Introduction

Treatment technologies that are commonly used to treat spent solvent wastewaters are steam stripping, carbon adsorption, and biological treatment. These technologies have also been determined by EPA to represent Best Demonstrated Available Technology (BDAT) for wastewaters containing any of the 25 spent solvents that are defined under the hazardous waste listings of F001 through F005. All of these technologies are demonstrated and a considerable amount of information exists on the waste characteristics that affect performance. Therefore, it needs to be evaluated regarding technology selection and use. One area of treatment design that has not been examined to any great extent, however, is whether past cost optimization studies are still valid in view of changes in treatment requirements associated with the land disposal regulations (LDR) and other regulations under the Hazardous and Solid Waste Amendments (HSWA) of 1984.

The principal purposes of this paper are to examine some of the new cost elements associated with each of the technologies mentioned previously and to provide some "food for thought" in designing new/modifying existing treatment systems. This paper, while providing some information on the operation and applications of these technologies, will focus on the changing economics of wastewater treatment and associated changes in the selection and sizing of these technologies. Following a discussion of each of these technologies, I have performed an optimization analysis which shows the impact of the land disposal restrictions rule on treatment economics.

Steam Stripping

Description

Because the term "steam stripping" is often used interchangeably with batch distillation, an important first step in describing the operation and application of this technology is the definition of terms. Steam stripping, as used here, and described in EPA's spent solvent final rule of November 1986, refers to a type of distillation technology that is used to treat wastewaters that contain low concentrations of volatile organic compounds. It is distinguished in two significant ways from the technology of batch distillation which uses steam to strip volatile compounds. First, steam stripping is used for low concentration wastestreams, with roughly less than one percent spent solvent content, compared to batch distillation which generally is used for wastes containing 50 to 90 percent spent solvents. Second, the primary purpose of steam stripping is to comply with wastewater treatment standards. The organics removed can be recovered, however, and somewhat offset treatment costs. For batch distillation, the primary purpose is economic recovery of spent solvents.

Application

A stream stripping unit consists of a boiler, a stripping section, a condenser, and a collection tank. The number of equilibrium stages needed (either in the form of trays or packing) in the stripping section depends on the particular waste to be treated.

In practice, steam stripping is used by a number of manufacturing facilities including those that manufacture agricultural intermediates or pharmaceuticals, where solvents are used as carrier solvents. Some commercial solvent recovery facilities use steam stripping where wastes have significant concentrations of water. Facilities also use steam stripping to treat residuals from solvent extraction recovery processes.

Steam stripping can be used to treat most of the F001 to F005 spent solvent compounds. EPA based BDAT on steam stripping for only 12 of the 25 spent solvents; however, the rulemaking record makes clear that for many of the compounds, treatment data were not available for steam stripping. Regardless, steam stripping can be used, provided the required standards can be achieved. Waste parameters that affect the selection of steam stripping are filterable
solids, oil and grease, total organic carbon, and other hazardous constituents that are minimally volatile.

**Selection and Optimization Considerations**

For facilities that plan to use, or are using, steam stripping as a treatment technology, a number of design and operating factors should be re-examined in light of the LDR and other regulations under HSWA.

First, and foremost, facilities need to examine the size of the steam stripper. Prior to the land disposal rule, many facilities would size steam strippers for 90 to 95 percent removal, and then use carbon as a polishing step. Under EPA's "derived from" rules, the spent carbon is also a hazardous waste that will now require treatment prior to land disposal. As a consequence of the treatment costs associated with the spent carbon, it may now be more cost effective to increase the size of the steam stripper and either eliminate the carbon system or significantly reduce the pollutant loading on the carbon system so that disposal costs are significantly reduced.

Another aspect to consider in the design of steam strippers is the type of trays. Some trays provide better contact and, therefore, increased efficiency. They may be more difficult to clean, however, and as a consequence, generate larger quantities of material to dispose. Again, under EPA’s "derived from" rule, the cleaning waste is also hazardous. Along this same line, facilities may also want to consider pretreatment with polishing filters to reduce fouling and associated cleaning costs.

