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Chapter 2

Identification and mapping of the research organizations in the field of MT

R. Al-Sa`ed, H. Abdel-Shafy, F. Atallah, Z. Mimi, S. Sayadi, A. Criscuoli, G. Schories

INTRODUCTION

In this chapter, we first discuss various aspects of current research efforts within the MENA countries focusing on current available published data. Secondly, using membrane technology (MT) in wastewater management, certain gaps of knowledge and overlapping activities are identified. Finally, recommendations pertinent to future research on MT are suggested to enhance their implementation as advanced sustainable water treatment processes.

The findings of this chapter are based on authors` own experience, data collected from scholar literature (114 articles of 550 peer-reviewed papers) on the application of MT for both water and wastewater treatment, and 22 installed lab and full scale membrane based treatment systems. To compile data on MBR installations and published works from the countries under study, the WERF-Database and MBR-Network were accessed (http://www.mbr-network.eu/mbr-database/literature.php).

National R&D programs for the MBR technology applications in wastewater treatment and reclamation have started in some Arab MENA countries, such as Algeria, Egypt, Morocco and Tunisia. Some of the research efforts made are presented and discussed.

2.1 EXPERTS AND TOPICS WORKING IN THE FIELD OF MEMBRANE TECHNOLOGY

In Palestine, a total number of 80 researchers identified their field of expertise in membrane technology including desalination application in water and sanitation facilities. Figure 1 illustrates the distribution of the researchers on R&D institutions, where about 67% are working in both academic and governmental agencies. The NGO (non-governmental organization) sector is actively working in the field of MT, where about 22% of experts are engaged in both local and foreign NGOs. The industrial sector has about 12% of experts employed. Almost half of the Jordanian academic staff (55%) are professionals working in the governmental sector (25%), leading to 80% of the experts are working by the public sector.

Compared to Jordan and Palestine, the situation in Lebanon is totally different, where the vast percentage (60%) of membrane professionals is employed by the industry. Despite many attempts to collect technical data on academic and

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governmental experts, only few were identified. About 24% of MT experts were found working at academic institutions and even less (4 %) are engaged in governmental departments.

