SECTION 2

ODOR GENERATION AND CHARACTERISTICS

ODOR GENERATION AND CHARACTERISTICS[1]

ODOR

Odor is defined as a sensation resulting from stimulation of the olfactory organs, whereas "an odor" is the experience of perceiving a smell. The property of a substance that affects or stimulates the sense of smell is called an "odorant" or "osmogene." The chemical and physical structure and characteristics of the molecules of most odorous substances produce the stimuli to the olfactory sensory cells that are responsible for "smell."

Many people are incapable of detecting some specific odors, but are very sensitive to others. Some odor-bearing substances in weak concentrations cause more intense olfactory response than when in strong concentrations. For instance, hydrogen sulfide (H_2S) in low concentrations is easily detectable; but in concentrations greater than 400 ppm, H_2S overcomes the olfactory senses and is thus odorless to humans as well as quite deadly. These and many more characteristics of odor production by plants and animals and the variability of various receptors to the same odors have made odor control a very difficult problem for engineers.

Below are a few facts of interest about odors.

- Individual substances sometimes exhibit different and highly characteristic odors.
- Similar substances sometimes have very different odors.
- Some substances have several possible odors, although this normally depends on the substance concentration.
- Substances of high molecular weight are usually not perceived odorous and are neither volatile nor soluble.
- The sense of smell is rapidly fatigued by some odorants, but not all.
- Two or more odors can cancel each other. Both mixed together can be imperceptible (Zwaardemaker pairs).
- Many products of depolymerization are acutely malodorous (for example, trimethylamine and skatole).
- Nearly all odors can be arrested, worsened, canceled, or neutralized.

Below are some general characteristics of odorous molecules that should be remembered in rendering decisions on odor prevention or control.

- Compounds of different constitutions may have similar odors.
- Compounds of very similar constitutions may have different odors.
- No element that occurs free in nature is odorous under normal conditions.
- Seven of the elements not free in nature are odorous. They are fluorine, chlorine, bromine, iodine, phosphorus, arsenic, and oxygen (as ozone).
- Polymerization reduces or destroys odor whether in elements or in compounds.
- The odor of amines is more ammoniacal when concentrated than when diluted. The fishy odor is stronger in diluted solutions than in concentrated solutions.
- Nitrogen compounds frequently have an "animal" odor. Compounds not containing nitrogen do not ordinarily have an "animal" odor.

[1] "Odor Control for Wastewater Facilities," Water Environment Federation, Manual of Practice No. 22, 1993 Edition.

- An oxygen linkage is frequently associated with a pleasant odor (for example, esters, lactones, and nitrates).
- Many reduced sulfur compounds, particularly where the sulfur is divalent, have offensive odors (for example, mercaptans).
- The general conclusion is that odor is determined by the structural arrangement of the molecule.
- The great difficulty is with the subjective nature of odor classification.

PRINCIPAL ODOR SOURCES

Odor-producing substances found in domestic wastewater and sludge as well as some that originate from the smaller industries associated with urban life, are listed in Table 2.1 (next page) with some of their more important characteristics. Osmogenes detectable by man are usually produced as a result of biological activity. Most of these substances result from the anaerobic decomposition of organic matter containing sulfur or nitrogen. Gas produced from domestic wastewater is sometimes called sewer gas and commonly includes hydrogen sulfide, ammonia, carbon dioxide, and methane. Often sewer gas includes highly odorous indoles, skatoles, mercaptans, amines, and others.

Malodorous substances can be generated in any location in a wastewater collection or treatment system where anaerobic wastewater or solids can become deposited as scum or sludge. Deposits of scum or sludge do not permit a sufficient inward diffusion of oxygen for them to stay aerobic and odor-free very long.

Odorous substances tend to be adsorbed on dark, coarse, porous surfaces, and these surfaces then emit odors for long periods into what seems to be clean rooms. Walls and ceilings of a facility, and even the clothing of employees, can adsorb and carry odors long after the odorous substances have apparently been removed.

HYDROGEN SULFIDE

Hydrogen sulfide (H_2S) is the most commonly known malodorous gas emanating from domestic and industrial wastewater collection and treatment facilities and industrial/chemical processes. It is highly soluble (2,800 mg/l at 30ºC to 5,650 mg/l at 5ºC) in normal domestic wastewater.

In addition to its rotten-egg odor, H_2S can cause highly corrosive conditions and is an extremely toxic substance. The walls and crowns of sewers or closed tanks often have droplets of attached spray or condensation on the surface. Water (such as condensed water vapor in the form of dew or droplets) saturated with H_2S as a result of bacterial action forms sulfurous acid (H_2SO_3) and some sulfuric acid (H_2SO_4), both of which are very corrosive to paint, concrete, metals, and other materials.

The toxicity of H_2S is on the same order of magnitude as hydrogen cyanide (HCN), and death may result when exposed to an H_2S concentration of 225 ppm by volume in the air. The maximum TLV permissible for an 8-hour working period for H_2S is 10 ppm.[2] Hydrogen sulfide is treacherous because a person's ability to sense large concentrations is quickly lost. If the person ignores the first notice, the olfactory senses will become numbed and will no longer give warning. The results may be fatal.

[2]"2000 TLVs and BELs," American Conference of Governmental Industrial Hygienists (ACGIH), latest edition. (Handbook discusses threshold limits for chemical substances/physical agents and biological exposure indices. These are the exposure limits used world-wide as the maximum limits for SHE regulations.)

