Survey of European MBR market, trends and perspectives

B. Lesjean* and E.H. Huisjes**

Berlin Centre of Competence for Water, Cicerostr. 24, 10709 Berlin, Germany.
(E-mail: boris.lesjean@kompetenz-wasser.de)
*Corresponding author.
** Now working at Delft University of Technology, the Netherlands

Abstract
A market survey of the European MBR industry was performed while contacting 33 suppliers or retailers of MBR filtration systems and/or MBR plant constructors. The study enabled to identify MBR plants constructed up to 2005: about 300 references of industrial applications (> 20 m^3/d) and about 100 municipal wastewater treatment plants (WWTPs > 500 p.e.) were listed. In average, the capacity of industrial applications is ten fold smaller than municipal applications (median flow of 180 m^3/d and 2,500 m^3/d respectively). In the coming years, at least 70 new MBR plants are expected to be constructed each year, from which about 50 industrial and 20 municipal applications. Taking the installed membrane surface as indicator of market share, it appears that the municipal sector represented in 2003-2005 75% of the market volume. The predominance of immersed MBR filtration systems in both sectors is undisputed, as during this 3-year period they represented 99% of the total installed membrane surface (Zenon-GE and Kubota, 2 non-European suppliers, representing respectively 63% and 30%). If the industrial market can be considered as mature and stabilized, the municipal market is expected to witness a further growth in the next decade under the combined effects of the acceleration of plant constructions and the capacity increase. This provides a commercial opportunity for novel European-manufactured technologies to increase their share in the European and global MBR market.

Key words
Membrane bioreactor (MBR), technologies, market, business, references, Europe.

INTRODUCTION

The technology of membrane separation of activated sludge, commonly referred to as “membrane bioreactor” (MBR), was first commercialized in the 70’s and 80’s for small and niche market applications such as treatment of ship-board sewage, landfill leachate or highly loaded industrial effluents (Stephenson et al., 2000). The MBR systems were at that time based on what have come to be known as side-stream configurations, i.e. the membrane separation step was employed in an external sludge recirculation loop, mainly with in-to-out flow through organic or ceramic tubular membranes. More recently, a new generation of MBR units have appeared, based on the so-called immersed filtration system, working with low negative pressure (out-to-in permeate suction) and membrane aeration to reduce fouling. This resulted in capital and operation cost savings, which rendered the technology viable for the treatment of municipal and domestic wastewater.

In Europe, the first full-scale MBR plant for treatment of municipal wastewater was constructed in Porlock (UK, commissioned in 1998, 3,800 p.e.), soon followed by Büchel and Rödingen WWTPs (Germany, 1999, resp. 1,000 and 3,000 p.e.), and Perthes-en-Gâtinais WWTP (France, 1999, 4,500 p.e.). Only a few years later, in 2004, the largest MBR plant worldwide so far was commissioned to serve a population of 80,000 p.e. (in Kaarst, Germany). The installations has thus grown from ‘small-size WWTPs’ to ‘very large-size WWTPs’ within only a few years.

The quick development pace of the technology resulted in regular and actualized technology reviews, among which some of the most informative were published by Stephenson et al. (2000), MUNLV-NRW (2003), Nieuwenhuijzen et al. (2005), Pinnekamp and Friedrich (2006), or Judd (2006). A recent market study was also completed for the North American continent by Yang et al. (2006), together with a literature survey on research activities and trends. However, to date, no detailed market survey is available for the European continent.

METHODOLOGY

The Berlin Centre of Competence for Water has been appointed by the European Commission (EC) to coordinate the project "AMEDEUS", one of the research projects subsidized by the EC and entirely dedicated to the development of the MBR technology in Europe (more info in www.mbr-network.eu). In order to provide a "snap-shot" of the MBR market in Europe (annum 2005), and to evaluate the trends and developments by the end of the project (annum 2008), the Berlin Centre of Competence for Water has performed a thorough review of the industrial and municipal MBR market in Europe.

