A COMPARISON OF PACKED-COLUMN AND LOW-PROFILE SIEVE TRAY AIR STRIPPERS

E. Mead[1] and J. Leibbert[2]

[1]U.S. Army Corps of Engineers, Hazardous, Toxic, and Radioactive Waste Center of Expertise, 12565 West Center Road, Omaha, NE 68144-3869; Phone: (402) 697-2576, Fax: (402) 697-2595, Email: s.ed.mead@usace.army.mil; [2]U.S. Army Corps of Engineers, Kansas City District, 700 Federal Building, Kansas City, MO 64106-2896; Phone: 816/983-3571, Email: jason.m.leibbert@usace.army.mil

ABSTRACT

Groundwater contaminated with dissolved volatile organic chemicals (VOCs) is a common problem. Air strippers are often used to remove these VOCs from groundwater. Air strippers operate by transferring the VOCs dissolved in groundwater from the water phase to an air phase. Packed-column air strippers and low-profile strippers are commonly used. The demand for low-profile air strippers has increased dramatically in the past few years. Are they always better than the traditional packed-column air strippers? The answer is probably no. There are advantages and disadvantages of each that must be considered in making a selection. Low-profile air strippers are easy to clean if they become fouled and are compact, but they often use more air than packed-column air strippers. This will increase the cost of off-gas (air) treatment. Packed-column air strippers can operate over a wider range of air flow rates. An economic evaluation is often needed in making the final decision.

Key words: *air stripper, packed-column, low-profile, diffused air*, *volatile organic chemicals*

INTRODUCTION

Volatile organic chemicals (VOCs) are common groundwater contaminants. Examples of VOCs are benzene, ethylbenzene, toluene, and xylene (BETX) from petroleum fuel leaks and discarded solvents such as trichloroethylene (TCE). Alcohols, aldehydes, and ketones are not easily air stripped. There are several ways to remove VOCs from groundwater. These include air strippers, activated carbon, and ultraviolet light/hydrogen peroxide/ozone oxidation. This paper discusses removal of VOCs with air stripping. The two types of air strippers used most frequently in hazardous waste remediation are packed-column and low-profile air strippers. Both kinds have been used in the chemical industry for decades. About fifteen years ago, when the hazardous waste industry was just starting, packed-column air strippers were used in most applications. More recently, low-profile air strippers have become popular. Diffused-air strippers are also used, but for most applications are not as efficient and are, therefore, not used as often. In some situations a packaged cooling tower may work. Specifically, this paper discusses packed-column and low-profile air strippers, compares them, and lists advantages and disadvantages of both to provide information for choosing which one to use. Air strippers remove VOCs from wastewater by contacting the water with air. This results in the volatiles being transferred from the water phase to the air (vapor) phase. The air is then released to the atmosphere or treated to remove the volatile organic chemicals and then released to the atmosphere. Air strippers are relatively simple devices, and the information needed to size air strippers is readily available. This is both an advantage and a disadvantage. The disadvantage is that although it is easy to design an air stripper that will get by, selecting the stripper that results in the lowest purchase, installation, and O&M costs (present worth) and meets other design criteria and institutional factors will take more effort. This paper presents information needed to pick and design the correct air stripper for the application.

THEORY

Air stripping involves the mass transfer of VOCs that are dissolved in water from the water phase to the air phase. A one-dimensional mass transfer equation is used to describe the mass transfer flux of VOCs transferring from the water phase to the air phase. The equilibrium relationship is linear and is defined by Henry's Law (Kavanaugh, 1980; Shulka, 1984). This mass transfer can be accomplished in a packed-column, a low-profile, or a diffused-air air stripper. The theory is available in textbooks (Treybal, 1980; McCabe, 1993).

TYPES OF AIR STRIPPERS

Packed-column

A packed-column air stripper consists of a cylindrical column that contains an open-structured packing material (Figure 1). The water containing the VOCs enters the top of the column and flows down through packing material (Treybal,1980). At the same time, air flows up through the column (countercurrent flow). As the water and air pass each other, the VOCs are transferred from the water phase to the air phase. The water phase leaves the bottom of the column with most of the VOCs removed. The VOCs that are now in the air phase exit from the top of the column. Detailed information on packed-column air strippers is available in the literature (Montgomery, 1985; Treybal, 1980; Kavanaugh,1980).

