White Paper

Carbon Adsorption & Reactivation:

Turning Obligation Into Opportunity in the Chemical Process Industry

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Making Water and Air Safer and Cleaner

Chemical, petrochemical, and oil-refining plants are process-intensive operations with regulatory requirements to protect the surrounding water and air from the effects of industrial pollution. These external demands are matched by equally compelling internal pressures to address product purification needs, find alternatives to utilizing costly and often scarce fresh water in production processes, reduce the carbon footprint, and operate efficiently and profitably.

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For more than 40 years, activated carbon, through a process called "physical adsorption," has proven to be a cost-effective material in the removal of organic contaminants from liquids and gases in both industrial process and environmental applications. Granular activated carbon (GAC) has a tremendous adsorptive capacity, an affinity for a wide variety of organics, the ability to be tailored to suit specific applications, and can be economically reactivated for reuse.

In the chemical process industry (CPI), GAC is widely used in liquid and gas purification, and to purify and reuse industrial process water. GAC can also be employed to meet regulatory requirements in wastewater treatment, groundwater remediation, and for volatile organic compound (VOC) abatement in vapor phase applications. One such example is the highly regulated benzene, a hazardous VOC. Additionally, recycling, or thermally reactivating spent carbon, gives CPI plants the opportunity to reduce cost and waste, save energy, lower CO_2 emissions, and conserve natural resources while reducing the long-term liability of spent-carbon disposal.

The use of GAC for organic contaminant removal from the liquid and vapor phase continues to grow as chemical companies seek the most cost-effective and proven solutions to address a host of applications within each plant. In fact, GAC has been classified as a U.S. Environmental Protection Agency (EPA) Best Available Technology (BAT) for removal of many organic contaminants.

Organics that are readily adsorbed by GAC include: aromatic solvents (benzene, toluene, and nitrobenzenes); chlorinated aromatics (PCBs, chlorobenzenes, and chloronaphthalene); phenols and chlorophenols; fuels (gasoline, kerosene, and oil); polynuclear aromatics, also known as PNAs, (acenaphthene and benzopyrenes); and pesticides and herbicides (DDT, aldrin, chlordane, and hepthaclor).

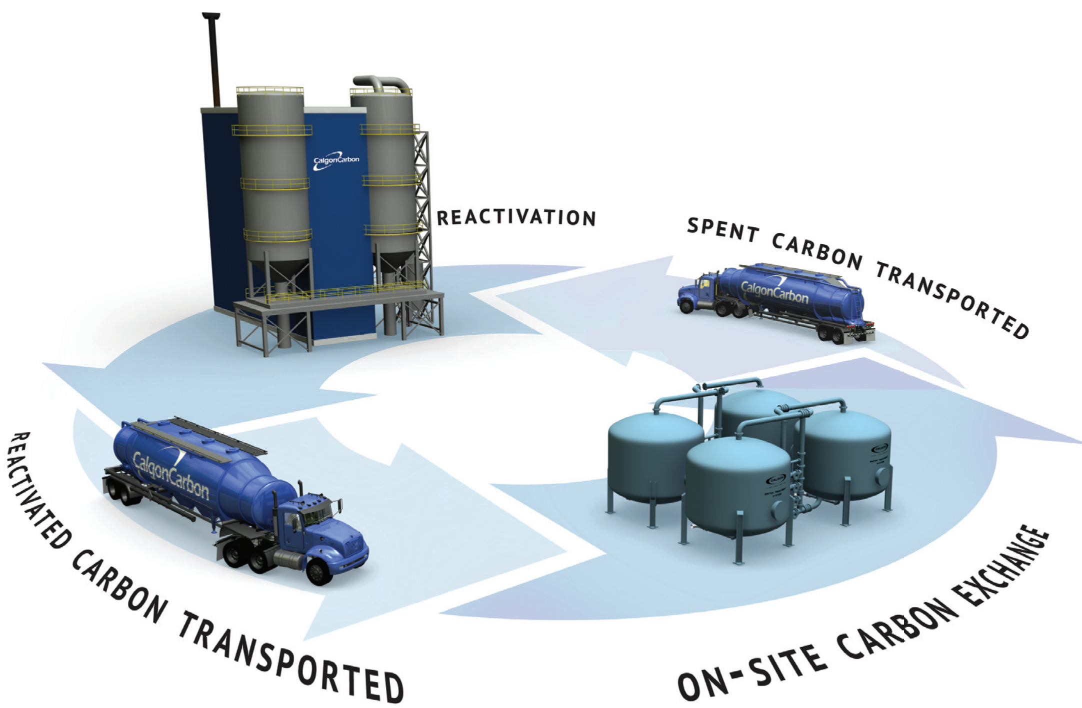
The primary raw materials used to make GAC are materials with a high carbon content, such as coal, wood, peat, or coconut shells. A standard, unimpregnated, bituminous coal-based material is most often used for adsorption of organic contaminants in industrial applications because this material has a wide range of pore sizes to adsorb a broad variety of organic chemicals. Re-agglomerated carbon is generally preferred over direct activated because it is a more robust material, with a fully developed porosity, and, at the same time, has the necessary strength to withstand use and reuse. Re-agglomerated GAC is produced by grinding the raw material to a powder, adding a suitable binder for hardness, re-compacting, and crushing to the specified size. The carbon-based material is then thermally activated in a furnace using a controlled atmosphere and high heat. The final steps in production include screening to remove unwanted oversized and undersized material followed by packaging.