EPA also has proposed regulations which govern air emissions from steam strippers (as part of the Hazardous and Solid Waste Amendments of 1984, Section 3004). As a consequence, facilities still in the planning stages should investigate various optimization scenarios for the stripper condenser. Examples include comparing the costs of chilled water versus the use of carbon adsorption downstream from the condenser. Another possibility is a larger condenser instead of add-on carbon adsorption to remove hazardous organic compounds. It would also be prudent to consider how you could modify the system if regulations were to become more stringent. Given the fact that many areas of the country are looking to further reduce VOC air emissions, facilities may want to build systems that can easily be modified. For example, you may want to pipe the system so that a second condenser could be easily retrofitted.

A final point regarding the use of steam stripping is that many of the facilities that use this technology will discharge the streams to POTWs or surface waters covered by an NPDES permit. These discharges would not be subject to land disposal restrictions, but rather, to the appropriate federal, state, and local regulations.

**Carbon Adsorption**

**Description**

Carbon adsorption can be used to treat spent solvent wastewaters by adsorbing the organic compounds onto specially prepared carbon granules. Activated carbon is derived from virtually any carbonaceous material including wood, coal, coke, and petroleum residues. The treatment system itself is quite simple, consisting of a packed column in which the wastewater generally enters from the top and discharges after the distribution plate. This plate serves to minimize the potential for channeling in the carbon bed.

Carbon can be purchased with a range of properties depending on the particular needs. These properties include surface area, pore size, particle size, hardness, and iodine numbers. The latter characteristic refers to a bench-scale test where the amount of iodine adsorbed is measured and used as an indicator of adsorption for low molecular weight organics.

**Application**

Carbon adsorption can be used for a wide range of F001 to F005 spent-solvent wastewaters. EPA determined that carbon adsorption, alone or in combination with other technologies, represents BDAT for eight of the 25 F001 to F005 compounds. The waste parameters that should be considered in selecting this technology are type and concentration of organic compounds, filterable solids content, oil and grease, and the type and concentration of various metals present in the waste.

**Selection and Optimization Considerations**

An important consideration regarding whether to use carbon adsorption is the regeneration and/or disposal of the carbon. As noted earlier, the spent carbon is considered a hazardous waste under EPA's "derived from" rule and facilities would therefore need to comply with RCRA provisions and incur associated costs for storing, transporting, and disposing of this material.

As a result, an important new consideration in optimizing the size of the beds is the number of times that the spent carbon has to be transported. It might be advantageous to increase the size of the beds to minimize the number of times that the spent carbon has to be transported as a hazardous waste. Of course, these costs would need to be compared with other offsetting costs including higher pumping costs
associated with the greater pressure drop across the larger bed.

Another factor that plays an important role in cost optimization is the type of carbon selected. It may be possible to use a carbon that is more expensive initially, but can be used for longer periods of time before regeneration.

**Biological Treatment**

*Description*

Biological treatment involves the use of naturally-occurring, acclimated, or genetically-altered microorganisms to degrade organic contaminants in the wastewater. Aerobic treatment is the most common, wherein organic constituents are converted by microorganisms to carbon dioxide, water, and cell protein. In the absence of oxygen (known as anaerobic treatment), wastes are converted to methane and carbon monoxide.

*Application*

Biological treatment can be used for most of the F001 to F005 spent solvents. EPA has determined that this technology, alone or in combination with steam stripping or biological treatment, represents best demonstrated available technology for nine of the 25 F001 to F005 spent solvents. Waste parameters that affect the selection of this technology include filterable solids, oil and grease, the presence of toxic metals, surfactants, and the presence of refractory organic compounds.