Low-profile sieve tray

Low-profile air strippers operate in a similar way to packed-column air strippers (Figure 2). The difference is that the water flows across trays that are perforated with small holes, over a weir to the next lower tray, tray by tray until the water exits the bottom of the stripper. Air is bubbled through holes in the trays. The VOCs are transferred from the water phase to the air phase as the air is bubbled through the water on the trays. Detailed information on low-profile air strippers is available in the literature (Treybal, 1980).

Diffused-aeration

A diffused-aeration air stripper is a vessel with air diffusers in the bottom of the vessel. Air from the diffusers rises through the water and exits at the top of the vessel. The contaminated water to be air stripped enters the top of the vessel and exits at the bottom (Figure 3). Transfer of the VOCs from the water to the air occurs as the bubbles rise through the water. Transfer of the VOCs from the water to the air can be improved by increasing the vessel depth and by producing smaller bubbles. This kind of air stripper is not as efficient as the other two kinds and is not used as often. Its main advantages are its simplicity, ability to handle high suspended solids, and resistance to fouling. Information on diffused aeration is available in the literature (Kavanaugh, 1980; Patterson, 1985)

DESIGN METHODS

The first step in designing an air stripper is to determine maximum and minimum flow rates of the contaminated water, water temperature, concentrations of VOCs in the water, and maximum allowed concentration of VOCs in the treated water. The designer then determines the type of air stripper (packed-column, low-profile, diffused-aeration) and uses manufacturer's software, commercial software, analytical equations, or graphical methods to determine the size of the air stripper. Packed-column air strippers can be designed by the engineer and filled with commercially available plastic packing. The internal components of low-profile air strippers are more difficult to design. These units are usually purchased from a manufacturer. The commercial software, manufacturer's software, analytical equations and graphical methods that are available to size air strippers are listed below.

Packed-column

The following methods are available for determining the size of a packed-column air stripper:

- Commercial software: Iowa State University
- Manufacturer's software: Carbonair Environmental Systems
- Analytical equations: Treybal (1980), Montgomery (1985), Shulka (1984), Ball (1984)
- McCabe-Thiele graphical method: Treybal (1980)

Low-profile sieve tray

The following methods are available for determining the size of a low-profile sieve tray air stripper:

- Manufacturers' software: Carbonair Environmental Systems; North East Environmental Products
- McCabe-Thiele graphical method: McCabe (1993), Treybal (1980)

Diffused-aeration

The following methods are available for determining the size of a diffused air stripper:

- Analytical equations: James M. Montgomery (1985), Roberts (1984)
- Pilot test results: Patterson (1985)

COMPARISON OF AIR STRIPPERS

Both packed-column and low-profile air strippers are used extensively. Diffused air strippers are also used, but for most applications , are not as efficient and are, therefore, not used as often. Simplicity, ability to handle high suspended solids, and resistance to fouling are diffused air strippers' main advantages. They will not be discussed any further. Both packed-column and low-profile air strippers are capable of removing over 99 percent of many VOC contaminants. There are advantages and disadvantages of both that the designer must consider in making a selection. Both will work in most applications, but one may be more appropriate for the particular application. Both can become fouled with solids that must be removed (Jaeger). It is important that the designer take the time to select the best type for the job. In some cases this is easy. In other cases it may be necessary to perform an economic analysis to help make this decision. The ratio of air to water flow rates is often lower for a packed-tower stripper than for a low-profile air stripper. That is, packed-columns often use less air for a given wastewater flow rate than low-profile air strippers. This is important when air pollution regulations require that air leaving the unit be treated to remove the volatile organic chemicals before being discharged to the atmosphere. In these cases, achieving the lowest air flow rate, and in turn the lowest air pollution control costs, may be the driving force in determining which type of air stripper to use. Packed-column air strippers can operate over a wide range of air flow rates. The advantage of this is that if the water flow rate to the column decreases, the air flow rate can also decrease. This will reduce the cost of treating air emissions. Increasing the height of a packed-column and increasing the air flow through a packed-column will increase the efficiency. However, increasing the air flow beyond a certain point will not be effective. The pressure drop through the packing of a packed-tower air stripper is often lower. This has a direct bearing on the size of the blower, blower motor, and electrical operating costs. Packed-column air strippers must be used for water that tends to foam. Air strippers often become fouled from iron, calcium, manganese, or biological growth. Packed-column air strippers must either have the packing removed for cleaning or be washed with an acid solution (Jaeger). Both operations are difficult.

