Abstract of a Workshop

ODOR CONTROL: SOURCES, EFFECTS & METHODS OF CONTROL
North Durham Water Reclamation Facility
July 19, 2001

Attended by over 50 wastewater treatment operators, administrators, State employees and regulators, and odor control vendors.

Odors associated with domestic wastewater are often the result of the degradation of organic matter. The most common odor associated with wastewater is the “rotten egg smell” which is that of hydrogen sulfide gas, resulting from the anaerobic decomposition of organic matter. Odors due to wastewater are a primary concern of the public, which must be addressed by municipalities and engineers, regarding operation and design, respectively. This workshop considered the physiological effects, characterization and measurement of odors, as well as reviewing several treatment techniques and operational changes that can be employed by operators and engineers to improve wastewater management.

Problems and Sources

Why has odor control become an issue?
- Collection systems are being extended further away from the point of treatment.
- Decrease in buffer areas between wastewater treatment facilities and pump stations with respect to business and homes.
- Odors are a major concern of the public with regards to the collection systems and treatment facilities.

Where do these odors come from?
- Degradation of organic matter by bacteria under anaerobic conditions.
- Production of noxious gases from inorganic matter by bacteria under anaerobic conditions.
- Additions of odor causing chemicals that are discharged into the sewer system by industry.

The Two Major Categories of Odorous Wastewater Gasses Are:

<table>
<thead>
<tr>
<th>Inorganic</th>
<th>Organic</th>
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<tbody>
<tr>
<td>Hydrogen Sulfide, $\text{H}_2\text{S}$</td>
<td>Methyl Mercaptan, $\text{CH}_3\text{SH}$</td>
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<tr>
<td>Ammonia, $\text{NH}_3$</td>
<td>Ethyl Mercaptan, $\text{CH}_3\text{CH}_2\text{SH}$</td>
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<tr>
<td>Methane, $\text{CH}_4$</td>
<td>Skatole, $\text{C}_8\text{H}_8\text{N}$</td>
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<td>Indole, $\text{C}_6\text{H}_5\text{N}$</td>
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Why is the understanding of Hydrogen Sulfide ($\text{H}_2\text{S}$) important?
- It is a Major cause of odors in wastewater systems.
- It can be recognized by the human nose at very low concentrations (less than 0.7 ppb).
- It has a distinct rotten egg odor that is offensive.
- It causes corrosion or deterioration of concrete sewers and manholes.

How is Hydrogen Sulfide Generated?
- It is generated through the reduction of Sulfate ($\text{SO}_4^{2-}$) by sulfate reducing bacteria under anaerobic conditions present in wastewater. The sulfate comes from public water supplies and many common industrial wastewater sources.
- Two major species of anaerobic bacteria associated with sulfate reduction are 1) Desulfovibrio and 2) Desulfobacter.
- Production of Hydrogen Sulfide is in the anaerobic slime layer found mainly on sewer pipe walls but other wastewater surfaces as well.
- The three forms of sulfide in Wastewater collection systems are
  - Hydrogen Sulfide, $\text{H}_2\text{S}$
  - Hydrogen Sulfide ion, $\text{HS}^-$
  - Sulfide ion, $\text{S}^-$
- Typically there are four slime layers on the pipe wall measuring about 1.0 to 1.5 mm thick (in total) and located under the water level. The different slime layers are:
- An **Inert Anaerobic Layer** *(against the sewer pipe wall)*
- An Anaerobic Layer
- A Facultative Layer *(typical layer reaction* \(2\text{HS}^- + 2\text{O}_2 \rightarrow \text{S}_2\text{O}_3^{2-} + \text{H}_2\text{O}\))*
- A Laminar Flow Layer *(next to the liquid moving down the pipe)*

- In the Anaerobic and Facultative layers, \(\text{SO}_4^{2-}\), organic matter and nutrients react with bacteria producing \(\text{H}_2\text{S}, \text{CO}_2\) other compounds, and waste products. Sulfide is also generated within this area (\(\text{S}^-\)).
- In the wastewater solution typical reactions are
  1) Oxidation of sulfide \(\text{H}_2\text{S} + \frac{1}{2}\text{O}_2 \rightarrow \text{S} + \text{H}_2\text{O}\)
  2) Precipitation \(\text{H}_2\text{S} + \text{Fe}^{2+} \rightarrow \text{FeS} + 2\text{H}^{2+}\)
  3) Soluble sulfide equilibrium \(\text{H}_2\text{S} \Leftrightarrow \text{H}^+ + \text{HS}^- \Leftrightarrow 2\text{H}^+ + \text{S}^-\)

**What is sewer corrosion by Hydrogen Sulfide?**

Hydrogen sulfide gas (\(\text{H}_2\text{S}\)) goes in and out of solution with the wastewater. At the top of the pipe or tank the \(\text{H}_2\text{S}\) gas forms condensate and reacts with oxidizing bacteria forming sulfuric acid (\(\text{H}_2\text{S} + 2\text{O}_2 \text{basic} \rightarrow \text{H}_2\text{SO}_4\)).