It was decided to open the study to all type of MBR technologies (i.e. with flat sheet, hollow fibers or tubular membranes), but to restrict the search only to the units constructed and commissioned up to the year 2005, with a design capacity **greater than 500 p.e. for the municipal applications** (i.e. approx. > 100 m^3/d as nominal flow), and **greater than 20 m^3/d for the industrial units**.

33 European MBR module producers, retailers or plant designers and constructors were identified through internet and specialist press, and were all contacted and asked for their reference list and corresponding main design data. As especially for the municipal applications much information is available publicly, a literature research enabled to complement the collected data. A database was then constructed with the Microsoft software *Access* in order to compile the data of the collected plant references. As the same reference could be encountered several times (for example supplied both by a module supplier and a plant constructor, or found both in a reference list and in the literature), the reference list was checked to identify and eliminate duplicates.

Some specific remarks have to be drawn on the collected information and the data presented later:

- The references were classified according to the module suppliers, and the market analysis was performed only with this "*product source*" perspective (other contributors in the overall MBR market was not accounted for)
- In the results presented later, Wehrle is the sole company which does not produce module but only design and construct MBR plants. In most cases they implemented tubular membranes from the companies Norit X-Flow, Berghof, Memos or Cut in side-stream systems.
- 3 references were presented both by Norit X-Flow and Wehrle: they were accounted for as Norit in the present study.
- About 60 references supplied by Zenon-GE (mainly industrial applications) were not dated: they were therefore distributed arbitrary over the years 2002 – 2005.
- The analysis on installed membrane surface was derived from the information available for some references. Average filtration fluxes were calculated for the different products, specifying between municipal and industrial applications. Extrapolation of installed membrane surface on the missing references was then undertaken using these fluxes.

RESULTS

Market evolution and repartition per supplier

During the study, **409 MBR references** were recorded, among which approximately one quarter was related to municipal references (111 plants) and three quarter to industrial applications (298 units). As expected, the industrial market was the pioneer market in the early 90's, whereas the municipal market really started to kick off in 1999 (Figure 1). In 2002, 154 MBR units could be counted, among which 85% were for industrial applications. Both municipal and industrial witnessed a sharp increase in the following years, corresponding to the commercial success and broad applications of the immersed MBR technologies, offering much lower capital and operation costs. In the next 3 years, the market growth rate was linear with at least **50 industrial units and 20 municipal plants constructed per year**. It is expected that this progression rate will be at least sustained in the

next years. A further acceleration of the rate will depend on improved competitiveness of the technology and the evolution and implementation of European and national regulations.

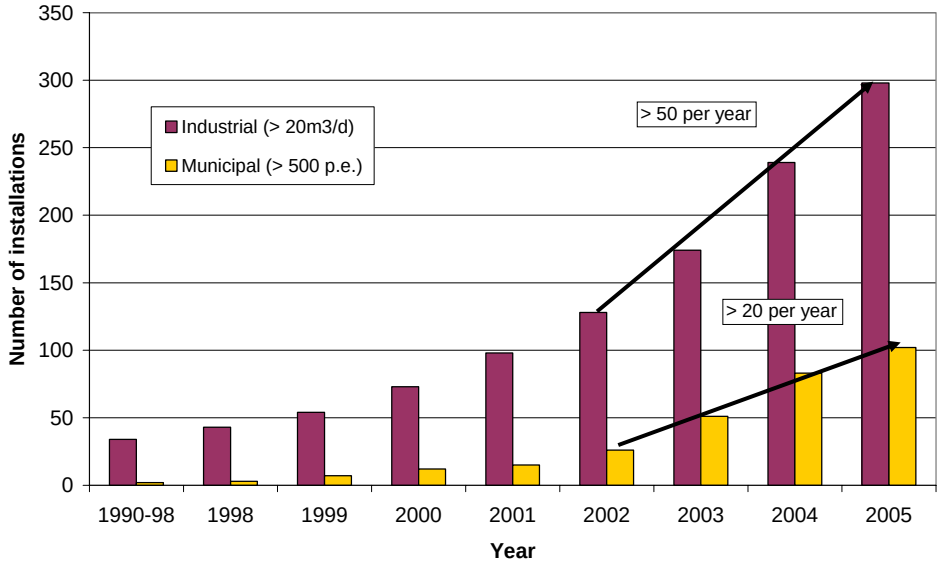

Figure 1. Development of industrial and municipal MBR markets (402 references in graph).

