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Optimize Water Cleanup with Activated Carbon

Follow a few pointers to make the most of your adsorption system

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TREATING AND reusing process water is a multidimensional challenge for process plants. Compliance with regulatory requirements to prevent and mitigate industrial pollution can require significant capital investment as well as ongoing maintenance outlays. The increasing scarcity and cost of fresh water for production processes also compounds the problem. (For insights on how major chemical manufacturers view water issues, see “The Tide is Turning,” www.ChemicalProcessing.com/articles/2013/sustainable-water-management-the-tide-is-turning/.) Ultimately, equally compelling pressures to address product purification needs, reduce the carbon footprint, and operate efficiently and profitably ratchet up the challenges.

The hard truth is that process plants need a practical solution that’s economical and regulatory-compliant. For more than 40 years, no other method has offered better results for control of organic chemicals in liquids and gases than activated carbon adsorption. However, some plants undermine their treatment efforts. So, let’s go over a few pointers.

DETERMINE THE BEST METHOD

Don’t presume that one process can handle everything. Instead, put in time to identify the most appropriate technology for the job(s) at hand. A wide range of treatment technologies, e.g., reverse osmosis (RO), ion exchange and granular activated carbon (GAC), exist

and can be used alone or in combination for industrial water treatment. The most-appropriate technology depends upon the feed water quality and effluent water purity required for a given application.

RO systems typically remove or reduce dissolved mineral salts, organics and other particles; they may require water pretreatment to protect the RO membranes against fouling, scaling or chemical degradation. Such systems usually incur higher investment and operating costs than a GAC system.

AVOID COMMON ERRORS

Plants potentially can compromise the life and efficiency of their GAC by making some all-too-frequent mistakes:

- *Installing an activated carbon system based on process assumptions without an actual pilot test.* Any trials should include appropriate comprehensive sampling and analysis so that the pilot can be meaningful and not simply raise more questions because insufficient results were obtained. Often the analytical costs will be the most significant portion of the pilot-plant costs.
- *Leaving spent carbon online for an excessive amount of time to save on change-out costs.* This can make the spent carbon unsuitable for reactivation due to contamination level and calcification.
- *Overlooking the potential need for prefiltration.* Undissolved contaminants and solids may limit access to the carbon and greatly reduce bed life. So, pretreat such streams to allow the activated carbon to focus on adsorption rather than having to contend with scaling or deposits.

CONSIDER SOME SUCCESSFUL RECENT APPLICATIONS

One prominent chemical maker sought a cost-saving alternative to wastewater disposal. Specifically, it was looking for a way to reduce the organic chemical content of its process wastewater so that water could go to a water treatment unit at the plant. After evaluating the available options, the site installed a modular carbon-adsorption system configured as two adsorbers with connected piping; each adsorber contains 20,000 pounds of GAC and treats up to 100 gpm. Instead of using virgin carbon, the plant 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 maker leased the carbon adsorption equipment from the carbon vendor, which also provided field service personnel for equipment maintenance and troubleshooting (Figure 1).

A major international chemical manufacturer wanted to reuse its process wastewater, so it could decrease its raw water intake from a nearby river and reduce its discharge volume to a local wastewater treatment plant. A principal concern was whether carbon adsorption could adequately purify the wastewater, which contained organic contaminants detrimental to the final product. After a trial test proved satisfactory, the plant decided on 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 purified wastewater was recycled to the process.

FIELD SERVICE



Figure 1. Vendor usually handles the installation of fresh activated carbon.

Systems with ion exchange resins can produce high-purity deionized water for reuse by exchanging the ions present in the water. The choice of resin depends upon the specific ions present. These systems typically aren't used to remove soluble organic species as GAC does.

GAC is a highly porous, high-surface-area adsorbent onto which contaminant molecules collect. It has an excellent track record as a cost-effective material for removing organic contaminants from liquids and gases. At process plants, GAC finds wide use in liquid and gas purification and to purify and reuse process water. GAC also meets regulatory requirements in wastewater treatment, groundwater remediation and for volatile organic compound (VOC) abatement in vapor-phase applications. GAC technology can help plants maintain emissions permit levels, meet state and local environmental requirements, and adhere to U.S. Environmental Protection Agency (EPA) guidelines and regulations such as the Resource Conservation and Recovery Act, the Clean Water Act and the Clean Air Act, particularly its National Emission Standard for Hazardous Air Pollutants program and benzene regulations.

Recycling or thermally reactivating carbon gives process plants the opportunity to reduce cost and waste, save energy, lower carbon-dioxide emissions and conserve natural resources while decreasing the long-term liability of spent-carbon disposal.

In fact, GAC has been classified as an EPA Best Available Technology (BAT) for removal of many organic contaminants. As defined by the EPA, "BAT effluent limitations guidelines, in general, represent the best existing performance of treatment technologies that are economically achievable within an industrial point source category or subcategory." That being said, how does a chemical company determine if GAC adsorption is the best technology to meet its organic contaminant removal needs?

SELECT THE RIGHT GAC

A fundamental consideration is choosing the type of activated carbon that will deliver on your water purification and reuse goals. Virgin GAC is best reserved for initial system startup and reactivation of spent GAC (which we'll discuss later).

A standard, unimpregnated, bituminous-coal-based material made by the re-agglomeration method is used most often for adsorption of organic contaminants in industrial applications because it has a wide range of pore sizes to adsorb a broad

variety of organic chemicals.