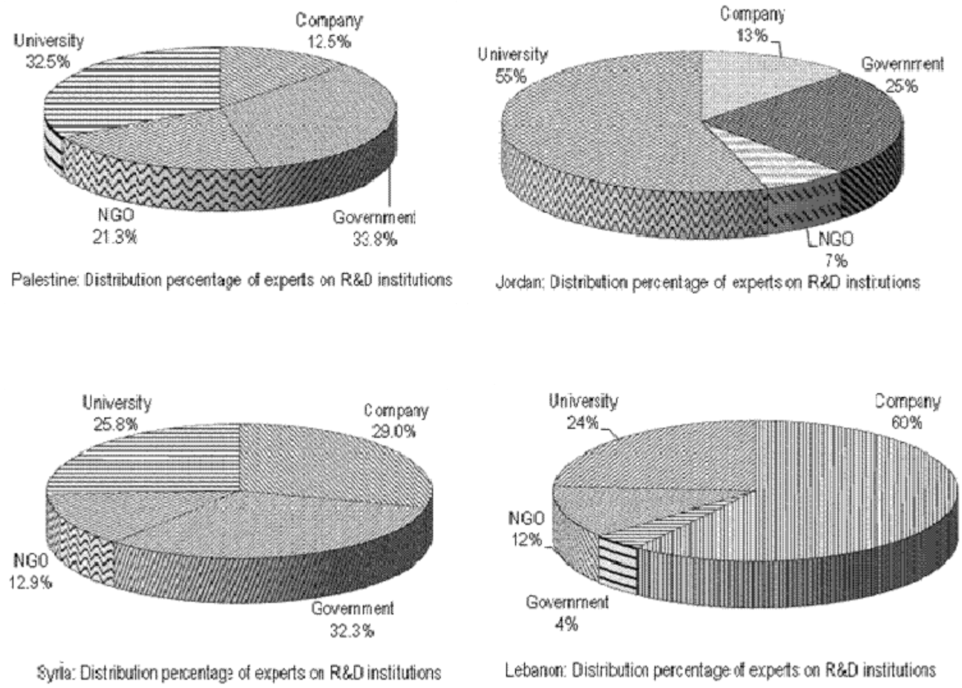

Fig. 1. Distribution of professionals identified as MT experts in region A

For Syria, Figure 1 shows a similar percentage of expert's distribution working at academic departments, however, with fewer shares (29%) of industry involved in MT technology planning and marketing. It is worth mentioning that a total percentage of 58% of MT identified themselves are employed within the public sector (academia and government), compared with 80 and 67% in Jordan and Palestine, respectively.

Compared with compiled published work from North Africa (Area B: total 70 articles), the total publications of 44 mapped in Area A were grouped into the following application areas (1) water treatment for potable purposes; (2) wastewater treatment (domestic, grey wastewater, industrial, municipal, leachate and effluent reclamation). The grouping was performed according to the main objective of the PROMEMBRANE project. As the number of professionals specialized in MT is limited in Area A, and the region is characterized as water scarce zone, the main focus of publications was on use of membrane technology applications for water treatment (Fig. 2). During the five years (1996-2000) very few papers (6) tackled the MT for water and wastewater treatment. However, Figure 2, where the number of published papers on water treatment (both brackish and saline water) is more than those for application of MT for wastewater treatment, 29 and 15 respectively.

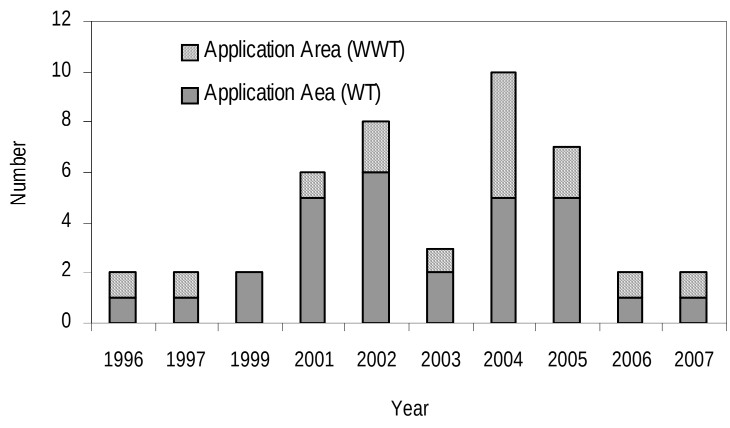

Fig. 2. Research publications on application areas of MT technology in region A

Al-Sa'ed, R., Atallah, F., Abdel-Shafy, Mimi, Z., H., Sayadi, S., Criscuoli, A., Schories, G. 2010. Identification and mapping of the research organizations in the field of membrane technology. *In: BIOAZUL (Ed.), Membrane Technology in Water Treatment in the Mediterranean Region: PROMEMBRANE*. IWA Publications. pp. 18-24.

A rapid increase of published articles is identified during the five years (2001-2005), where about 52% of papers were on use of MT for both water desalination of brackish water and marine water sources for drinking water purposes. Also a marked increase 25% of published scientific work is made on use of MT in wastewater treatment and effluent reclamation. This shows, definitively, the importance of membrane processes as a part of water scarcity and production of reclaimed effluent suitable for agricultural irrigation. This might be induced by annual drought periods, limited quantity and degraded quality of available freshwater resources due to overexploitation, additions of allocthonus pollution loads and salt intrusions, stringent local and regional standards on treated effluent destined to agricultural irrigation. Also, the current professional batch within this region come directly from either M.Sc. or Ph.D. programs with little practical experience in engineering offices or MT companies working at international level.