The resultant product has an incredibly large surface area per unit volume and a network of submicroscopic pores where adsorption takes place. The walls of the pores provide the surface layer carbon molecules that are essential for adsorption. GAC has the highest volume of adsorbing porosity of any material known to humankind. Amazingly, five grams of reagglomerated carbon have the surface area of one football field.

Adsorption is the adhesion of the molecules of liquids, gases, and dissolved substances to the surface of solids because of physical or chemical forces. Physical adsorption is the primary means by which GAC works to remove contaminants from liquids and gases. Carbon's highly porous nature provides a large surface area for contaminant molecules to collect. Physical adsorption occurs because all molecules exert attractive forces, especially those at the surface of a solid (carbon pores in this case), and these surface molecules seek other molecules to adhere to. Solid substances are called "adsorbents" and attracted surface molecules of a liquid or gas are called "adsorbates." Adsorption effectiveness can be measured through capacity tests that measure the mass of adsorbate removed per unit weight or unit volume of activated carbon.

To ensure optimal GAC adsorption operations, installations at chemical plants typically include carbon adsorption equipment with the associated transfer piping. These systems can be operated with single or multi-stage treatment vessels, depending on the desired treatment objective.

During the carbon adsorption process, the available surface and pores of the GAC begin to fill up with chemicals. At some point, the required performance criteria will not be met, and the carbon is said to be "spent." At a manufacturing plant, this is determined when the effluent quality of the carbon treatment vessel begins to



approach the quality of the influent. The spent activated carbon must be disposed of and replaced, or recycled for reuse, so the carbon adsorption process can continue.

Three options for dealing with spent carbon include shipping it to a landfill or incinerator, regeneration, or reactivation. The landfill and incineration options necessitate the purchase of new carbon and may not be environmentally friendly. Regeneration and reactivation allow for reuse of the activated carbon. Regeneration and reactivation are possible options for a company looking to reduce its carbon footprint and save money. Regeneration (chemical or steam) may be more favorable than the landfill option, but only if it is used to recover and reuse a valuable adsorbate. It is generally not applied for strictly environmental reasons because it is usually less efficient than reactivation. High-temperature thermal reactivation is the preferred method for reuse of the activated carbon because if the reactivation is efficient, most of the adsorption capacity can be restored.

Due to the “green” environmental advantages and bottom-line cost savings that it offers, reactivation has been growing in use throughout the CPI. If profiling and testing identify reactivation as an option, plants can have their spent activated carbon recycled for reuse, eliminating the costs and long-term liability associated with disposal. Reactivation utilizes a high-temperature thermal process, whereby adsorbed organic compounds are destroyed, and the GAC’s adsorptive capacity is restored. Reactivating spent GAC results in a cost savings of typically 20 to 40 percent over the purchase of virgin GAC.

Reactivation is better for the environment, significantly reducing the CO_2 footprint associated with the production and use of virgin GAC. With reactivation, up to 95 percent of the virgin activated carbon capacity is recovered. The reactivated carbon can then be blended with a small amount of virgin carbon to make up for the minor loss of volume. GAC has a nearly infinite reactivation capability, meaning it rarely ends up in a landfill or incinerator. Depending on the economics and volume of spent activated carbon produced, some plants may have on-site reactivation facilities or contract for reactivation and reuse services from a company that offers off-site reactivation service.

Reactivated carbon is considered an environmentally friendly product since reactivation produces only about 20 percent of the greenhouse gases generated by the production of virgin activated carbon.