*Selection and Optimization Considerations*

Biological treatment can result in the generation of solid residuals that would be classified as hazardous under EPA's "derived from" rule. Accordingly, facilities that plan to use this technology need to evaluate costs associated with storage, transport, and disposal of these hazardous residuals. Facilities may also want to take a closer look at technologies that have been developed more recently, such as wet air oxidation to replace or enhance biological treatment. Wet air oxidation would likely be more energy intensive than biological treatment, for example, but the fact that less residual material is generated may result in an overall savings. Additionally, biological treatment of certain compounds can result in air emissions which the EPA is studying with respect to the need for regulation. A final point with regard to the use of biological treatment is that it may be possible to delist the treated residuals. If this is the case, then the economics would not change significantly.

**Cost Optimization Example**

Below is a cost optimization example that compares treatment costs for two systems prior to and after implementation of the land disposal requirements. While this example uses a number of simplifying assumptions, it provides a good illustration of the potential impact that the land disposal rules can have on treatment costs. The particular wastestream being evaluated is one that contains 500 mg/L of methylene chloride and trace amounts of other constituents, including filterable solids and oil and grease. The technologies being compared are steam stripping (10-tray column) in combination with carbon adsorption and steam stripping alone, but with 50 equilibrium stages. The cost analysis has been simplified and includes only capital costs for the various technologies and annual costs associated with disposal of the spent carbon. An actual cost analysis would be much more complex, including such annual costs as regeneration of carbon prior to the need for disposal (remember also, that any wastewater generated as part of regenerating the carbon is also hazardous), disposal costs for non-reuseable material from steam stripping, and costs for air emission controls on the steam stripper. Many of these annual costs have been considered in past optimization studies.

In this example, the facility needs to reduce the concentration of methylene chloride from 500 mg/L to 0.5 mg/L to comply with federal wastewater treatment requirements. It is assumed that a 10-tray column can reduce the methylene chloride content by 99 percent to 5 ppm, and that addition of the carbon system will achieve the 0.5 mg/L standard. It is also assumed a 50-tray steam stripper can achieve a reduction of 99.9 percent and, therefore, achieve the treatment standard alone without the need for carbon adsorption. Prior to the LDR, one could assume minimal costs for land disposal; however, today the treater must include treatment costs for incineration at an approved incinerator prior to land disposal of the spent carbon. The analysis assumes that the carbon is regenerated once every seven days, and after the fifth regeneration cycle it is no longer useful and must be disposed as a hazardous waste. Disposal costs are $300/drum and transportation costs are $500 per trip.

As shown in Table 14-1, the inclusion of treatment costs due to the LDRs reverses the treatment selection picture. Without these costs, the combination system (i.e., steam stripper plus carbon adsorption) is $76,000 less than the 50-tray steam stripper; with these increased treatment and disposal costs converted to capital dollars, the steam stripper is $212,000 less expensive than the combination system based on a present-worth analysis.

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Table 14-1. Cost Optimization Summary

<table>
<thead>
<tr>
<th>Method</th>
<th>Case I</th>
<th>Case II</th>
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<tr>
<td>Steam stripping (10 trays)</td>
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<td>$512,000</td>
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<td>and carbon adsorption</td>
<td></td>
<td></td>
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<tr>
<td>Steam stripping (50 trays)</td>
<td>$300,000</td>
<td>$300,000</td>
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</tbody>
</table>

* Assumes minimal cost for disposal of spent carbon.
* Includes cost for incineration of spent carbon prior to land disposal.

Conclusions

Effective treatment of spent solvent wastewaters can be accomplished with a variety of individual technologies or technology trains. With the promulgation of the land disposal restriction rules and other regulations being developed under the Hazardous and Solid Waste Amendments of 1986, facilities may want to re-examine the economics of the wastewater treatment technologies either planned or now being used.

One important aspect of these recent regulations may well be that past practices of including polishing or back-up systems as part of treatment trains is no longer cost effective. Under today's requirements, facilities may find improved control systems to be a better alternative. One possibility is continuous monitoring of the wastestream and automatic diversion to holding tanks when the waste does not comply with regulatory requirements.