Compared to membrane technology applications in water treatment (desalination), the introduction of wastewater membrane and reclamation facilities in the MENA region has been if any, more regionally based. While in the Mediterranean zone (region A), a larger number of research studies were conducted in the area of potable water desalination than for wastewater treatment, the situation was reversed in North Africa (region B). This could be attributed to the existence of well established research groups, funds availability, and enforcement of national laws pertinent to protection of tourist coastal areas. This enabled MBR research and applications to flourish at lab, pilot and full scale installations for high strength industrial flows, municipal sewage treatment and tourist sites.

It is assumed that the caution of North African municipalities to consider advanced treatment systems as MBRs to the well established conventional treatment options, might have delayed the application of MBRs into the municipal arena. However, the promotion of MBR in industrial applications, particularly for high strength, difficult to treat waste streams, allowed for alternative technologies such as MBRs. This has been reflected in more than 70 published articles from research groups in Tunisia, Algeria, and Morocco, and Egypt the installation of three full scale installations for industrial wastewater treatment in Tunis, and Algeria [Ben Aim and Semmens, 2003; Bentama et al., 2004; Benzaoui and Bouabdallh, 2004, Abdel Shafy et al., 2005; Hussaine-Sadi and Sadoun, 2005]. As per May 2007, the total number of installed membrane based wastewater treatment plants (immersed and external MBRs, UF/RO) in lab and full scale applications (domestic, industrial and municipal) has reached 22 (Table 1).

Table 1. Number of membrane based WWTPs in the Mediterranean and North Africa zone

Number	Full scale	Country	Number	Lab scale	Country
3	domestic	Egypt	0	Domestic	Non
3	municipal	Palestine, Israel	4	Municipal	Tunis
3	industrial	Tunis, Algeria	9	Industrial	Tunis, Morocco, Algeria
Total number	9		13		

More than half of the membrane based WWTPs installed within the MENA zone is installed for R&D activities including membrane development, process performance optimization, and fundamental research. Table 1 shows that all installed membrane based treatment systems, except the one (UF/RO) applied as a post-treatment stage, are of MBR type [Khamis et al., 2005; Oron et al., 2008]. The MF modules are applied for both municipal and industrial wastewater treatment. Eight out of 12 of the full scale installed MBRs, of which 50% serve municipal sector, are membrane immersed with hollow-fiber configuration, polymeric material and ZeeWeed fabric products. Detailed technical data are available but as of space limitation in this article are not shown.

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Compared to conventional WWT systems, MBRs are advantageous as of small land area demand, process flexibility and excellent reclaimed effluent which suitable for various purposes including unrestricted agricultural irrigation. However, MBRs show higher energy demand, require a higher level of automation, skilled operational staff and frequent cleaning due to fouling and scaling. To-date, much of the research efforts made within the African countries on membrane based treatment systems have mainly focused on bench or pilot scale studies [Abdel-Shafy et al., 2005; Khemekhem et al., 2006; Abdessemed and Nezzal 2002; Abdessemed and Nezzal 2005] and short term operations in municipal applications. Lab scale studies on industrial applications with particularly high strength and difficult to treat waste streams, however, were conducted as alternative technologies such as MF/UF/NF [Fersi et al., 2005; Masmoudi et al., 2006; Bouguecha and Dhahbi 2002; Saffaj et al., 2004; Bentama et al., 2007]. However, regardless of the source of wastewater, whether it is municipal or industrial, very few publications involved full-scale studies for long-term operational periods [Khider et al., 2004; Dhouib et al., 2006]. For pathogen removal and municipal wastewater pretreatment, anaerobic MBRs have proven to be a particularly reliable technique [Ellouze et al., 2006; Saddoud et al., 2007]. Few research studies were made on development of local material to improve membrane structure, control fouling, and improve flux permeate at lab scale experiments using MF/UF membranes [Harussi et al., 2001; Khamis et al., 2005; Al-Sa`ed et al., 2008; Oron et al., 2008].

Table 2 illustrates one of the databases developed using Excel program, where the data (only scholar literature between 1996-2007) can be filtered (indexed) according to users` search. The table below shows an excerpt of articles search pertaining to the use of MT only for wastewater treatment (WWT) in Arab MENA region (country filtered).

Table 2. Database on published scholar literature on MT application for wastewater treatment in Arab MENA.

