

Elemental Odor Control

New trends in activated carbons

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For decades, wastewater treatment plants have used activated carbon systems for odor control. The advantages of these systems are clear: They have few moving parts, require minimal operator intervention, and are simple to operate and maintain. Over time, these odor-control media have become more effective, safe, and environmentally friendly. Today, plants can choose from a variety of activated carbons, including some newer media that are becoming more popular.

How They Work

Activated carbons are highly porous materials. Due to large surface areas, activated carbon is able to adsorb hydrogen sulfide, its reaction products, and other odor-causing reduced sulfur compounds. In the presence of air and moisture, activated carbons catalytically oxidize hydrogen sulfide to a combination of elemental sulfur and sulfuric acid. These reaction products are stored in the carbon's pore structure, where they compete with other reduced sulfur compounds and volatile organic compounds (VOCs) for adsorption space.

Temperature and reactant concentrations control the rate of chemical reactions that occur during the hydrogen sulfide removal and oxidation process. Therefore, the system design must allow sufficient time for these reactions to occur. Today, many odor-control systems are designed to operate at a superficial velocity of about 18 m/min (60 ft/min) and an empty-bed contact time of approximately 1 second.

What's Available

Currently, there are three main types of media used for large-scale odor control.

Virgin activated carbons are the oldest media type on the market. Manufactured from coal or coconut shells, these carbons are similar in hydrogen sulfide removal capacity but differ in

how they handle organic odors in the gas stream. They have limited capacity for hydrogen sulfide removal, which can lead to frequent changeouts and increased operating costs.

Chemically impregnated carbons have been available for nearly 20 years. These carbons are typically coal-based and impregnated with a caustic, such as potassium hydroxide, sodium hydroxide, or potassium iodide. The addition of an impregnant significantly increases the carbon's hydrogen sulfide removal capacity, making the media more cost-effective for use in odor- and process-control applications. While virgin activated carbons have the capacity to hold 4% to 7% of their weight in hydrogen sulfide, impregnated carbons have a hydrogen sulfide holding capacity that is 20% to 25% by weight. The addition of an impregnant to activated carbon also tends to lower its ignition temperature.

The *newer carbons* are seeing widespread

Finley, Ohio, controls odors at this pump station with a 7-ft single-bed activated carbon vessel.



acceptance and use today. There are two types currently on the market: sulfuric-acid-selective, water-regenerable (or "water-washable") carbons; and single-use, sulfur-selective carbons.

Water-Regenerable Carbons

Sulfuric-acid-selective, water-regenerable carbons are manufactured from coal. During the last stages of the activation process, in which the coal char is converted into an activated carbon, an amine-based compound is introduced into the activation furnace. This material reacts with the carbon at high temperatures in the absence of oxygen, leaving functional groups dispersed on the carbon's surface. These functional groups give water-regenerable carbons their properties.

These carbons remove hydrogen sulfide from a gas stream by almost exclusively oxidizing the hydrogen sulfide to sulfuric acid. Under most conditions, little or no sulfur is formed. The sulfuric acid that is formed initially is stored in the carbon's pore structure. Since the sulfuric acid is soluble in water, it can be leached from the carbon by water-washing. Once the carbon reaches its maximum hydrogen sulfide capacity, it must be thoroughly water-washed to restore capacity for continued use.

These carbons have a lower initial hydrogen sulfide capacity than impregnated carbons. The holding capacity for hydrogen sulfide is approximately 14% to 18% by weight, as measured by ASTM test method D-6646. Each water-washing cycle restores from 75% to 90% of the previous

hydrogen sulfide capacity. VOCs that are generally present in the sewer gas are also adsorbed by the water-regenerable carbon but are not effectively removed by the water-washing process. These adsorbed VOCs can build up over time in the carbon's pore structure, reducing pore volume and surface area, and potentially reducing the carbon's hydrogen sulfide removal capacity with each cycle.

Sulfur-Selective Carbons

Sulfur-selective catalytic carbons also are manufactured from coal. Catalytically active ingredients are added before converting the bituminous coal to an activated carbon, and they become an integral part of the carbon's pore structure. As catalysts, the active ingredients are not consumed when hydrogen sulfide and other reduced sulfur compounds are oxidized.

These carbons have demonstrated a high capacity for both hydrogen sulfide removal and VOC adsorption. The molecular size of the sulfur atom is less than one-third the molecular size of the sulfuric acid molecule, which means that 3.5 times more sulfur can be stored in the same pore volume space as can one sulfuric acid molecule. These carbons have a 65% to 75% hydrogen sulfide capacity by weight and require no operator intervention to achieve full capacity.

Sulfur-selective carbons' high hydrogen sulfide removal capacity depends on their ability to selectively oxidize the hydrogen sulfide to elemental sulfur and to minimize the formation

Comparison of Odor-Control Carbons

	Virgin carbon	Impregnated carbon	Water-regenerable carbon	Sulfur-selective carbon
Apparent density, g/cc	0.50	0.55	0.56	0.40
H ₂ S capacity, wt. %*	4-7	20-25	14-18	65-75
Impregnant	None	NaOH/KOH	None	None
Fate of H ₂ S	Sulfur/H ₂ SO ₄	Sulfur/H ₂ SO ₄	H ₂ SO ₄	Sulfur
Butane number **	23.5	N/A	15.6	26.0
Ignition temperature	~380°C (~720°F)	~150°C (~300°F)	~420°C (~790°F)	~540°C (~1000°F)
pH of spent carbon	Acidic	Acidic	Acidic	Neutral
Hazardous when spent	Yes	Yes	Yes***	No

H₂S = hydrogen sulfide.

H₂SO₄ = sulfuric acid.

NaOH = sodium hydroxide.

KOH = potassium hydroxide.

*ASTM standard test method D-6646.

**ASTM D-5742.

***Unless thoroughly water-washed before disposal.



of sulfuric acid. The kinetics of this conversion process tends to be slower than the nonselective oxidation of the hydrogen sulfide all the way to sulfuric acid. Therefore, sulfur-selective carbons tend to require slightly longer contact times and slower superficial velocities for the same removal efficiencies.

These carbons have a high ignition temperature and can tolerate high inlet hydrogen sulfide concentrations without suffering a significant loss in hydrogen sulfide removal capacity. Once the sulfur-selective carbons have reached the end of their useful service life, they are disposed of as a nonhazardous waste.

Optimizing Performance

When designing an odor-control system, hydrogen sulfide capacity and breakthrough are normally the standard measures of performance. However, once the hydrogen sulfide is removed, if other organic and reduced sulfur compounds remain in the stream being treated, they will cause odor problems. Therefore, an odor-control system should be designed to remove both hy-

drogen sulfide and other odorous compounds.

Other reduced organic sulfur compounds that may make up a portion of the VOCs are removed by adsorption. If mercaptans are present, they are converted to disulfides, which are more easily adsorbed by the odor-control media. (This occurs extensively with catalytic and impregnated carbons, and to a limited extent with virgin carbons.)

Selecting the best media for a particular application requires a careful analysis of site conditions and the desired objectives of the odor-control system. An odor-control carbon with a fully developed open-pore structure and a high surface area can best accomplish simultaneous VOC odor control by adsorption and hydrogen sulfide oxidation.

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Four dual-bed activated carbon vessels in Singapore.