Table 2.1: Odorous Substances (Osmogenes)

	Formula	Characteristic Odor	Odor Threshold (ppm)	Recognition Threshold (ppm)	Molecular Weight
Acetaldehyde	CH_3•CHO	Pungent, fruity	0.004	0.21	44.05
Allyl mercaptan	CH_2•CH•CH_2•SH	Strong garlic, coffee	0.00005	----	74.15
Ammonia	NH_3	Sharp, pungent	0.037	46.8	17.03
Amyl mercaptan	CH_3•$(CH_2)_3$•CH_2•SH	Unpleasant, putrid	0.0003	----	104.22
Benzyl mercaptan	C_6H_5•CH_2•SH	Unpleasant, strong	0.00019	----	124.21
Butylamine	C_2H_5•CH_2•CH_2•NH_2	Sour, ammonia-like	----	0.24	73.14
Cadaverine	H_2N•$(CH_2)_5$•NH_2	Putrid, decaying flesh	----	----	102.18
Chlorine	Cl_2	Pungent, suffocating	0.01	0.314	70.91
Chlorophenol	Cl C_6H_5O	Medicinal, Phenolic	0.00018	----	128.55
Crotyl mercaptan	CH_3•CH:CH•CH_2·S	Skunk-like	0.000029	----	90.19
Dibutylamine	$(C_4H_9)_2NH$	Fishy	0.016	----	129.25
Diisopropylamine	$(C_3H_7)_2NH$	Fishy	0.0035	0.085	101.19
Dimethylamine	$(CH_3)_2NH$	Putrid, fishy	0.047	0.047	45.08
Dimethyl sulfide	$(CH_3)_2S$	Decayed vegetables	0.001	0.001	62.13
Dipheny sulfide	$(C_6H_5)_2S$	Unpleasant	0.000048	0.0021	186.28
Ethylamine	C_2H_5•NH_2	Ammoniacal	0.83	0.83	45.08
Ethyl mercaptan	C_2H_5•SH	Decayed cabbage	0.00019	0.001	62.1
Hydrogen sulfide	H_2S	Rotten eggs	0.00047	0.0047	34.1
Indole	C_2H_6 NH_2	Recal, nauseating	----	----	117.15
Methylamine	CH_3 NH_2	Putrid, fishy	0.021	0.021	31.05
Methyl mercaptan	CH_3 SH	Decayed cabbage	0.0011	0.0021	48.1
Ozone	O_3	Irritating above 2 ppm	0.001	----	48
Propyl mercaptan	CH_3•CH_2•CH_2•SH	Unpleasant	0.000075	----	76.16
Putrescine	NH_2 $(CH_2)_4$ NH_2	Putrid, nauseating	----	----	88.15
Pyridine	C_6H_5N	Disagreeable, irritating	0.0037	----	79.1
Skatole	C_9H_9N	Fecal, nauseating	0.0012	0.47	131.2
Sulfur dioxide	SO_2	Pungent, irritating	0.009	----	64.07
Tert-butyl	$(CH_3)_3C$•SH	Skunk, unpleasant	0.00008	----	90.19
Thiocresol	CH_3•C_6•H_4•SH	Skunk, rancid	0.0001	----	124.21
Thiophenol	C_6H_5SH	Putrid, garlic-like	0.000062	0.28	110.18
Triethylamine	$(S_2H_5)_3N$	Ammoniacal, fishy	0.08	----	101.19

ODOR TRANSMISSION

Odor transmission requires a sender, a carrier, and a receiver. The olfactory senses are the human's receiver. Air currents act as the carrier of odorous vapors and gases.

All substances with vapor pressure have the potential to emit odors—that is, to act as senders. A person's limited receiving apparatus does not pick up most odorous messages. Rather, people are most sensitive to unusual odors, or odors associated with the unknown, with what is feared, or with what is disliked. Osmogenes use the previously described forms of energy as the carrier of the odor message or stimuli. The degree to which senses can pick up an odor depends on the concentration of the osmogenes, distance from the osmogene, air current strength, and the condition of the individual detecting the odor.

Odor vectors may be stationary objects with adsorbed osmogenes or may be airborne particles. Adsorbed odors can continue to be the source of odor, sometimes for years. For example, clothes often will retain an odor despite heavy washing with detergents and bleach. Similarly, buildings formerly occupied by a malodorous industry will continue to emit odors from apparently clean surfaces. Ventilation ducts in a closed system will continue to emit odors for a long time if not adequately filtered and continuously diluted with fresh air.

ODOR EFFECTS ON THE HUMAN ENVIRONMENT

People can distinguish more than 5,000 odors. Odors can alter or create moods. It was proved that odors can cause increased heart rates, respiration, blood pressure, and even pain. Moreover, continued exposure to an odor can eventually cause atrophy of the olfactory apparatus. The odor key is locked into memories of past events and tends to cause recall of both pleasant and unpleasant happenings.

Humans no longer depend on odors to warn them of danger or to make them aware of the location of food, their mates, or their children. However, odors are still an important part of life. The increasing population and its concentration in urban areas resulted in an accumulation of odors that are not as dispersed as they were a century ago when a large proportion of the population was rural and population densities were less.

People associate some odors with human excrement, spoiled food, disease, or other unpleasantness. When such odors are present, people often become uncomfortable, unhappy, or fearful. Other osmogenes cause aromas, scents, or fragrances to bring pleasant or neutral thoughts and feelings to the person perceiving them.