Figure 2 shows the market repartition according to the suppliers of MBR filtration systems. This demonstrates the **predominance of the two suppliers Kubota (Japan) and Zenon (Canada)**[1] on the European market. Their technologies based on immersed filtration modules have shown an outstanding success since 2002. In the recent years, the European market can therefore be seen as a quasi-duopoly of two non-European suppliers. In opposition, the most successful MBR technologies in the 90's based on **side-stream configurations** and supplied by Wehrle, Norit X-Flow, Berghof, Rodia Orelis etc **did not experience any significant market growth in the last 3 years**. This could explain the recent move of companies such as Wehrle and Norit to develop and commercialise novel energy-low MBR filtration systems

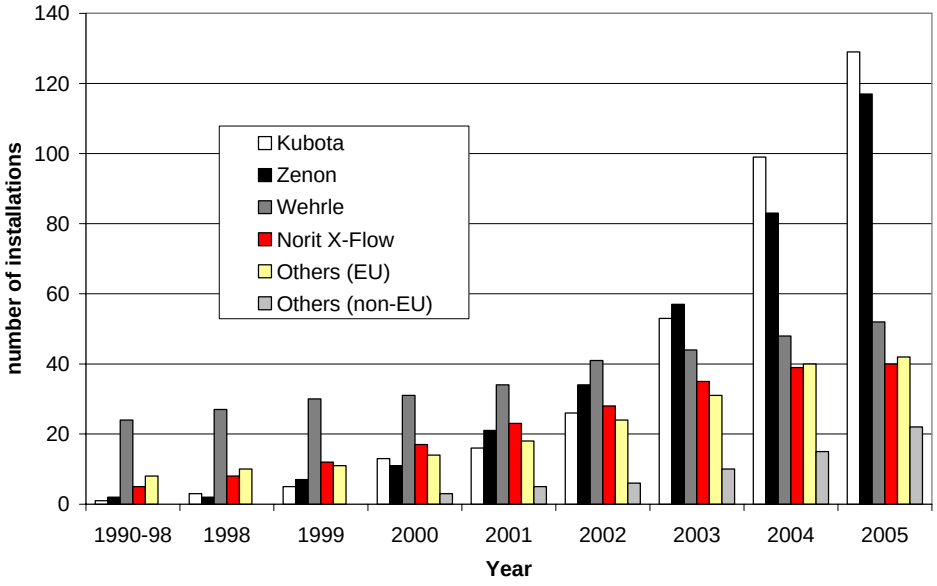

Figure 2. Market repartition per supplier of MBR filtration systems (402 references in graph).

[1] Purchased in 2006 by General Electric (US)

Geographical repartition

Figure 3 presents the geographical distribution of industrial and municipal MBR plants in Europe in the year 2005. For sake of clarity, in both diagrams, only the main market players and the main countries are represented.

Industrial sector. Unexpectedly, **Italy comes in the first position for industrial applications** and gathers 20% of the installed plants. Germany, France, and the Netherlands are the next countries of implantation, with 40 to 60 MBR units in operation. **No real leadership can be noted**, as most of the industrial applications concern small but highly loaded flows, therefore the cost of the filtration system is not the differentiating factor. As expected, **historical and geographical market predominance** can be noted in each country, such as Kubota / Zenon in Italy, Wehrle in Germany, Zenon / Rhodia in France, Norit / Mitsubishi in the Netherlands, Kubota / Wehrle in Spain, or Zenon in Hungary.

