Experiences on Desalination of Different Brackish Water

Authors: *Domingo Zarzo Martinez, Carlos Gabriel Garcia Soto and Rafael Buendia Candel*

Presenter: *Domingo Zarzo Martinez*
Technical and R&D Director – Valoriza Agua – Spain

Abstract

Many countries and Spain is a good example of it, have suffered an important lack of water resources that is aggravated with time and includes cyclical drought periods, like the current situation. Leaving apart the big seawater desalination plants developed mainly by Governments or in the case of Spain, by the program from the Environment Ministry in the last 5 years, in this situation, and in order to obtain water at low costs, a number of brackish water reverse osmosis (RO) plants have been developed for different uses (industrial, agricultural irrigation, drinking water, reuse).

In this paper we will describe the technical solutions and costs for some relevant examples of facilities producing water from brackish water RO or electrodyalisis reversal (EDR) plants.

We will describe some examples of desalination plants using brackish water from different sources (well water, superficial water and wastewater) and with different technological solutions developed by Valoriza Agua. Different technical problems presented will be described too (sulphates, iron, increasing salinity, high content in SS and organic matter), as well as innovative solutions (use of energy recovery devices for brackish RO, use of used membranes as "fuse" membranes, etc.)

One of the most important problems in these facilities is the brine disposal. We will describe a very interesting experience in a fruit juice factory with a zero liquid discharge diluting brine with the wastewater generated in the same industry from a membrane bioreactor (MBR) system.

One R&D program about possible solutions for brine discharges in inland will be briefly described too, including salts extraction, deep well injection, researching about dilution mathematical models and evaporation of brines.

As conclusions, we could point that:

- Desalination of brackish water is sometimes the only way to obtain a new resource in scarcity situations, as well as a way to improve the quality of water for different purposes (drinking, agriculture, industry)

- Cost of desalination of brackish water is very competitive and can be assumed by all the end-users, even the agricultural industry.

- Desalination of inland brackish water raises problems even not well solved due to the brine discharges or brine disposal, and it's necessary to research more about this important topic.

I. INTRODUCTION

As it is well known, Spain has suffered historically an important lack of water resources that is aggravated with time and includes cyclical drought periods, like the current situation.

These problems are more important in the most drought areas in Spain, as the south Mediterranean coastal areas, or in the islands (Balearic and Canary).

The history of desalination in Spain began at 60's, and we could resume it as follows;

1964: 1st desalination plant in Lanzarote (Canary Islands)
1970's: construction of further desalination plants in Canary Islands
1980's: installation of desalination plants for irrigation in Canary Islands as well as on the mainland
1990's: installation of desalination plants for irrigation on the mainland, due to the severe drought
1995-2000: significant growth in installed capacity
2000-2005: execution of large desalination projects
Installation of desalination plants treating wastewater
2005-present: AGUA Program

Other interesting data about this application is;

Desalination in Spain represents about 2-3% of the available water resources and 5% of drinking water supply.

- In the Canary Islands desalination represents more than 30%; For Lanzarote Island, this figure is around 80%. In Mediterranean regions 15% of water needs will be supplied by non-conventional resources (desalination and reuse).
- Europe-wide, Spain has the highest desalination production and reuse levels in overcoming water deficits.
- 900 desalination plants in Spain produce 1.5 GL/day with approx. 3 GL/day expected by 2010.
- 75 % of water demand stems from agriculture and irrigation (25% for drinking water, 10% industry and 3% services).
- 3,500 GL/year of wastewater are treated in Spain (80%). 13% is reused (400-500 GL/year).
- 88% of desalination in Spain is by RO. 60% seawater and 40% brackish water.
- Water use split: 59% drinking water, 22% irrigation and 19% industry.

Leaving apart the big seawater desalination plants developed mainly by Governments or in the case of Spain, by the program from the Environment Ministry in the last 5 years, in this situation, and in order to obtain water at low costs, a number of brackish water RO plants have been developed for different uses (industrial, agricultural irrigation, drinking water, reuse).

Valoriza Agua, through its water engineering company, Sadyt, has designed and built more than 55 desalination plants from the establishment of the company in 1995. Leaving apart the big projects involving seawater in different countries, many brackish desalination plants has been developed with many different applications and feed water supplies. With this wide experience, in this paper we will describe some of these designs organized by applications.