Low-profile air strippers are often desirable when fouling is expected to occur. Low-profile units are often fastened together tray by tray, and can easily be disassembled for physical removal of the fouling. Some have access ports on the side of each tray for cleaning with a high-pressure spray. Low-profile units are designed to operate over a fairly narrow range of air flow rates. If the flow rate is too high, the air will disperse most of the water. If the flow rate is too low, the water will flow down through the holes in the sieve trays. The main concern here is that if water flow rate decreases as the result of changed operating conditions, air flow rate cannot be decreased very much. That is, the cost of treating the air emissions cannot be decreased. In contrast to the air flow rate, the flow rate of water through the low-profile unit can vary up to a factor of 20 (5 to 100 gpm, for example). Low-profile sieve tray air strippers are usually designed by the manufacturer. Items such as the length, location and height of the overflow weirs, weir geometry, clearance under the down comer, fractional hold area, etc., are very important and must be designed by a manufacturer experienced in the design of sieve tray columns. Additional trays can be added to many low-profile air strippers if additional treatment is needed, and the air blower and motor are capable of handling the increased pressure drop from the additional trays. Institutional factors such as height restrictions or architectural restrictions may require that a low-profile air stripper be chosen even if a packed-tower stripper would otherwise be more cost-effective.

ECONOMIC EVALUATION

The above advantages and disadvantages of each type of air stripper, along with capital costs, installation costs, and long term O&M, must be used to select the best air stripper for the application (Ball, 1984). The Remedial Action Cost Engineering and Requirements System (RACER) software can be used to develop a cost comparison among the various types of air strippers. Major factors in the economic evaluation and comparison of air strippers are the cost of treating the off gas and cost of preventing or removing fouling.

CONCLUSIONS/SUMMARY

Volatile organic chemicals such as benzene, ethyl benzene, toluene, xylene (BETX) and chlorinated solvents such as trichloroethylene (TCE) are often removed from groundwater by air stripping. Packed-column air strippers and low-profile sieve tray air strippers are often used for this. Other types of air strippers such as diffused air strippers or cooling towers are sometimes used, but for most applications they are not as efficient. The following are characteristics of packed-column air strippers:

- Efficiency increases as the packing height increases
- Pressure drop is lower
- Preferred for liquids that tend to foam
- Difficult to clean when fouled
- Often use less air–reduced air pollution costs
- Operate over a wider range of air flow rates

The following are characteristics of low-profile sieve tray air strippers:

- Efficiency increases as the number of trays increases
- Fouling is easier to remove
- Operate over a fairly narrow range of air flow rates
- Operate over a fairly wide range of water flow rates
- Compact
- Aesthetically pleasing
- Fabricated by manufacturer
- Designs include trays that can be stacked

The above advantages/disadvantages along with an economic evaluation must be used to determine the best design for the application.

REFERENCES

Ball, W., M.D. Jones, and M.C. Kavanaugh, 1984. Mass Transfer of Volatile Organic Compounds in Packed Tower Aeration, J. Water Pollution Control Federation, Volume 56, Number 2, pp. 127-136

Jaeger Products, Inc., 1611 Peachleaf, Houston, TX 77039, jpadmin@jaeger.com/1006foul.htm

James M. Montgomery, Consulting Engineers, Inc., 1985. Water Treatment Principles & Design, John Wiley & Sons, New York, pp. 237-261

Kavanaugh, M., and R. R. Trussell, 1980. Design of Aeration Towers to Strip Volatile Contaminants from Drinking Water, Journal AWWA, December, pp. 684-692.

McCabe, W.L., J.C. Smith, and P. Harriott, 1993. Unit Operations of Chemical Engineering, McGraw-Hill, New York, pp. 501-736.

Patterson, J., 1985. Industrial Wastewater Treatment Technology, Butterworths, Boston, 2nd ed., Chap. 18.