Municipal sector. The municipal market looks very different, **4 out of 10 MBR plants being constructed in the United Kingdom** (45 known references, 2/3 being constructed with Kubota). The United Kingdown appears therefore to be the single country hosting more municipal than industrial MBR plants. The next countries for the municipal sector are Germany and Italy, with 10 to 20 plants, followed by France, Spain and the Netherlands with 5 to 10 references. The commercialization of immersed technologies opened the municipal market to the MBR process; this is therefore not a surprise to see that **this market is strongly dominated by the two leaders Zenon-GE and Kubota**. Newcomers with immersed technologies have recently acquired few references, such as KMS-Puron, A3, Toray, but more surprising is the quasi absence of older market players such as Mitsubishi or Memcor (purchased in 2004 by Siemens, Germany).

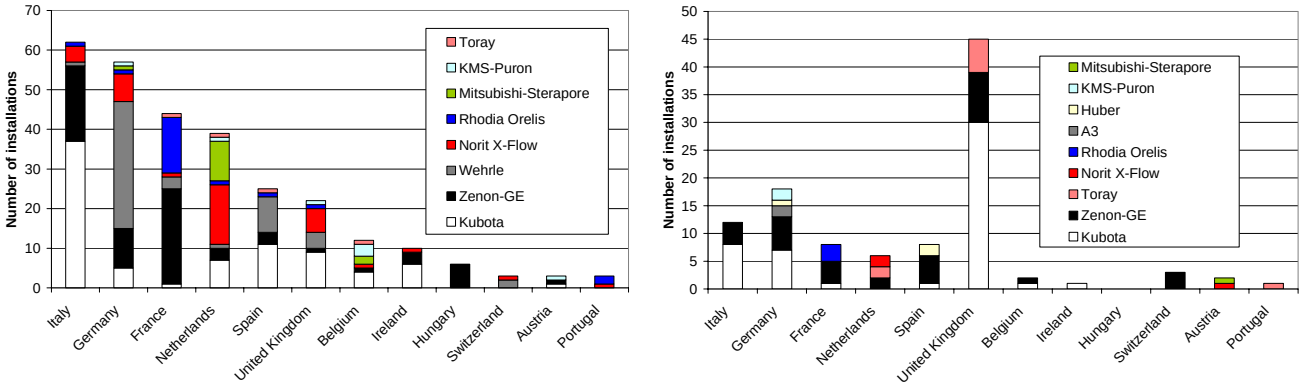

Figure 3. Geographical distribution of MBR references in Europe (a. 285 industrial units in graph, b. 105 municipal plants in graph)

Industrial applications

Figure 4 presents the repartition of the industrial applications for the main suppliers. Historically, the MBR application was **mainly implemented for landfill leachate treatment** (see the long record of Wehrle, both pioneer and leader in Europe on this application). The apparition of immersed systems enabled to diversify the offer on applications with less pollutant loads and more water volumes. Today, the **MBR technology is applied to a very broad range of industry wastewaters presenting carbonaceous pollution** (usually in the range 1,000-20,000 mgCOD/L). Despite landfill leachate treatment, the main applications are find to treat the wastewaters from origins as diverse as cleaning process, food and beverage industry, chemical industry, pharmaceutical industry, textile industry and laundry. Another important sector, not reported in Figure 4 concerns maritime applications, to treat the wastewater aboard boats and marine vessels.

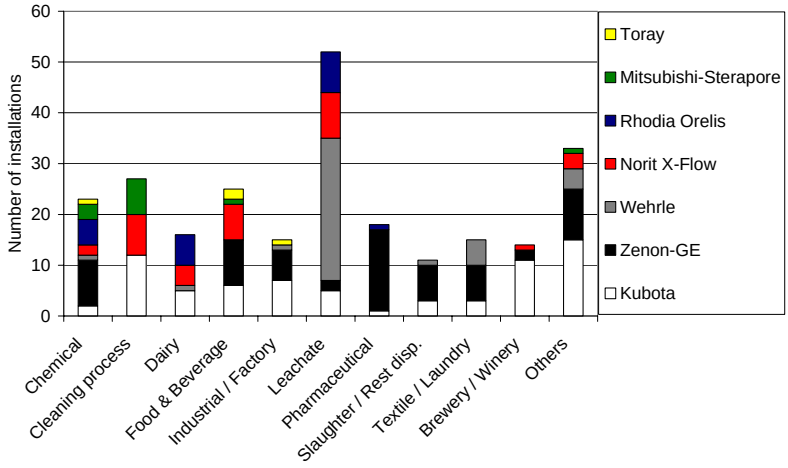

Figure 4. Repartition of industrial applications for main industry suppliers.