Authors (Names)	Year	Title	Journal Name, volume (issue),	Abstract	Country	Funding Agent	Technology used	USE (WT/WWT)
M.Khamis,A.Manassra,M.Dakiky	2005	eatment by advanced membran	International conference	ation to plant and soil atertiary treatmen	Palestine	PCG& Belgian	UF-RO	WWT/Municipalities
Badania,Z., Ait-Amara,H., Si-Salahb,A.	2005	Treatment of textile waste water	Desalination 185 (1-3) 4	variable operating conditions to estima	Algeria	NA	MBR	WWTdomestic
Mandil,M.A.,Bushnak,A.A.	2002	r desalination in South Mediterra	Desalination 152 (1-3) 1	pected to play during the first quarter of	Syria	Dar Al-Taqniya	Desalination	WT &WWT(seawater, bra
Deane,J.	2002	ion in the Mediterranean Middle	Desalination 152 (1-3) 5	articipation (PSP) in desalination project	Syria	NA	Desalination	WT &WWT(seawater, bra
Darwish,M.R., Shararaa,M.,Sidahmeda	2006	conditions of wastewater reuse	Resources, Conservatio	of a reservoir with different capacities ar	Lebanon	NA	Land application	WWT
Mohsen,M.S., Jaber,J.O.	2002	Potential of industrial wastewate	Desalination 152 (1-3) 2	requirements, wastewater production,ty	Jordan	NA	Desalination	WWT/Industrial
Mohsen,M.S., Jaber,J.O.	2004	Treatment and reuse of industria	Desalination 167 (15 Au	reuse in Jordan's A1-Hussein thermal p	Jordan	NA	RO	WWT/Industrial
Shatanawi,M.and Fayyad,M.	1996	Effect of Khirbet As-Samra treat	Desalination 1996, Pag	ouk River. Comparison of the results of	Jordan	NA		WWT/domestic
Redondo,J.A.	2001	ish-, sea- and wastewater desali	Desalination 138 (1-3) 2	oblems encountered in application of m	Middle East	NA	RO & NF	WT&WWT(Brackish-, sea
Afonso,M.D., Maria,A., Alves,B., Mohse	2002	Crossflow microfiltration of marb	Desalination 149 (1-3) 1	nd recycling of the wastewaters generat	Jordan	NA	MF	WWT/Domestic
Mohsen,M.S.	2004	Treatment and reuse of industria	Desalination 167 (15 Au	water reuse in Jordan's Al-Hussein the	Jordan	NA	RO	WWT/Industrial
Saddoud,A., Hassai¨ri,I., Sayadi,S.	2006	Anaerobic membrane reactor wi	Bioresource Technology	membrane bioreactor with phase separ	Tunisia	(MRSTDS, Tur	Cross-flow microfiltra	Cheese whey
Dhouib,A., Hamad,N., Hassai¨ri,L., Sa	2003	Degradation of anionic surfactan	Process Biochemistry 3	or the treatment of a cosmetic industry v	Tunisia	SERST/Progra	Membrane bioreacto	WWT/Anionic surfactants
Sayadi,S., Allouche,N., Jaoua,M., Alou	2000	Detrimental effects of high mole	Process Biochemistry 3	polyphenolics were the most problemati	Tunisia	EEC&SERST-I	UF	WWT/(OMW)
Mechichi,T., Sayadi,S.	2005	Evaluating process imbalance of	Process Biochemistry 4	imbalance using an up-flow anaerobic f	Tunisia	Hedi Aouissao	Anaerobic filter react	WWT/Olive mill
Dhouib,A., Hdiji,N., Hassai¨ri,I., Sayadi	2005	Large scale application of memb	Process Biochemistry 4	braakii strain able to degrade wide rang	Tunisia	«Secre´tariat d	(UF)Membrane biore	WWT/Industrial
Benzaoui,A., Bouabdallah,A.	2004	Desalination and biological wast	Desalination 165 (15 Au	n about the treatment processes of larg	Algeria	NA	biological treatment	WWT/domestic
Jaber,J.O.,Mohsen,M.S.	2001	Evaluation of non-conventional v	Desalination 136 (1-3) 8	onal water resources supply; these inclu	Jordan	NA	Desalination	WT&WWT(BW,SW,dome
Abu Zahra,B.A.A.	2001	Water crisis in Palestine	Desalination 136 (1-3) 9	crisis caused mainly by the lack of con	Palestine	NA	Desalination	W&WWT
Ahmed,S.A., Tewfik,S.R.,Talaat,H.A.	2002	Development and verification of	Desalination 152 (1-3) 3	This paper addresses the development	Egypt	NA	RO	WWT/domestic
Wheida,E., Verhoeven,R.	2004	Desalination as a water supply t	Desalination 165 (1-3) 8	This paper summarises the techniques,	Libya	NA	Desalination	W&WWT

