

GARBAGE ROOM ODORS REMEDIATION

By: Normand Brais P.Eng., M.A.Sc., Ph.D



A graduate from Polytechnique Montreal, Normand Brais holds a mechanical engineering degree, a Master degree and a PhD in Nuclear Engineering from Polytechnique. He was appointed as a professor at the Energy Engineering Institute of Polytechnique and has founded several technological companies in various fields such as atmospheric pollution from combustion equipment, biomass combustion, photonics and water treatment. In 1995, he left his professorship and founded Sanuvox Technologies, manufacturer of air handling and of surface sterilization devices using high frequency ultraviolet light. He is involved as a volunteer and sponsor for the next generation as President of the Polytechnique Alumni Foundation from 2013 to 2016 and he contributes to the creation of Polyfab, a new creative space for the future entrepreneurs of Polytechnique. He has also served several years as Treasurer for the United Nations Association of Canada.

Content

Origins of household waste odors.....	2
Odor control methods.....	3
Dilution by ventilation	3
Refrigeration.....	3
Oxidation	4
Technology and references in photo-oxidation	6
Technical specifications of photo-oxidation devices.....	6
Maintenance.....	6
References.....	7

Origins of household waste odors

The perception of odors is analogous to the operation of a lock where the key is a molecule whose chemical form makes it suitable to unlock and thus activate one of the multiple olfactory sensors of the nose.

As an example, while the H₂O water molecule does not trigger any olfactory perception, the simple change of the oxygen atom O by a sulphur atom S in this molecule changes the chemical form to H₂S and brings a major change of olfactory perception; a strong unpleasant rot odor. In the same way, a methane molecule CH₄ is odorless even with a strong concentration of several ppm (parts per million) whereas inserting one sulphur atom into the methane molecule to transform it in Methylmercaptan CH₃SH and renders it unpleasant even at concentrations of a few parts by billion. This is the reason why these types of «mercaptan» molecules are intentionally added to gas distribution networks to allow easy olfactory detection in case of leaks.

Table 1 below gathers the main molecules of odors generated by the decomposition of organics contained in household waste.

Table 1: Fragrant molecule from household waste

Class Odor	Name of Molecule	Chemical formula	Characteristic odour	Olfactory threshold (mg/Nm ³)
Sulfured	Hydrogen sulfide	H ₂ S	rotten egg	0,0001 à 0,03
	Methylmercaptan	CH ₃ SH	cabbage and garlic	0,0005 à 0,08
	Dimethylsulphur	C ₂ H ₅ SH	decaying cabbages	0,0001 à 0,03
	Dyethylsulphur	(CH ₃) ₂ S	vegetables	0,0025 à 0,65
	Dimeththylsulphur	(C ₂ H ₅) ₂ S	decomposition	0,0045 à 0,31
			(CH ₃) ₂ S ₂	ethereal putrid
Nitrogenous	Ammonia	NH ₃	very spicy, irritating	0,5 à 37
	Methylamine	CH ₃ NH ₂	fish in	0,021
	Ethylamine	C ₂ H ₅ NH ₂	decomposition	0,05 à 0,83
	Dimethylamine	(CH ₃) ₂ NH	spicy, ammoniacal	0,047 à 0,16
	Indole	C ₃ H ₆ NH	fish damaged	0,0006
	Scatole	C ₉ H ₈ NH	fecal, nauseous	0,0008 à 0,10
Cadaverine	NH ₂ (CH ₂) ₅ NH ₂	fecal, nauseous decaying meat	--	
Organic Acids	Acetic	CH ₃ COOH	vinegar	0,025 à 6,5
	Butyric	C ₃ H ₇ COOH	rancid butter	0,0004 à 3
	Valeric	C ₄ H ₉ COOH	sweat	0,0008 à 1,3

Odor control methods

There are three ways to mitigate the odors of a garbage room. The first one is dilution, the second is the reduction in the rate of odor generation by refrigeration, and the third consists in gradually oxidizing the odorous molecules by thermal or photolysis to convert them into molecules without or with less odors. The first two are the most commonly used and we will not discuss them too much here except to review their practical limits of applications.

Dilution by ventilation

The first reflex when dealing with odors is as old as the history of civilization: it starts by waving our hands around our nose and opening all the windows to ventilate the area. The idea is to ventilate the room with enough fresh air to dilute the smells below their detectable threshold concentration. As highlighted in table 1, the olfactory detection threshold is usually a matter of very low concentrations for certain molecules. Several sulfur compounds like hydrogen sulfide for example will still smell even at concentrations as low as 0.0001 mg Nm³, this is only 0.07 part by billion.

Even in the case where the rate of generation of this molecule is very low, it will require a huge ventilation rate to cope with it by dilution. For this reason, the ventilation rates specified in codes and regulations are often insufficient to control odors. Furthermore, evacuation of this vitiated air turns out to be a nuisance for the neighborhood. Not only ventilation often fails to solve the problem, but it amplifies it by spreading it around.