Capacity repartition

As shown in Figure 5, for industrial applications, the Kubota technology (flat sheet) appears to be most successful in the lower capacity range, and the Zenon product (hollow fiber) in the upper capacity range. Similarly, in municipal projects, the Kubota technology is preferred in the range 1,000-20,000 p.e., whereas the Zenon system appears to be advantageous for larger plant capacities beyond 20,000 p.e. These results may be distorted by the wide implantation of Kubota in the UK municipal market, by far the largest market in Europe.

The largest plants recorded for industrial and municipal applications are respectively the Daldowie MBR plant in the United Kingdom (sludge water treatment with Kubota, 12,888 m^3/d) and the Nordkanal WWTP in Germany (with Zenon-GE, 80,000 p.e., max. 48,000 m^3/d). However, Figure 5 shows that the favored range for MBR systems is only 100-500 m^3/d and 1,000-20,000 p.e. respectively for industrial and municipal wastewaters. Precisely, when looking at the statistics, **the design capacity of the industrial units is above one order of magnitude smaller than for the municipal wastewater treatment plants**: whereas 50% of the industrial MBR plants are smaller than 180 m^3/d, and 90% smaller than 1,000 m^3/d, the equivalent distribution lays respectively by 2,500 m^3/d and 13,000 m^3/d for the municipal references. Due to the cost reduction and the increased confidence, **a relative greater number of larger plants should be seen in the coming years, especially in the municipal sector** (up to 100,000 p.e.). The construction of few very large MBR plants (> 100,000 p.e.) was recently announced with most publicity; this should however remain exceptional in Europe in the next years, as life cycle costs of WWTP plants equipped with tertiary membrane filtration should in most cases be more economical than MBR (Lesjean et al., 2004), except when compacity is a primary driver for the use of MBR technology.

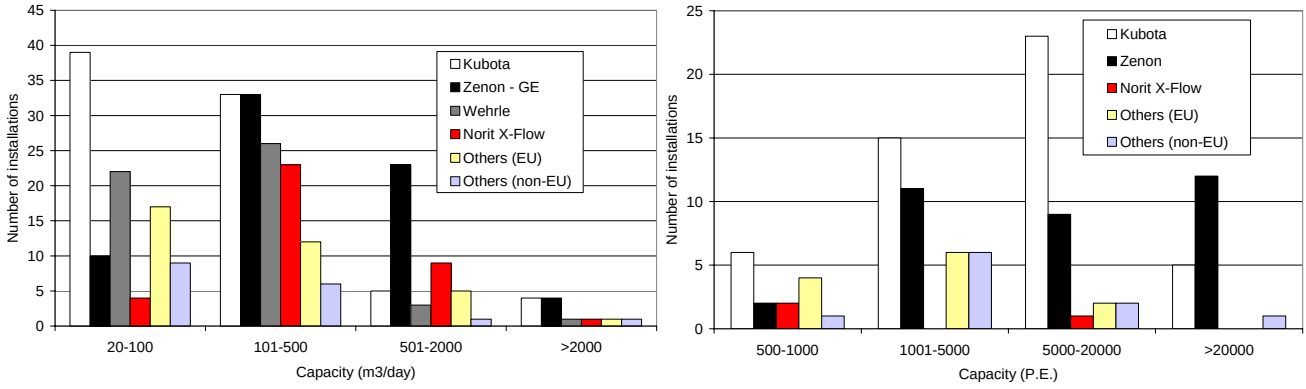

Figure 5. Repartition of MBR plants per capacity and suppliers (a. 292 ref. in graph, b. 111 ref. in graph).