Field Services associated with reactivation programs include: spent activated carbon analyses; spent activated carbon removal and packaging; non-hazardous and/or hazardous waste handling; transportation to the reactivation plant; carbon vessel inspection with minor repair; and vessel reloading with reactivated carbon.

Reactivated carbon is considered an environmentally friendly product since reactivation produces only about 20 percent of the greenhouse gases generated by the production of virgin activated carbon. Reactivation ends the chain of custody for adsorbed contaminants, eliminating spent carbon handling and disposal liabilities. Some facilities may qualify to receive environmental credits issued by regulatory agencies for waste minimization due to the fact that reactivated carbon is considered a recovered resource.

In addition to the “green” solution offered by reactivated carbon, GAC adsorption offers many other environmental benefits to chemical manufacturers. GAC technology helps plants maintain emissions permit levels, meet state and local environmental requirements, and adhere to EPA guidelines and regulations such as the Resource Conservation and Recovery Act (RCRA), the Clean Water Act, and the Clean Air Act, particularly its NESHAP (National Emission Standard for Hazardous Air Pollutants) program and benzene regulations.

A successful long-term growth strategy requires that companies take a proactive stance with regard to sustainability. While carbon adsorption is considered a "mature" technology used to treat many of the same organic contaminants for over four decades, one area that has the potential to expand its use is contaminants of emerging concern (CECs) and other increasing environmental issues. The EPA maintains a contaminant candidate list (CCL) of CECs, detailing substances not currently regulated by the federal government but which the EPA may consider for future regulation. Some carbon manufacturers provide forward-looking assistance to the CPI by monitoring the EC list, offering a preview of what federal and state rules may require for treatment technologies, and utilizing their R&D component to advance the use of activated carbon and treatment methods for removing ECs.

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How does a chemical facility determine if GAC adsorption is the best technology to meet its organic contaminant removal needs? Prior to the design of a GAC system, a pilot plant study should be performed to determine if the technology will meet discharge permit requirements, and to quantify optimum flow rate, bed depth, and operating capacity on FOR a particular liquid or gas. This information is required to determine the dimensions and number of carbon contactors required for continuous treatment. Carbon manufacturers can then accurately predict the viability, capital and operational costs of applying adsorption treatment at a chemical plant. These costs can be compared to other applicable technologies.

Carbon adsorption and reactivation systems are at work in chemical, petrochemical, and oil-refining plants around the world. The case studies below detail three examples of GAC adsorption programs undertaken recently at facilities in the United States.

Every chemical manufacturer must balance the ongoing demands of achieving regulatory compliance while maintaining operational profitability and creating high-quality products. For organic contaminant removal from liquids and gases in industrial process applications, GAC remains a proven, reliable way to satisfy environmental management demands and product purification needs. Furthermore, use of reactivated carbon instead of virgin carbon for organic contaminant removal offers additional cost efficiencies and environmental benefits.

GAC Adsorption Case Studies

Case Study 1: VOC Abatement in Maintenance, Startup, Shutdown (MSS)

Challenge: Regulations in many states require VOC abatement to meet permit requirements associated with MSS activities. A large oil refinery in Texas needed to comply with MSS permit requirements established by the Texas Commission on Environmental Quality (TCEQ). The refinery also wanted to mitigate hazardous waste liability, reduce its carbon footprint, and contain costs. Refineries typically use vacuum trucks equipped with sumps and vacuum tanks to clean up gasoline spills at the facility, an activity classified under MSS. The laydown yard where the vacuum tanks and sumps are cleaned can also be classified as an MSS site. Gasoline contains the volatile aromatic compounds benzene, toluene, ethylbenzene, and xylene (BTEX), among others. The majority of the VOC abatement for MSS conformance is needed for benzene, which is highly regulated under the Benzene National Emission Standard for Hazard Air Pollutants (NESHAP). It is necessary to capture the VOC emissions coming off the vacuum tanks and at the laydown yard.

Solution: Because the EPA designates use of a carbon adsorption system as a Best Available Control Technology (BACT) for VOC remediation at chemical facilities, many refineries select this option. The vacuum trucks are equipped with a scrubber for primary treatment followed by carbon adsorber canisters to provide secondary treatment of VOC emissions coming off the trucks and vacuum tanks. Each carbon canister typically holds 1,000 pounds of GAC for treating air sources up to 750 cfm.

At the laydown yard/MSS site, air movers typically consist of two carbon beds containing 12,500 pounds of GAC with a flow rate of 10,000 scfm for the high-volume air emissions. Reactivated vapor phase activated carbon is typically used in these emissions control activities. The reactivated carbon is a cost-effective alternative to virgin carbon. It also contributes to a lower overall CO2 footprint for adsorption because it can be recycled and reused with the need for new raw materials.