**Physiological Effects**

The human Olfactory Bulb, located at the top of the nasal chamber, is the sensory organ for smell, and a direct conduit to the brain. It is in proximity to that part of the brain that gives emotional response to smells. Normal breathing will typically channel the majority of air along the bottom of the human nasal chamber. That is why an odor becomes more clearly identified when a person takes in a big sniff. The Olfactory Bulb can be damaged by exposure to strong odors, by prolonged exposure to odors, by strong odors, by chemical Co-Pollutants associated with odors, or by any combination of the above. Damage to the bulb can take several forms including lesions and partial or complete loss of the ability to smell. As the concentrations of odorous gases increase irritation, then physical symptoms, then sickness and even death can occur.

Three types of odors that can affect health were covered by this workshop.

1) **The first are types of odors that reach threshold levels and cause irritation and physiological effects.** These odors are noticed at “Threshold Level” and depend on duration and strength of exposure. At higher levels they can cause physiological effects such as reflex, transitive apnea, neurogenic inflammation, or elevated blood pressure. Continuous exposure to odorous compounds, like ammonia or Hydrogen sulfide, can lead to “Odor Fatigue” and/or a tolerance that may endanger health when warning signals are not adequately perceived.

2) **The second are types of odors that are mixed with “Co-Pollutants”, which are the cause of physiological effects.** Co-Pollutants may be may be toxins, endotoxins, feed dust, airborne manure particulates, allergens, or microorganisms. Health effects will depend on the co-pollutant compound(s).

3) **The third are types of odors that cause symptoms from non-toxicological levels.** These odors act as neural markers that can recall pleasant or unpleasant associations. Unpleasant odors can result in learned odor induced symptoms.

The basic nomenclature of odor and human smell as odor concentrations increase is:

1) Odor Detected - “Threshold Level” which typically is not a health effect.
2) Odor Recognized - Irritation begins.
3) Odor Annoyance - Annoying but is at a tolerated level.
4) Odor Intolerance - Levels which most people begin to show symptoms.
5) Perceived Irritant - Physiological effects begin for most people.
6) Somatic Irritants - Physiological damage begins.
7) Chronic Toxicity - Physiological effects lasting a long time.
8) Acute Toxicity - Physiological effects very serious or even critical.

Individuals are affected by odors at different rates. An odor at one level is an irritant to one person but is only a threshold level for another. However all people will notice and/or become affected by an odor as it becomes
stronger. Often people will smell wastewater odors for days after they leave a treatment plant, or swine facility. Odorous gases can attach to dust particles and become lodged in the nose or clothes. Some odorous gases are absorbed through the lungs into the blood stream, stored in the tissues, then released back into the blood stream out the lungs and smelled going back out the nose.

A good example of human health being affected by odor levels can be found with the odor affects of different levels/concentrations of Hydrogen Sulfide.

- 0.2 ppb to 0.5 ppb - Back ground concentration in isolated wilderness areas
- 0.7 ppb - Detected by 14% of population 2% annoyed
- 5.0 ppb - World Health Organization recommends not exceeding ½ hr. exposure.
- 7.0 ppb to 27 ppb - On annual average, evaluated health symptoms in 9% to 12% of people.
- 10 ppb - Odors detected by 56% of population and 17% annoyed.
- 10 ppb w/100 ppb peaks - Neuropsychological abnormalities appear for some people.
- 30 ppb - Odors detected by 83% of population 40% annoyed
- 40 ppb - 50% of population annoyed
- 70 ppb - Acute (1 to 14 days) inhalation min. risk level with no adverse effects
- 0.32 ppm over 1 hr. - Nausea, diarrhea, sleep disruption, shortness of breath, etc.
- 2.5 ppm to 5 ppm - after 15 minutes, coughing and throat irritation
- 10 ppm - OSHA's TLV (threshold limit value)
- 10 ppm to 50 ppm - sore eyes, irritation
- 30 ppm - Lesions in olfactory mucous
- 50 ppm to 100 ppm - NIOSH’s IDLH (Immediate Danger to Life and Health)
- 1000 ppm - KILLS VERY QUICKLY

Unpleasant odor is a warning. Odors and odorous gasses can still affect a persons’ health, even if the odor is tolerated. This is commonly referred to as the “Healthy Worker Effect”. People exposed to harmful levels of odors, odorous gasses and co-pollutants can have a wide range of health symptoms, such as: olfactory bulb damage, sore throat, cough, chest tightness, breathlessness, thirst sweating, irritability, loss of libido, or elevated blood pressure. A method of measuring unpleasant odors is RD50, which means that level that decreases a person’s respiratory level by 50%.