2.2 IDENTIFICATION OF KNOWLEDGE GAPS AND OVERLAPPING ACTIVITIES IN MT

In a similar way, the 44 total publications found in region A, were classified and grouped into the following main research fields (1) general research (GR) papers on review and theoretical aspects of MT use in water treatment and wastewater treatment; (2) fundamental research aspects; which includes operation and design parameters, fouling, cost, modeling, membrane aided treatment systems, hybrid modules, pre- and post-treatment. As the number of research papers is few, the papers were grouped in only two application areas without differentiation on the type of water or wastewater. Figure 3 illustrates chronically the distribution of published papers within the two research topics of MT applications; general research issues (GR) and specialized applied research themes (FR).

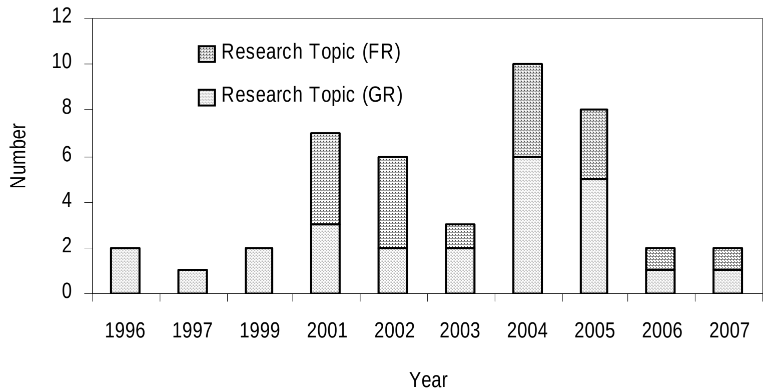

Fig. 3. Research publications on application areas of MT technology in region A

Al-Sa'ed, R., Atallah, F., Abdel-Shafy, Mimi, Z., H., Sayadi, S., Criscuoli, A., Schories, G. 2010. Identification and mapping of the research organizations in the field of membrane technology. *In: BIOAZUL (Ed.), Membrane Technology in Water Treatment in the Mediterranean Region: PROMEMBRANE*. IWA Publications. pp. 18-24.

It is obvious that only general research papers (GR) on MT applications are made during the nineties (1996-1999), this is clearly due to the limited human and financial resources available in the region. However, the applied research (FR) has been published from conducted research on MT application in both water and wastewater treatment first in 2000. There are sharp variations in the number of published work among the individual countries with the Area A. For example, only 4 papers were found published by the experts in both Lebanon and Syria, while Palestine and Jordan have published 10 and 29 respectively. GR papers constitute about 57% while applied fundamental research (FR) entailed only 41% of the total published articles in this region. This is a good sign that MT has gained interest from the research community and policy makers for the provision of drinking water and improving effluent quality.

2.3 IDENTIFICATION OF TECHNICAL REQUIREMENTS AND NEEDS FOR COOPERATION

The results obtained identified wide research areas related to the types of scientific and technical advances that are crucial for membrane water treatment technologies to find broad acceptance and application in the countries under study. To achieve sustainable, affordable and adequate wastewater treatment facilities in the MENA zone, allocation of regional research funds that will guide the membrane processes research in the Mediterranean and North Africa region are required.