This solution allowed the refinery to meet VOC environmental regulations and permit requirements, while reducing its carbon footprint and costs by using GAC adsorption technology along with off-site reactivation and reuse.

Case Study 2: Environmental Responsibility at a Chemical Facility in the Southern U.S.

Challenge: A large, multi-national chemical manufacturer was seeking an environmentally friendly industrial wastewater recycling and reclamation solution at one of its facilities in the Southern U.S. The plant wanted to reuse its process wastewater, thus decreasing its raw water intake from a nearby river and reducing its discharge volume to a local wastewater treatment plant.

The plant sought to reduce costs by purifying and reusing its industrial wastewater generated from the manufacturing processes. A principal concern was whether carbon adsorption could adequately purify the industrial wastewater for reuse due to the fact that the waste stream contained organic contaminants that were detrimental to their final product.

Solution: The chemical manufacturer was already using GAC adsorption technology to handle other product purification needs. After researching available options, it was determined that GAC offered the best potential for the removal of dissolved process contaminants and impurities in its industrial wastewater. So, in late 2011, the carbon manufacturer conducted an organic contaminant removal trial at the plant using a portable liquid treatment unit and acid-washed virgin GAC. When the trial results proved satisfactory, the plant decided to purchase a full-scale carbon adsorption system. The modular carbon adsorption system was configured as two adsorbers with connecting piping, with each adsorber containing 20,000 pounds of GAC and treating up to 100 gpm. The process wastewater was purified through GAC adsorption and recycled into the plant process, thereby reducing raw water intake from the nearby river as well as the volume of wastewater sent to the local wastewater treatment plant. In addition, the facility chose to have its spent activated carbon reactivated by the carbon manufacturer, who provides off-site reactivation services.

Through the use of a GAC adsorption system, the chemical manufacturer was able to remove organic contaminants effectively from its process wastewater, thereby purifying the water for reuse. In the process, the plant also demonstrated environmental responsibility by decreasing its raw water intake from a nearby river and reducing its influent at a local wastewater treatment plant. Additionally, by reducing its raw water intake, the plant minimized its impact on the river and allowed it to function in a more natural manner.

Case Study 3: Organic Compound Reduction in Plant Wastewater

Challenge: In 2011, a prominent chemical manufacturer invested a large amount of capital at its factory in the Southern U.S. to meet skyrocketing demand for one of its products. The product and its derivatives are used in a broad range of chemical compounds that have applications in industrial, consumer, agricultural, and pharmaceutical end-use products.

The plant was seeking a cost-saving alternative to wastewater disposal. If the factory could find an in-house treatment for the industrial wastewater to reduce its organic chemical content, the water could go to water treatment in the plant instead of disposal.

Solution: An engineer at the chemical facility contacted a carbon manufacturer after exploring available options for the organic contaminant removal in its wastewater. A solution with a rapid turnaround time from design to delivery was required. The carbon manufacturer quickly made a recommendation, conducted pilot testing for suitability, and installed a modular carbon adsorption system configured as two adsorbers with connecting piping, with each adsorber containing 20,000 pounds of GAC and treating up to 100 gpm. The system was custom-designed to allow process wastewater to be purified through GAC adsorption. Instead of virgin carbon, the refinery reduced its carbon footprint and costs by purchasing a large volume of reactivated-grade carbon and implementing an ongoing protocol for spent activated carbon reactivation by the carbon manufacturer. The chemical plant leased the carbon adsorption equipment from the carbon manufacturer, who also provided Field Service personnel for equipment maintenance and troubleshooting.

The chemical plant met its cost savings goal by selecting a carbon adsorption system that could effectively reduce and remove organic contaminants in its industrial wastewater so the water could go to water treatment in the plant instead of disposal. The use of reactivated GAC instead of virgin activated carbon also provided cost savings as well as a reduction in the carbon footprint when compared to the use of virgin activated carbon.

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About Calgon Carbon Corporation

Calgon Carbon Corporation (NYSE: CCC) is a global leader in services and solutions for making water and air safer and cleaner and for purifying food, beverage, and industrial process streams. Headquartered in Pittsburgh, Pennsylvania, U.S., Calgon Carbon employs approximately 1,100 people at more than 15 carbon manufacturing, reactivation, and equipment fabrication facilities in the U.S., Asia, and Europe. The company also has more than 20 sales and service centers throughout the world. In Europe, Calgon Carbon is known as Chemviron Carbon.

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