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MEMBRANE CONTACTORS IN INDUSTRIAL APPLICATIONS

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In a membrane contactor the membrane separation is completely integrated with a conventional phase contacting operation like extraction or absorption. In this way the benefits of both technologies can be fully exploited. The membrane contactor technology is a new technology. The first full scale membrane contactor installations that have been installed in industry are running successfully for some years now. Industrial applications of membrane contactors, including aromatics recovery from a process water, selective removal of heavy metals from a galvanic process bath and ammonia product recovery from an off gas stream, are discussed. Membrane contactors are of interest for the chemical, petrochemical, pharmaceutical and galvanic industry for both water and gas treatment as end of pipe technology but also for product recovery and as integrated process solution. New applications under development—CO_2 membrane gas absorption and pertraction for produced water treatment—are discussed technically and economically to show the wide scope of the technology.

Keywords: membrane contactor; ammonia; carbon dioxide; heavy metals; pertraction; membrane gas absorption.

INTRODUCTION

Although it is difficult to introduce new technologies in industry there is still a large demand for new improved processes, especially in the field of separation technology. Stringent demands are put onto these new separation technologies in order to compete with the existing proven technologies and in order to meet stricter product quality requirements, environmental legislation, energy efficiency demands and last but not least needs for cost reduction. In order to meet these ever increasing needs there is a tendency to combine processes to a hybrid process. In a membrane contactor membrane separation is not only combined with an phase contacting process like extraction or absorption but both processes are fully integrated and incorporated into one piece of equipment. In this way advantages of both processes can be fully exploited. The membrane offers a flexible modular efficient device with a low volume and weight so that it can be easily integrated in existing installations. The extraction or absorption process can offer a very high selectivity and a high driving force for transport even at very low concentrations. Applications of membrane contactors are of interest for the chemical, petrochemical, pharmaceutical and galvanic industry for both water and gas treatment as end of pipe technology but also for product recovery and as integrated process solution.

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Many different developments in the field of membrane contactor technology are going on worldwide. Development of a specific application normally starts with a proof of principle followed by a feasibility study, further development, pilot plant tests and finally full-scale demonstration on site.

After a general introduction some examples of successful developed full-scale industrial membrane contactor installations and on-going developments will be discussed in this paper. The industrial reference installations, in the field of pertraction, emulsion pertraction and membrane gas absorption, help to gain confidence of end users in the membrane contactor technology. With these demonstrations further market introduction will be facilitated as well as development of new applications for membrane contactors.

In the pertraction process, water is treated in a membrane contactor with an extraction liquid. Typical applications are hydrocarbons (e.g., aromatics, phenol, haloginated hydrocarbons) removal and recovery from waste and process water and selective recovery of heavy metals from e.g., galvanic bath liquids or waste water. In a membrane contactor also ammonia can be removed and recovered from waste water in a combined stripping and absorption process.

In the membrane gas absorption process the gas stream to be treated is brought very efficiently into contact with an absorption liquid in the membrane contactor. Typical examples are ammonia recovery from off gases, CO_2 removal from flue gas or indoor air, flue gas desulphurisation, indoor air conditioning, or H_2S removal from natural or bio gas.

PERTRACTION

Principle

Pertraction is a nondispersive membrane based liquid–liquid extraction process. Nonpolar organic substances such as aromatics or chlorinated hydrocarbons can be recovered from process or wastewater flows by pertraction. The organic components are removed from the water by extraction into an organic extractant, which is immiscible with water. The extractant is flowing at one side of the membrane and the water phase at the other side of the membrane. The role of the membrane is to keep the phases separated and to provide a stable interface between the two phases. The membrane itself has no selectivity. The process selectivity must come from the extractant.