Installed membrane surface

Figure 6 presents the evolution of the installed membrane surface within the municipal and the industrial MBR markets, and the corresponding distribution per supplier. The installed membrane surface confirms that although ¾ of the plants were erected for industrial schemes, given the larger capacity of the municipal plants, **the revenue of the European MBR market originated mostly from the municipal sector since 2002.** In the period 2003-2005, about 400,000m² of membranes were installed in municipal applications, and only 65,000m² in industrial plants. This trend is expected to be even stronger in the coming years, where **most of the revenue growth is anticipated in the municipal market rather than in the industrial sector**. We can estimate that in the next five years 150,000 to 300,000 m² of membranes will be installed per year in Europe, for the far greatest part in municipal projects.

It is also interesting to note that about 670,000 m² of membrane were installed by end 2005 (without considering any possible module replacement), from which as much as 630,000 m² correspond to modules delivered by Zenon-GE or Kubota. This confirms once more the undisputed leadership of these technologies on the European MBR market. This performance results primarily from the quasi-monopole of these two suppliers in regards of the larger municipal plants. Over 540,000 m² membrane installed by 2005 in municipal applications, 475,000 m² equipped the few 18 plants with a capacity greater than 20,000 e.p. (12 of them equipped with Zenon-GE, and 5 with Kubota), most of them constructed after 2003. The success of Zenon-GE for the largest plants marks the difference with Kubota in terms of installed membranes.

These statistics highlight that **the usually reported annual market greater than 10% for the entire MBR market has been since 2002 essentially generated by the implantation and outstanding success of the two leading immersed technologies**. In 2005, the immersed technologies represent 97% of the cumulative installed membrane surface, and more than 99% of the annually installed area over the period 2003-2005 (Zenon-GE and Kubota representing respectively 63% and 30%).

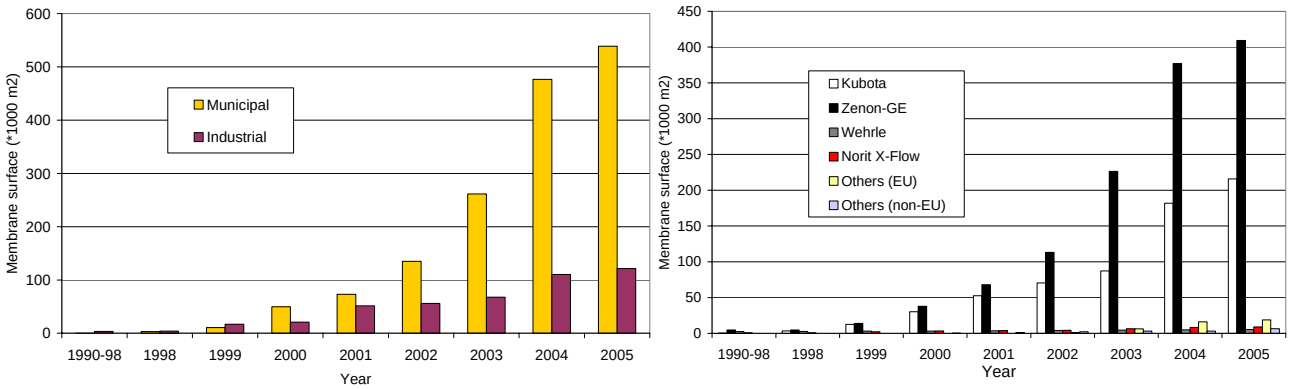

Figure 6. Cumulative installed membrane surfaces (a. repartition municipal vs. industrial, b. rep. per supplier).

Future market trends

The market analysis of the MBR European market in the past 15 years enables to identify the following future market trends for the next decade.

For industrial applications.