In largely populated cities this alternative is often inapplicable if one wants to maintain good relationship with the neighbourhood.

Refrigeration

Refrigeration is the fall back alternative when constraints and drawbacks of ventilation does not allow the evacuation of the odors outside.

Odororous molecules being by-products of the anaerobic bio-digestion of organic waste, thermophile biologic activity maybe significantly slowed down by cooling the garbage storage area. By maintaining garbage rooms at temperatures ranging between 4 and 7 C (40 to 45 F), the generation rate of odorous molecules can be considerably reduced. Since construction criteria require that garbage rooms be built in concrete (preferably smooth to facilitate cleaning) and since concrete is a very poor thermal insulator, electrical energy consumption per unit area often becomes considerable. The poor seal of the large sliding metal access doors that has little or no insulation further adds to the refrigeration load.

It is important to note that the elevated level of humidity in the garbage rooms also contributes to increase the energy consumption of the refrigeration system. In addition, the presence of dusts

and organic acids combined with water condensation generally leads to premature degradation of the cooling coil, ending up in refrigerant leaks and failure of the cooling unit. This alternative to ventilation ends up being very expensive not only to operate but also in maintenance costs. Certain owners that are forced to comply using this alternative will often have a tendency to become delinquent and stop the operation of the system based on economic motivations.

Oxidation

The third method to eliminate odors is based on chemical oxidation of the odorous molecules. This is the process that occurs naturally outside in the atmosphere by interaction with the sun light. For example, the oxidation of hydrogen sulfide H_2S produces a completely odorless molecule of water (H_2O) and a molecule of sulfur dioxide SO_2 that has an odor threshold of 5 mg / Nm^3 which is 50,000 times less odorous than the initial hydrogen sulfide molecule. Commonly called "combustion" in the case of conventional fuels, oxidation reaction requires a high temperature to get started. There is however another way to initiate chemical oxidation reactions by using high energy photons such as UV light. This process of oxidation at ambient temperature is called "photolysis" or "photo-oxidation".

The amount of energy carried by the photon increases as the light wavelength decreases. With a wavelength of 400 nm, the violet photons are more energetic than the red photons with wavelength of 700 nm. The more the photons have energy, the more they are like a big caliber bullet capable of breaking the bonds between atoms within a molecule. To initiate the oxidation reactions, these bonds must first be broken to free the atoms which can then be combined with oxygen atoms. By using ultraviolet light sources with wavelength of 254 nm for UV-C and 185 nm for UV-V respectively, it is possible to emit photons with energies large enough to break and then oxidize any odor molecule listed in Table 1. By way of example, let's have a closer look at the steps of photo-oxidation process of hydrogen sulfide (H_2S).

The first step is to break the chemical bond between the sulfur atom S and the hydrogen atom H. The energy of this bond is well-known in chemistry and has been established at 347 kJ/mole as shown in Table 2, whereas the energy of UV-C photons is higher at 470 kJ / mole. UV-C photons will therefore have no difficulty in breaking the S-H bonds and momentarily freeing the sulfur and hydrogen atoms.

The second step is to bring some oxygen atoms to react with the sulfur and hydrogen atoms. The ambient air contains many oxygen atoms (close to 21% of the air volume, the remainder being essentially nitrogen), but they are bound together in molecular pairs with a bond energy of 495 kJ/mole. In this case, UV-C photons (470 kJ / mole) do not carry enough energy to break this bond and release oxygen atoms. It will be necessary to resort to more energetic photons. This is

precisely the case of UV-V photons at 185 nm wavelength with their energy of 646 kJ / mole that easily exceeds the binding energy of oxygen molecule (495 kJ / mole).

Once these two steps are done, the oxidation reaction will occur at ambient temperature via a hydroxyl (OH *) radical which serves as a transmission media for free oxygen atoms. The end result is the conversion by oxidation of odorous molecules into other molecules that have little or no odor at all.

Table 2: Energy of Chemical Bonds

Average Bond Energies (kJ/mol)

Single bonds			Multiple bonds
H-H 432	N-H 391	I-I 149	C=C 614
H-F 565	N-N 160	I-Cl 208	C≡C 839
H-Cl 427	N-F 272	I-Br 175	O=O 495
H-Br 363	N-Cl 200	S-H 347	C=O* 745
H-I 295	N-Br 243	S-F 327	C≡O 1072
C-H 413	N-O 201	S-Cl 253	N=O 607
C-C 347	O-H 467	S-Br 218	N=N 418
C-N 305	O-O 146	S-S 266	N≡N 941
C-O 358	O-F 190	Si-Si 340	C≡N 891
C-F 485	O-Cl 203	Si-H 393	C=N 615
C-Cl 339	O-I 234	Si-C 360	
C-Br 276	F-F 154	Si-O 452	
C-I 240	F-Cl 253		
C-S 259	F-Br 237		
	Cl-Cl 239		
	Cl-Br 218		
	Br-Br 193		

*C=O in CO₂(g)=799

Technology and references in photo-oxidation

Fully developed, patented, and built by the Montreal based company Sanuvox Technologies since 1995, the S-300 and S-1000 photo-oxidation units for the removal of garbage room odors are used today in more than 20 countries around the world. Over 2000 units have been installed so far.