II. DESALINATION OF BRACKISH WATER

In general, the desalination treatment of brackish water is more difficult than seawater, due that the high variability and different quality of raw water, with specific problems like high SS and organic matter contents, increasing salinity, sulphates, silica, etc, and it requires much more care in the pre-treatment designs.

We will describe in a resumed way 4 examples for each application. The plants have been not selected by the importance or size of it; the criterion has been to show interesting experiences in all the possible circumstances, water quality, technologies, pre-treatment, etc.

III. DESALINATION OF BRACKISH WATER FOR DRINKING WATER

Desalination for drinking water applications at this time is used to solve 2 different problems:

- increase the available resources, by means of seawater desalination
- increase the quality of drinking water to meet DW standards

The most useful problems of quality in drinking water are;

- presence of Nitrates in groundwater, mainly caused by agricultural irrigation practices
- high levels of sulphates or salinity, in general
- micropollutants as pesticides, heavy metals or THMs (mainly in surface water with high organic matter levels)

It is easy to see that this application will be increased in the next future due to the increasing quality required by the drinking water standards in all the countries.

In this case, the most used technology is RO, although there are some plants working with nanofiltration (NF) or even with EDR.

Table 1. Examples of desalination plants for drinking water production

	1	**2**	**3**	**4**

Plant	Calpe	Vall D'Uixó	Nules	Abrera
				
Owner	Diputación de Alicante	FACSA	FACSA	ATLL
Erection (year)	2002	1997	2002	2008
Capacity (m^3/day)	4,000	7,500	6,000	200,000
Technology	RO	RO	RO	EDR
Raw water	Groundwater	Groundwater	Groundwater	River water
Salinity	12,000 µS/cm	2,000-2,500 µS/cm with 270 ppm NO_3	1,529 ppm TDS with 212 ppm NO_3	
Product water requirements	Drinking water	NO_3< 25 ppm	TDS< 80 ppm NO_3< 20 ppm	< 100 µg THM's
Physical Pretreatment	Sand filtration + cartridge filters	Sand / Anthracite filtration + cartrigde filters	Sand filtration + cartridge filters	Conventional DWTP (clarifiers, sand filters, activated carbon filters, cartridge filters)
Chemical pretreatment	NaClO, $NaHSO_3$, Antiscalant	NaClO, $NaHSO_3$, Antiscalant	NaClO, $NaHSO_3$, Antiscalant, Acid (optional)	Antiscalant and HCl
Postreatment	Lime + NaClO	None	None	Lime with CO_2 and NaClO dosage
Technical innovations	Energy recovery system (turbocharger)	One of the first plants using low pressure membranes (1997)	2 different membrane manufacturers (1 for each train, low pressure membranes)	Reuse of off-spec water and electrode water = 90% recovery
Difficulties	High levels of sulphates	Problems with one membrane manufacturer about NO_3 rejection and it was the reason 2 develop a new generation of membranes installed for 1st time in this plant		High variability in raw water
Electric consumption (kWh/m^3)	1.72	0.6	0.83	<0.8
Operational costs (€/m^3)	0.29	0.14	0.17	<0.2

The problem of Nitrates in groundwater is very common in many areas of Spain, as in Valencia or Castellon. We have installed 3 facilities with 7,500, 6,000 and 4,000 m^3/day respectively in different towns. Those plants were installed in the beginning of the low pressure membranes development (1997) and then there were an interesting place to explore the results of these technologies.

One detected problem was the low rejection of nitrates in one of these membranes, which it caused the development of a 2nd new generation of membranes to meet the standards required.

Other important problem in drinking water in Spain is the presence of sulphates, that it has been solved typically by means of RO or NF. At this time many installations are projected in inland areas to solve these problems.

About Abrera plant, we will not describe it in depth because is the object of another paper, but I would like to say that EDR has been installed for drinking water more in the Canary Island than in Inland until more recently with some installations for reducing nitrates in Valencia Region, or Abrera plant to reduce the level of Trihalomethanes in river water.

About the remineralisation systems, in general, in small systems is used simply a blending with raw water (when it's possible due that the pollutant concentration). Large plants, as Abrera, include remineralisation by means of calcite beds or lime concentrators with or without CO_2.