The industrial market has become a mature market: the MBR technology is considered as “Best Available Technology” by many industries, and the market is highly competitive over the entire range of plant capacity and wastewater types. The main drivers will remain essentially the national and European regulations (Integrated Pollution Prevention Control Directive 96/61/EEC, Urban Waste Water Treatment Directive 91/271/EEC), and the economical pressure towards internal water

recycling. The number and the size of the constructions will most probably continue under the current conditions (50-60 plants per year with a median capacity of 180 m^3/d), therefore package units mounted in containers or skids will be economically competitive. A gradual displacement of the market to central and eastern European countries can be expected, as well as new and still virgin territories for MBR such as the Scandinavian and Baltic countries.

For municipal applications.
The market is still growing and not mature yet. An increased number and capacity of plants is expected, as well as an increased competition. At medium term, submerged filtration technologies will remain the standard for most cases, at the possible exception of the smaller systems < 5,000 p.e. The main drivers for further growth will be: the European Water Framework Directive (WFD), Urban Waste Water Treatment Directive (91/271/EEC), and Bathing Water Directive, but also increased competitiveness (technological improvement, standardization etc), lack of place, retrofitting of existing plants and water scarcity (water reuse or recycling). The following trends are expected, depending on the capacity range:

- The larger plants (> 20,000 p.e.), although in small number, will keep representing the main share of the market and driving the annual revenue growth. The market volume increase and installed membrane surface will be drawn up by the construction of some very large plants (> 100,000 p.e.), which will remain exceptional, and therefore unrepresentative of the market, but will attract much attention.
- Medium-size plants (5,000 - 20,000 p.e.) will remain the core of the plants to be constructed in the next decade. New suppliers will tackle the market with this size, therefore a strong competition is expected. Plant upgrade and retrofitting (hybrid plant MBR with conventional activated sludge) will constitute a large share of the demand, particularly in central-eastern Europe. Water reuse should motivate MBR projects in southern Europe.
- Small-size plants (semi-central applications, 200 – 5,000 p.e.) will be always handicapped by relative high costs and lack of regulation for this size. Technological adaptations, inspired from industrial applications of similar size (simple, robust and standardized containerized solutions) will render MBR process affordable for this capacity in sensitive and remote areas (tourist sites, camping, villages, etc).
- Households / community units (4 – 50 p.e.) is a concept pioneered by the company Busse in 2000 (Germany, see Table 1). In meanwhile this became a very competitive market (at least 8 products available in Germany), although under leadership of Busse. The units are mostly delivered under maintenance contracts. The number of sales will increase to address wastewater schemes of small and remote communities, but the revenue will remain marginal in the overall European MBR market.

Table 1: Number of BUSSE-MF units installed up to December 2005.

Capacity	1-4 p.e.	5-8 p.e.	10-32 p.e.	36-50 p.e.
Installed units	185	60	15	6

Other considerations in regards to the evolution of the European MBR market
Module replacement. For both markets, a niche will emerge as the constructed plants get older: this of modules replacement. Considering an annual market growth of 10% (new plants) and an average module life span of 5 years, the market of module replacement may ultimately represent up to 40% of the membrane surface sold each year. Most of the new comers in the market are developing their systems so that they can easily replace the products of the two main suppliers (Zenon-GE and Kubota). A standardization process driven by the end-users could accelerate this evolution and contribute to the market development (De Wilde et al., 2007).

Public and private research & development. The European Commission decided in 2005 to boost the MBR technology in Europe through the 6th Framework Program while financing 4 projects entirely dedicated to the development of the MBR technology for municipal applications. These 4 projects (namely AMEDEUS, EUROMBRA, MBR-TRAIN and PURATREAT) will be performed over the period 2006-2009 and formed the projects coalition 'MBR-Network' (www.mbr-network.eu). € 16 millions will be invested over 4 years in this R&D initiative gathering about 50 European and international companies and institutions (Lesjean et al., 2006). In addition, we can estimate the R&D investment of the private sector and other funding bodies (national programs, European LIFE program etc) to be of similar level. Therefore, about € 8 millions per year is anticipated to be pumped in Europe into the development of the MBR technology in the next years. This is very significant when considering the actual market size, estimated to be around € 57 millions per year, (Frost & Sullivan, 2005), i.e. up to 2009 10 to 15% (!) of the yearly European MBR market volume will be invested in R&D. In particular, technological breakthroughs will foster the competitiveness of the technology, and novel cost-effective MBR filtration systems 'made-in Europe' should increase their share in the European and international markets.