WASTE MANAGEMENT in Ontario has been using them widely and has made it a standard for its garbage rooms for several years. Among the many successes, we are particularly proud that our technology has solved some major odor problems in the Bell Center in Montreal, home to our famous hockey team “The Montreal Canadians” and at the Museum of Civilization in Quebec City.

Technical specifications of photo-oxidation devices

The operating principle requires the circulation of vitiated air through a chamber where its exposure to intense ultraviolet sources combination of UV-C and UV-V ensures the oxidation of odorous molecules.

Best practice dictates that it is best to capture the odors at their emission source, then oxidize them and reject the air at the entrance of the room, thus preventing the transmission of odors through the access way. Two distinct unit sizes can be used depending upon the size of the room: the S-300 unit (300 CFM) and the S-1000 unit (1,000 CFM). The sizing is based on a recirculation equivalent to 6 to 8 air changes per hour. Experience has shown that the S-300 will easily control the odors in a room of 3000 ft³ (85 m³) and that the S-1000 can satisfy a 10,000 ft³ (283 m³) garbage room.

The selected unit operates continuously and is equipped with a (MONITOR) that performs air sampling every minute to control the generation of oxidizing hydroxyl radicals as a function of concentration of odorous molecules. Should the room become free of materials to oxidize, the UV-V sources would then be turned off automatically. This monitor connected by a 6 meters wire should be installed preferably at the outlet of the unit for quickest feedback response. The unit is also equipped with filters to protect the mechanical components.

Maintenance

The useful life of UV-C and UV-V high-intensity sources is 10,000 hours and requires replacement on an annual basis. Filter replacement must also be done on a regular basis: for this purpose it is advisable to inspect the filters regularly to determine the best changeover time. By default, we recommend that the filters be replaced quarterly. As for the MONITOR, its electronic board must be recalibrated or replaced every 4 years.

References

1. Haag, W.R., M.D. Johnson and R. Scofield, Direct photolysis of trichloroethene in air: Effect of contaminants, toxicity of products, and hydrothermal treatment of products. *Environ. Sci. Technol.*, 30(2), 414-421 (1996).
2. Scheytt, H., G. Emig and H. Oetzmann, Photoinduced oxidation of chlorinated hydrocarbons in the gas phase. The First International Conference on Advanced Oxidation Technologies for Water and Air Remediation. London, Ontario, Canada, Jun. 25-30 (1994).
3. Sarathy, S.R. and M. Mohseni, An overview of UV-based advanced oxidation processes for drinking water treatment. *IUVA News*, 7(1), 1-12 (2006).
4. Mcgregor, F.R., P.J. Piscaer and E.M. Aieta, Economics of treating waste gases from an air stripping tower using photochemically generated ozone. *Ozone-Sci. Eng.*, 10(4), 339-351 (1988).
5. Lin, C.J., Y.H. Liou, S.Y. Chen and M.C. Tsai, Visible-light photocatalytic conversion of CO₂ to methanol using dye-sensitized mesoporous photocatalysts. *Sustain. Environ. Res.*, 22(3), 167-172 (2012).
6. Shie, J.L., C.Y. Chang, C.S. Chiou, Y.H. Chen, C.H. Lee and C.C. Chang, Characteristics of N-doped titanium oxide and photodegradation of formaldehyde using visible light lamp and light emitting diode. *Sustain. Environ. Res.*, 22(2), 69-76 (2012).
7. Bhowmick, M. and M.J. Semmens, Ultraviolet photooxidation for the destruction of VOCs in air. *Water Res.*, 28(11), 2407-2415 (1994).
8. Cruz, R., L. Hinojosa Reyes, J.L. Guzmán-Mar, J.M. Peralta-Hernández and A. Hernández-Ramírez, Photocatalytic degradation of phenolic compounds contained in the effluent of a dye manufacturing industry. *Sustain. Environ. Res.*, 21(5), 307-312 (2011).
9. Suidan, M.T. and B.F. Severin, Light irradiance models for annular UV disinfection reactors *AIChE J.*, 32(11), 1902-1909 (1986).
10. Bolton, J.R., Calculation of ultraviolet fluence rate distributions in an annular reactor: Significance of refraction and reflection. *Water Res.*, 34(13), 3315-3324 (2000).
11. Serpone, N., Relative photonic efficiencies and quantum yields in heterogeneous photocatalysis. *J. Photoch. Photobio. A*, 104(13), 1-12 (1997).
12. Powers-Schilling, W.J. 1995. Olfaction: chemical and psychological considerations. *Proc. of Nuisance Concerns in Animal Management: Odor and Flies Conference*, Gainesville, Florida, March 21-22.