Roberts, P.V., C. Munz, and P. Dandliker, 1984. Modeling Volatile Organic Solute Removal by Surface and Bubble Aeration, J. Water Pollution Control Federation, 56, pp. 157-163.

Shulka, H., and R.E. Hicks, 1984. Process Design Manual for Stripping of Organics, EPA- 600/2-84-139.

Treybal, R., 1980. Mass-Transfer Operations. McGraw-Hill, New York, 3rd ed., pp. 275- 313.

SOFTWARE

Carbonair Environmental Systems, Inc., 2731 Nevada Avenue North, New Hope, MN 55427-2864, (612) 544-2154

North East Environmental Products, Inc., 17 Technology Drive, West Lebanon, NH 03784, (603) 298-7061

Remedial Action Cost Engineering and Requirements System (RACER), Talisman Partners, Ltd., 5460 S. Quebec St. Suite 100, Englewood, CO

Figure 1. Simplified diagram of a packed-column air stripper.

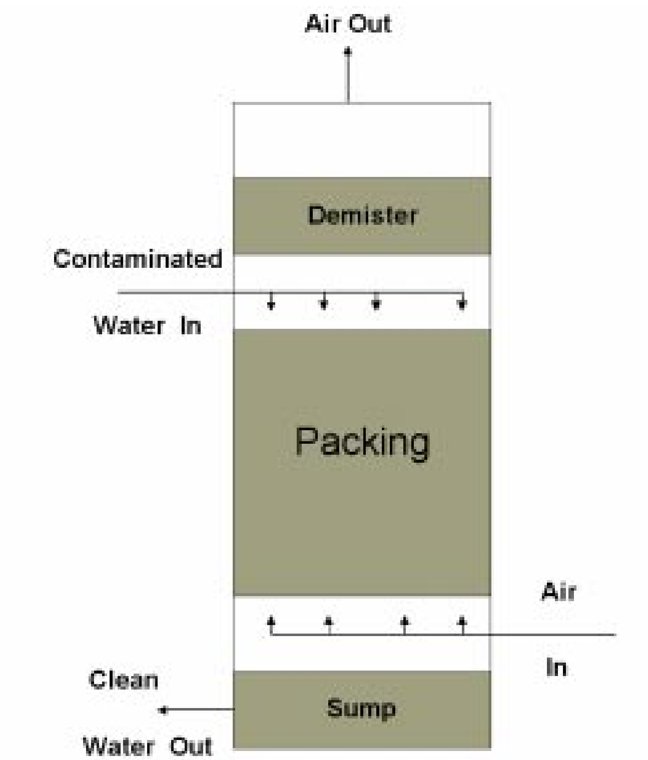

Figure 2. Simplified diagram of a low-profile sieve tray air stripper.

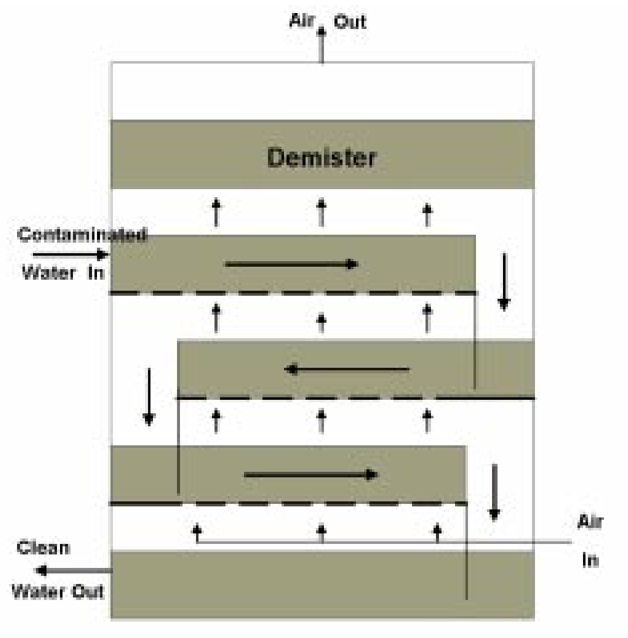

Figure 3. Simplified diagram of a diffused-aeration air stripper.