Re-agglomerated GAC is produced by grinding the raw material to a powder, adding a suitable binder for hardness, recompacting and then crushing to the specified size. Next, the material is thermally activated in a furnace using a controlled atmosphere and high heat. The resultant product has an incredibly large surface area per unit volume and network of submicroscopic pores where adsorption takes place. GAC has the highest volume of adsorbing porosity of any known material. Amazingly, five grams of re-agglomerated carbon have the surface area of one football field. Re-agglomerated carbon is generally preferred over direct activated because it's a more-robust material with a fully developed porosity, and at the same time has the necessary strength to withstand use and reuse.

To ensure optimal GAC adsorption operations, process plant installations typically include carbon adsorption equipment with the associated transfer piping. These systems can be operated with single- or multi-stage vessels, depending upon the desired treatment objective. The adsorption system generally follows chemical clarification and filtration and precedes disinfection, if these steps are required.

Activated carbon can remove a variety of VOCs and semi-volatile organic compounds in one unit operation. It's important to fully characterize a stream prior to analyzing it for activated carbon purification. Information on a vapor-phase stream should include all VOCs and gases present, humidity concentration, temperature and pressure. All these factors will affect activated carbon performance. Similarly, characterization of a liquid-phase stream, including its ionic content and profile, types and concentrations of suspended solids, and pH, is crucial. Capacity tests that measure the mass of adsorbate removed per unit weight or unit volume of activated carbon then can measure adsorption effectiveness.

PILOT THE PROCESS

When considering a GAC system, a pilot plant study can determine if the technology will meet discharge permit requirements. Pilot plant testing of actual streams is the most reliable means to predict performance. Pilots should match the full-scale project equipment as closely as possible as far as superficial velocity, bed depth and empty bed contact time. For example, you can conduct an organic contaminant removal trial that uses a portable liquid-treatment unit and a liquid-phase GAC. Organics readily adsorbed by GAC include:

- aromatic solvents (benzene, toluene and nitrobenzenes);
- chlorinated aromatics (polychlorinated biphenyls, chlorobenzenes and chloronaphthalene);
- phenols and chlorophenols;
- fuels (gasoline, kerosene and oil);
- polynuclear aromatics, e.g., acenaphthene and benzopyrenes; and
- pesticides and herbicides, e.g., DDT, aldrin, chlordane and heptachlor.

The pilot study also should quantify optimum flow rate, bed depth and operating capacity for a particular liquid or gas. This information is needed to determine the dimensions and number of carbon contactors required for continuous treatment. Other options also might be possible. For example, point source treatment of lower flows may provide a more-economical alternative than whole effluent treatment. Through use of computer predictive modeling or treatability studies, a supplier can determine if carbon adsorption technology can effectively reduce the concentration of the pollutants to levels that would allow discharge into the total wastewater stream — thus eliminating the need for more-expensive treatment methods for the total wastewater flow. By using these various studies and analyses, activated carbon manufacturers accurately can predict the viability as well as capital and operating costs of applying adsorption treatment, allowing you to compare these costs to those of other applicable technologies.

KNOW WHEN TO REPLACE THE GAC

During the carbon adsorption process, the available surface and pores of the GAC fill up with chemicals. At some point, the system no longer can meet the required performance criteria — often this is determined when the effluent quality from the carbon treatment vessels begins to approach the quality of the influent. The carbon is said to be “spent” and must be replaced. The spent carbon then either is discarded or recycled for reuse.

OPT FOR REACTIVATION

Three alternatives exist for dealing with spent carbon. The first is shipping it to a landfill or incinerator. However, this approach necessitates the purchase of new carbon and isn't the most environmentally friendly.

Regeneration via either a chemical or steam process may offer advantages over disposal in a landfill. However, this option generally is reserved for recovering and reusing a valuable adsorbate. It also is less efficient than reactivation.

The third option, high-temperature thermal reactivation, usually makes the most sense. The process destroys the adsorbed organic compounds and restores the GAC's adsorptive capacity. Reactivation can achieve up to 95% recovery of the virgin activated carbon's capacity. The reactivated material then can be blended with a small amount of virgin carbon to make up for the minor loss of volume.

Over the past few years, reactivation and reuse have surged in popularity at process plants for several reasons. From an environmental standpoint, reactivated carbon is considered an environmentally friendly product because reactivation produces only about 20% of the greenhouse gases generated in making virgin activated carbon. Moreover, GAC has a nearly infinite reactivation capability, so it rarely ends up in a landfill or incinerator. Reactivation is a logical choice for companies that incorporate sustainability in their long-term strategy.

Reactivation also delivers significant cost savings — it typically costs 20–40% less than purchasing virgin GAC. In addition, it 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 because reactivated carbon is considered a recovered resource.

The profiling and testing processes to identify reactivation as an option are very straightforward. Depending upon the economics and volume of spent carbon produced, some plants may opt for onsite reactivation facilities. Those deciding to contract for off-site reactivation services should look for a vendor with the following field capabilities:

- spent carbon analyses;
- spent carbon removal and packaging;
- appropriate waste handling (hazardous or non-hazardous);
- transportation to the reactivation plant;
- carbon vessel inspection with minor repair; and
- vessel reloading with reactivated carbon.

TACKLING EMERGING APPLICATIONS

Carbon adsorption has treated some organic contaminants for

more than four decades and is considered a mature technology. However, its role promises to expand as the EPA regulates additional chemicals. The agency maintains a contaminant candidate list of chemicals of emerging concern (CECs) that the EPA may consider for future regulation. Some carbon manufacturers like Calgon Carbon provide forward-looking assistance to chemical makers by monitoring the CEC list, offering a preview of what federal and state rules may require for treatment technologies, and conducting research and development to advance the use of activated carbon and treatment methods for removing CECs.

Every chemical manufacturer must contend with 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 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 offers additional cost efficiencies and environmental benefits. ●

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