It was demonstrated that the availability of experts and well-trained practitioners, well-equipped research facilities, availability of funds, economical affordability and technical feasibility of MT, as well as the official commitment and endorsement of stringent effluent standards on treated effluent for intended uses depend on each other.

Protecting the quality of surface and groundwater requires sustainable management on a watershed basin scale to consider all impacts on the water. Of equal importance, public health protection calls for safe brine disposal or effluent reuse [Nghiem et al., 2004; Wilderer, 2005; Galil and Levinsky, 2007]. This implies use of advanced treatment technologies, among of which are membrane based processes. However, because water quality criteria are dependent on local conditions within the MENA region, it is necessary to define groups of similar rivers by clustering them as eco-regions. As protection of the aquatic environment and public health pertinent to emergent pollutants more often lacks a confirmed scientific, financial and managerial basis, further research and updating of criteria based on large scale MBRs are needed [Gander et al., 2000; Chen et al., 2003; Abdel-Shafy et al., 2005; Cornel and Krause, 2006].

Forming cooperation between technology developers and leading companies is a crucial approach that dramatically shortens the time required to promote membrane technology and address some of key business problems and challenges. The approach provides ready access to professionals best qualified to provide commercial development guidance for new MT based options [Oron et al., 2004; Oron et al., 2008]. It enables development or co-development of new membrane based systems through collaboration or joint development with trend setting companies who are expert and leaders in their fields [Escobar, 2005; Frechen et al., 2006; Quazzani and Bentama, 2008].

Water scarcity in the MENA region has promoted the use of unconventional water sources, namely seawater, brackish water and treated/reclaimed wastewater, which are actually unlimited. With adequate membrane design, utilizing MF/UF as pre-treatment processes might reveal wastewater desalination costs lower than seawater desalination cost, thus making wastewater desalination as one of the feasible processes to produce water quality that fits many industrial water quality requirements [Adham et al., 2001; Rebhun, 2004; Aboabboud and Elmasallati, 2007; Liao et al., 2007; Wichelns and Nakao, 2007; Elhassadi, 2008]. In the future it is likely that direct processing of wastewater in MBRs followed by RO will open up more opportunities for effluent reuse for a wide range of purposes. However, several studies [Bouhabila et al., 2001; Fane and Fane 2005; Fane, 2007; Rosenberger et al., 2006; Zhang et al., 2006] made on MBRs sustainability, revealed an overall sustainability for the MBRs as good, however the current capital and operational costs of membrane based treatment technologies may not necessarily satisfy some economical and ecological sustainability criteria [Ondrey, 2005; Le-Clech et al., 2006; Yang et al., 2006].

The technical feasibility of MT applications in wastewater treatment is very well documented, but the widespread utilization of membrane based processes is constrained by the high capital and operational costs. The price of membranes, their replacement frequency and the electrical energy consumed are the most important factors influencing the global costs of the processes [Semiat, 2000; Al-Bastaki, 2004; Kim et al., 2004; Fane and Fane, 2005; Lesjean et al., 2005; Saddoud et al., 2007; Ellouze et al., 2009]. Thus, it is important to select an adequate membrane type as well as to

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optimize the operational conditions of the preceding treatment stage case by case. However, recent rapid proliferation of MBRs as a result of the technological advances and reduced costs has resulted in many owners, operators and engineers considering them as part of plant upgrades and expansion plans of overloaded sewage works [DWA, 2005; Ondrey et al., 2005; Balkwill and Arviv, 2006; Cornel et al., 2006; Frechen et al., 2006; Le-Clech et al., 2006; Yang et al., 2006; Quazzani and Bentama, 2008]. Nevertheless, a breakthrough in MT advancement for wastewater treatment and effluent reclamation can be only made, if we can prove its cost effectiveness and sustainability for developing counties, a revolution in nanoscience and membrane engineering will have potential impacts on social, environmental and economical development as well as on the political stability in Arab MENA countries in particular.

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