**Odor Chemistry and Measurement**

It is reported that wastewater decomposition can generate between 80 and 200 compounds. Studies of swine operations report over 400 odorous compounds discovered. It was stated that most individual treatment plant, or swine, facility odors are below the threshold levels. Very often the majority of individual treatment plant odors never last beyond the fence line. However, studies have noticed that odors can combine to form stronger odors greater than the sum of the individual odors. In effect the aggregate of all the odors can cause irritation. North Carolina’s Odor Regulations are found in NCAC.15A subchapter 2D section 0.1800 “Control of Odors”.

Odorous gas concentration is often measured with an instrument. As odors have several categories, these instruments must have specific calibrations or specific chemical reactants for the different gasses. Noxious gases can adhere to the surface of airborne particles, such as dust, increasing odor concentrations several fold. These particles can travel for miles farther than the odor alone. Unfortunately these particles can clog electronic based smelling instruments and give false readings. Other odor measuring instruments are:
- Colorimetric tubes - using specific chemical tubes to detect specific gasses
- Scentometer - a box like device using special size holes to help the human nose isolate smells
- Olfactometry - a table of scales, for smells, used by a panel of trained people to rate smells
- Gas Chromatography - using mass spectroscopy to identify compounds

**Odor Control Technologies**

Chemical and physical control of odors typically works by preventing the formation of odorous compounds or changing the chemistry of odorous compounds. Treatment of odor can take place in the “Liquid phase”, usually while the wastewater is still in the pipe, or in the “Vapor Phase” as gasses leave the liquid wastewater,
wherever it is exposed to the air. In many cases treatment can be an economical combination of both liquid and vapor technologies.

Liquid Phase technologies and chemicals can prevent the formation of atmospheric sulfite, help prevent corrosion of pipes and treat multiple odor release points. The location of the odors, the compounds involved, the wastewater treatment limits, the lines and side streams, the treatment process, and the optimum chemical solution must be known to be effective. Examples of chemical processes involved are:

- **Bioxide Process** – sulfide removal process, nitrate solution, which prevent and remove sulfur
- **Anthaquinone Suspension** – interrupts sulfate reduction in sulfate reducing bacteria
- **Iron Salts** – specific to sulfide it oxidizes and precipitates sulfide (is corrosive)
- **Oxidizers** – such as hydrogen peroxide and potassium chloride (can be hazardous)
- **pH Adjustment** – keeping pH high keeps sulfide in solution (sulfide escapes later)

Vapor phase technologies provide point source solutions, treat a wide range of compounds and provide area ventilation. Types of Vapor phase technologies are wet air scrubbers, bio-filtration systems, and absorptions systems. Examples are:

- **Packed Tower Scrubbers** use water and chemical adjustment to pull odor compounds out of the air. There are Single stage scrubbers and more effective double or multi stage scrubbers
- **Bio-filtration** technology diverts odorous gasses through an aqueous film, followed by oxidization and sends the gasses up through a biological media (such as mulch or sawdust) to let microorganisms finish off the compounds.
- **Cover technology** traps odorous gases by putting covers on tanks, manholes, and/or treatment processes that let odors escape, and then collects and treats the odorous gasses in some other way.

**Odor Modeling**

Finding the locations where odors emerge into the air is the key to economical odor control in a wastewater treatment plant. Odors tend to emerge from specific locations at treatment plants. Finding and controlling these, often small, points of odor release can make a big difference in odor control. Many plants are turning to covers for odorous tanks and process units to prevent odors from escaping the facility. The gasses are then diverted to an appropriate treatment process. It is also reported that odors are remarkably controlled by proper house keeping, at a treatment facility. Examples are:

- Keeping screening and grit dry as possible
- Maintaining the wet well at a level to prevent off gassing
- Keeping solids well mixed in flow equalization
- Frequent scum removal from clarifiers

In short, many odor sources are from letting wastewater, and waste solids, have time to sit too long and decompose during the treatment process.

**Conclusion**

The rest of the workshop consisted of reviewing case histories and examples covering the information reviewed above. Potentially, odors can be a danger to human health. Most odors do not travel very far past the treatment facility fence. Odors cost money to control and are a greater expense if not controlled. The gasses associated with odors can cause deterioration of pipes, tanks, and other equipment. Measuring odors can be difficult and expensive. There is a wide variety of technologies to either chemically prevent odorous compounds, change odorous compounds, and contain odorous compounds. And, treatment plant odors mainly come from specific points or processes, not the entire plant, making it possible to economically control odors. Much of the information in this workshop should be explored in greater detail to fully appreciate and be more effective in preventing and controlling odors.