Capitalization of know-how on construction and operation. The European MBR professional community has grown on 15 years of expertise and know-how, but remains very fragmented and sometimes lacks communication and organization. In some countries like Germany or the Netherlands, public associations or institutions such as the German Water Association (DWA) or STOWA enable through their working groups of experts and/or demonstration projects to capitalize the experience gathered on key municipal and industrial MBR plants. Their reports and guidelines are publicly available and provide state-of-the-art sets of best practices which should accelerate the establishment of high engineering and operation practices and improve trust towards the technology while sustaining the market growth. Recent key literature references such as 'the MBR-book' (Judd, 2006) or 'Membrane Technology for Waste Water Treatment' (Pinnekamp and Friedrich, 2006) provide also extensive information on the MBR technology and case studies.
The webplatform of the coalition 'MBR-Network' www.mbr-network.eu is designed to complement this offer while providing actual on-line information on MBR technology. In particular, it includes an extensive database of articles and reports, as well as a discussion forum accessible by the international MBR community (About 400 members registered over first 9 months of existence). Such public communication platforms and networks will optimize the diverse research activities, accelerate the set up of good practices and increase awareness and acceptance towards the technology. This will positively accompany the global growth of the MBR market.

CONCLUSION

The detailed market survey of the European MBR industry revealed that the municipal sector generated the strong market revenue growth observed since 2002. This is a consequence of the process becoming technically and economically viable for large municipal plants with the successful introduction and commercialization of the immersed configuration. This trend is expected to continue in the coming years, although novel products are entering this promising market and will compete with the two immersed technologies (Zenon-GE and Kubota) which literally dominated the market since 2002.

ACKNOWLEDGEMENT

The study reported in this article was performed within the FP6 European project "AMEDEUS" (contract n° 018328, www.mbr-network.eu). The authors would like to acknowledge the European Commission for the financial support. The authors express also their gratitude to all the suppliers, retailers and constructors of MBR filtration systems who kindly provided their list of commercial references with often useful technical details for the review.

REFERENCES

De Wilde W., Richard M., Lesjean B., Tazi-Pain A., 2007, Towards standardisation of MBR technology ?, IWA 4th International Membrane Technologies Conference, 15 - 17 May 2007, Harrogate, UK

Frost & Sullivan, 2005, Strategic Analysis of the European Membrane Bioreactor Markets, July 2005

Judd S., 2006. The MBR Book. Principles and applications of membrane bioreactors in water and wastewater treatment. *Elsevier*, ISBN-13: 978-1-85-617481-7

Lesjean B., Rosenberger S., Schrotter J.C., 2004. Membrane-aided biological wastewater treatment – an overview of applied systems, *Membrane Technology* (2004) 5-10.

Lesjean B., Leiknes T., Hochstrat R., Schories G., Gonzalez Gonzalez, A., 2006. MBR: technology gets timely EU cash boost, *Filtration + Separation*, November 2006

MUNLV-NRW, 2003. Abwasserreinigung mit Membrantechnik, ISBN 3-9808617-0-8

Nieuwenhuijzen A.F., 2005. State of the Science Report Membrane Bioreactor, Anno 2005. report STOWA – Global Water Research Coalition.

Pinnekamp J. and Friedrich H., 2006. Membrane Technology for Waste Water Treatment, *FiW – Verlag*, ISBN 978-3-939377-01-6.

Stephenson T., Judd S., Jefferson B. and Brindle K., 2000. Membrane Bioreactors for Wastewater Treatment. *IWA publishing*.

Yang W., Cicek N. and Ilg J., 2006. State-of-the-art of membrane bioreactors: Worldwide research and commercial applications in North America. *Journal of Membrane Science* 270 (2006) 201-211.