	0.0056	0.2-0.5	na
Katz ^a	Funnel	≤8	0.18	24	na
Young	Mask	57	0.0094	na	3.1
Cederlof	Hood	100	0.01	na	3.3
Wilby ^b	10 ft ² port	2830	0.0063	na	2.1

^a High value may be due to undetected olfactory fatigue or lower than reported odorant flow rate.

^b Recognition threshold (All others detection thresholds)

Table 2. Mass flow rates from other odor threshold values.

Odorant	Source	Q _{odorant} (lpm)	Odor Thresh- old, (mg/m ³)	Mass flow rate (mg/s)	
				Q _{odorant}	Q _{inhalation}
Isoamyl acetate	Nishida	2	1100	0.0387	na
	Punter ¹²	5	0.07–0.084	5.8–7 x 10 ⁻⁶	na
	Katz	8	0.018	2.4 x 10 ⁻⁶	na
n-Butanol	Dravnieks	0.15	1.92	1.6 x 10 ⁻⁵	na
	Williams	0.5	1.02	8.5 x 10 ⁻⁶	na
	Punter	5	3.95	3.3 x 10 ⁻⁴	na
	Hellman	20–80	0.9	na	3.0 x 10 ⁻⁴
Toluene	Dravnieks	0.15	60	1.5 x 10 ⁻⁴	na
	Punter	5	25.4	21.2 x 10 ⁻⁴	na
	Nader ¹³	15–20	0.39	na	1.3 x 10 ⁻⁴
	Stalker ¹⁴	15–20	1.00	na	3.3 x 10 ⁻⁴
	Hellman	20–80	0.6	na	2.0 x 10 ⁻⁴
Propanol	Dravnieks	0.15	100	2.5 x 10 ⁻⁴	na
	Punter	5	5.9	4.9 x 10 ⁻⁴	na
	Laing ¹⁵	10	100	16.7 x 10 ⁻³	na
	Hellman	20–80	0.075	na	2.5 x 10 ⁻⁵
Acetone	Dravnieks	0.15	1550	0.0039	na
	Punter	5	8.5	0.00072	na
	Hellman	20–80	48	na	0.016
Methyl mercaptan	Williams	0.5	3 x 10 ⁻⁶	2.5 x 10 ⁻¹¹	na
	Nishida	2	0.038	1.3 x 10 ⁻⁶	na
	Katz	≤8	0.081	1.08 x 10 ⁻³	na
	Wilby	2830	0.002	na	6.7 x 10 ⁻⁷
Styrene	Dravnieks	0.15	8	2.0 x 10 ⁻⁵	na
	Stalker	15–20	0.073	na	2.4 x 10 ⁻⁵
	Hellman	20–80	0.22–0.64	na	7.3–20 x 10 ⁻⁵

References

1. American Industrial Hygiene Association, *Odor Thresholds for Chemicals with Established Occupational Health Standards*. Akron, Ohio: American Industrial Hygiene Association (1989).
2. May, J. Odor "Thresholds of Solvents for Assessment of Solvent Odors in Air," *Staub*. 26: pp. 385–389 (1966).
3. Dravnieks, A., "A Building-Block Model for the Characterization of Odorant Molecules and Their Odor," *Ann. N.Y.Acad. Sci.* 237: pp. 144–163 (1974).
4. Hellman, T.M. and F.H. Small "Characterization of the Odor Properties of 101 Petrochemicals Using Sensory Methods," *J. Air Pollut. Contr. Assoc.* 24: pp. 979–982 (1974).

5. Williams, F.D., J.F. Emele, and M.C. Alford, "The Application of the Dynamic Triangle Olfactometer to the Evaluation of Oral Odor," *Chem. Senses Flavour* 2: pp. 497-502 (1977).
6. Nishida, K., M. Yamakawa, and T. Honda, "Experimental Investigations on the Combined Actions of Components Mixed in Odorous Gas," *Mem. Fac. Eng., Kyoto Univ.* 41, part 4: pp. 552-565 (1979).
7. Adams, D.F., F.A. Young, and R.A. Luhr "Evaluation of an Odor Perception Threshold Test Facility," *Tappi* 51 (3): pp. 62A-67A (1968).
8. Katz, S.H. and E.J. Talbert, *Intensities of Odors and Irritating Effects of Warning Agents for Inflammable and Poisonous Gasses* (U.S. Bureau of Mines, Technical Report no. 480.) Washington, DC, U.S. Dept. of Commerce (1930).
9. Young, F.A. and D.F. Adams, "Comparison of Olfactory Thresholds Obtained on Trained and Untrained Subjects," in *Proc. 74th Annual Conv. Am. Psychol. Assoc.*, pp. 75-76 (1966).
10. Cederlof, R., M.L. Edfors, L. Friberg, and T. Lindvall, "On the Determination of Odor Thresholds in Air Pollution Control: An Experimental Field Study on Flue Gases from Sulfate Cellulose Plants," *J. Air Pollut. Control Assoc.* 16: pp. 92-94 (1966).
11. Wilby, F.V. "Variation in Recognition Odor Threshold of a Panel," *J. Air Pollut. Control Assoc.* 19: pp. 96-100 (1969).
12. Punter, P.H., "Measurement of Human Olfactory Thresholds for Several Groups of Structurally Related Compounds," *Chem Sens.* 7: pp. 215-235 (1983).
13. Nader, J.S., "An Odor Evaluation Apparatus for Field and Laboratory Use," *Am. Ind. Hyg. Assoc. J.* 19: pp. 1-7 (1958).
14. Stalker, W.W., "Defining the Odor Problem in a Community," *Am. Ind. Hyg. Assoc. J.* 24: pp. 600-605 (1963).
15. Laing, D.G., H. Panhuber, and R.I. Baxter, "Olfactory Properties of Amines and n-Butanol," *Chem. Senses Flavor* 3: pp. 149-166 (1978).