IV. DESALINATION OF BRACKISH WATER FOR AGRICULTURE IRRIGATION

In the case of Spain, farmers and other users of this water have been assumed in their production costs the price of this new water coming from desalination or reuse installations.

It's interesting to emphasize that the investment costs for this application, as well as the water production costs, are in general lower than the cost for other applications (drinking water, industrial water), fundamentally based in some reasons:

- Limited requirements of personnel, chemicals, membrane replacement
- Possibility to regulate water production according with electrical tariffs in order to produce water at lower energy cost
- Lower requirements about product water salinity
- Lower requirements of civil works, automation, safety measures to guarantee production

About the benefits and disadvantages of the use of desalination in agriculture, we can point it as:

Benefits:

- Fresh resources available
- Resources not too much dependant on the weather (not dependent in the case of seawater desalination)
- Increase of productivity and quality of the products
- Recovery of salty soils

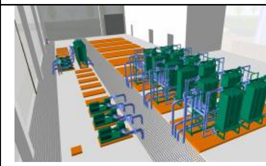
Disadvantages:

- Higher water costs
- Water must be balanced – SAR / RAS (sodium adsorption rate) and other indexes
- High quality requirements from the agricultural irrigation use for some parameters like BORON (negative effects observed in vegetable species with B>1 ppm)

There will be described too other interesting aspects of this application like the quality requirements of the product water, especially in some parameters as the SAR (sodium adsorption rate) or the boron, which it have important implications on the design of the facilities.

For example, in the case of Boron concentration, the high quality requirements from the agricultural irrigation use (usually below 0.5 ppm) implies that, in general, in seawater facilities it's necessary to install a partially second pass RO (or other alternatives like ionic exchange) to meet the required standards (however, in the UE countries the limit of boron concentration for drinking water is higher; 1 ppm).

Table 2. Examples of desalination plants for agriculture irrigation

	1	2	3	4
Plant	**Cuevas de Almanzora**	**Mazarrón**	**Drenajes**	**Terciario Alacantí Norte**
				
Owner	C.R. Cuevas de Almanzora	C.R. Mazarrón	Spain's Environment Ministry	EPSAR
Erection (year)	2003	1995	1997	2010
Capacity (m^3/day)	25,000	13,500	6,000	5,000
Technology	RO	RO	RO	EDR
Raw water	From wells with increasing salinity	From wells with increasing salinity	Surficial water from agricultural drainages	Wastewater secondary treated
Salinity	9,000-18,000 µS/cm	9,000-20,000 ppm TDS	12,500 µS/cm (average)	3,500 µS/cm
Product water requirements	<500 µS/cm	<300 ppm TDS	<250 ppm TDS	<1000 µS/cm
Physical Pretreatment	Sand filtration + cartridge filter	Physical-chemical treatment with clarifier + double stage filtration (sand + sand/anthracite) + cartridge filters	Physical-chemical treatment with clarifier + double stage filtration (sand + sand/anthracite) + cartridge filters	Fluidized bed filtration + cartridge filters
Chemical pretreatment	Antiscalant	NaClO, $NaHSO_3$, HCl, antiscalant	Acid, NaClO, $NaHSO_3$, coagulant, floculant, antiscalant	Antiscalant, acid. Coagulant, NaClO
Post- treatment	Blending with raw water	Blending with raw water	Blending with raw water	Blending with raw water
Technical innovations	Energy recovery (turbocharger)	Energy recovery (turbocharger)	Energy recovery (turbocharger), different membranes (antifouling) and spacers on each train	
Difficulties	Increasing salinity, increasing sulphates	Increasing salinity	Variable water quality with high organic matter loads	Wastewater
Electric consumption (kWh/m^3)	1.2	old plant that has been reformed; we have no current data	1.2	1.55
Operational costs (€/m^3)	0.246	no current data	0.3	0.36

From the scarcity period around 1995, many farmers and agriculture businessmen decided to install desalination plants in the southwest of Spain (mainly Mediterranean coastal areas) to solve the problem of available resources. These technologies were very used previously in Canary Island but it was this moment the beginning in the mainland. We estimate that between 1995 and 2000 were installed more than 200 desalination plants for this application in these area, with typical sizes rating between 100 and 5000 m^3/day, with some plants treating more than 10,000 m^3/day.