The interface between wastewater and extractant is immobilized using a hydrophobic microporous hollow fibre membrane by means of a small transmembrane pressure gradient (~0.1 bar) (Kiani *et al.*, 1984; Klaassen *et al.*, 1994b, Klaassen, 1998), see Figure 1. Contrary to conventional extraction processes there is no direct mixing of extractant in the wastewater stream. This offers important advantages over conventional extraction:

- The often difficult and time-consuming separation between water phase and extractant is not necessary.
- Flows of waste water and extractant are flexible, and can be adjusted independently of another, making process optimisation simple and allowing a highly efficient contact between a large volume of (waste) water and a very small quantity of extractant.
- Pertraction installation can be of very compact construction, thanks to the high specific surface area and good mass transfer of the pertraction membrane modules.
- No differences in density between the water phase and the organic extractant are required and tilt of the installation is allowed.

Alternative techniques for the pertraction process are air stripping, activated carbon filtration and biological treatment. These techniques are only able to remove specific groups of compounds. By air stripping only volatile compounds can be removed. By activated carbon filtration only adsorbable compounds can be removed. Biological treatment is only possible for nontoxic compounds.

Table 1. Comparison pertraction with activated carbon and air-stripping.

	Removal techniques for organic pollutants		
	Activated carbon	Air-stripping	Pertraction
Application for hydrophobic compounds	+	+volatile −nonvolatile	++
Removal at every concentration level	−	o	+
Removal to every desired concentration level	+	o	+
Scale-up problems	o	−	+
Effluent guarantee	−	+	++
Compactness installation	o	−	+

− = poor performance.
o = normal performance.
+ = good performance.
++ = very good performance.

Unlike air stripping and activated carbon filtration, pertraction makes no distinction between volatile compounds such as halogenated and mono-aromatic hydrocarbons or adsorbable nonvolatile compounds such as poly aromatic hydrocarbons. In Table 1 an overview of the comparison between pertraction and alternative techniques is given.

In Figure 2 a typical flow sheet of a pertraction installation is shown. The contaminated water is led through a number of membrane modules which are coupled in series and or in parallel. The number of membrane modules in series determines the removal efficiency for the contaminants whereas the number of modules coupled in parallel are determined by the total water flow rate to be treated.

The extractant is led counter currently through the membrane modules. The contaminants are concentrated in the extractant. The latter can be either directly re-used or regenerated in e.g., a vacuum film evaporator, and can thus continue to circulate in the system, while the pollutants are released in pure form.

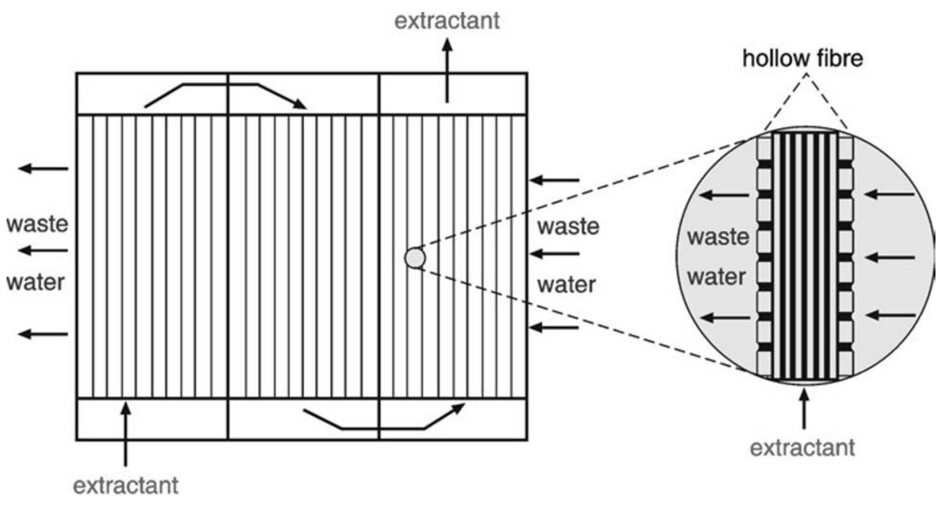

Figure 1. Principle of pertraction.