Two examples of it, are the Mazarron an Cuevas de Almanzora plants, with a size of 13,500 and 25,000 m^3/day, respectively. Mazarron plant was build following a project from the owner and, although it incorporated some technical innovations as energy recovery devices (turbocharger) it was not successful due that the increase of salinity in less than a year from 9,000 ppm of TDS to more than 20,000 ppm of TDS, being finally re-turn into a seawater desalination plant.

With this experience, the design of the more recent Cuevas plant was different including;

- Plant able to treat water with high and increasing salinity with;
- Energy recovery devices, special HP pump with frequency variation
- Seawater materials installed (pressure vessels, pipes,..) in order to transform into a SWRO at low cost if it's necessary. Even a longer axis in HP pump with the aim to installing in the future a Pelton Turbine
- Management of the water wells in order to maintain groundwater equilibrium

Drenajes plant was too an interesting experience. This was a 1997 Environment Ministry project for the construction of a pipe network to collect agriculture drainage, brine discharges and other wastewater discharges to the Mar Menor (highly polluted seawater lagoon), and finally a desalination plant to treat these effluents.

The main objective was to reduce high salinity (up to 18,000 µS/cm variable) to re-direct irrigation channels – high SS and organic matter loadings

As innovative design in 1997 we could remark the installation of energy recovery turbines with brackish water (turbocharger) and the installation of the 3 RO trains with different membranes (different chemistry and spacers) in order to evaluate the effect of these differences in the membrane fouling.

About wastewater desalination in some coastal areas high salinity in wastewater is detected (in some cases >3,000 µS/cm). For this reason, some desalination plants treating wastewater have been constructed or under study.

Some examples:

- Alicante and Benidorm plants: UF + RO between 30-50,000 m^3/day
- Alacanti Norte: EDR 5,000 m^3/day
- Xeresa Golf: 5,000 m^3/day RO
- Many plants in Canary Islands with EDR or RO

In some cases projects include prior membrane wastewater treatment, such as MBR.

About EDR, it is very used in Canary Island but is less used in mainland. The Alacanti Norte plant will treat 5,000 m^3/day of wastewater using as pre-treatment a fluidised bed sand filtration. This plant is the result of local government doubts about the efficiency of RO treating wastewater due that not too much good past experiences.

V. DESALINATION OF BRACKISH WATER FOR INDUSTRIAL USES

Several plants have been constructed and in some cases operated by our company for industry applications. Next table 3 shows some of them.

Table 3. Examples of desalination plants for industrial uses

	1	**2**	**3**	**4**
Plant	**Puente Genil**	**Cítricos del Andevalo**	**Basrah Refinery**	**Sidmed**
				
Owner	Sedebisa	Grupo García Carrión	Basrah Refinery	SIDMED
Erection (year)	2004	2007	1998	1995
Capacity (m^3/day)	50	1,200	5,040	750
Technology	RO double pass	RO	RO	RO
Raw water	Surface water	Groundwater	River water	Tap water
Salinity	2,780 µs/cm	1,200 µS/cm		800 µS/cm
Product water requirements	Ultrapure water	2 currents 1) <50 µS/cm, 2) <500 µS/cm	Water for boilers	Water for boilers
Physical pretreatment	Sand Filtration + Ultrafiltration + cartridge filters	Sand filters + cartridge filters	Sand filters + cartridge filters	Mesh filters + hidrocyclon + sand/anthracite filters + cartridge filters
Chemical pretreatment	NaClO, acid (optional), antiscalant, $NaHSO_3$	Antiscalant, $NaHSO_3$ and NaClO	NaClO, acid (optional), antiscalant, $NaHSO_3$	NaClO, acid (optional), antiscalant, $NaHSO_3$
Post- treatment	EDI	Degasifier	Degasifier	Degasifier
Technical innovations	UF as pre-treatment, EDI as demineralisation, brine concentrator	90% recovery		
Difficulties	Raw water with very high load of suspended solids and organic matter		High temperatures, variability of water quality	Presence of Aluminium in raw water
Electric consumption (kWh/m^3)		0.86		1.2
Operational costs (€/m^3)	0.26 1st RO 0.38 2nd RO 0.59 EDI	0.14		0.22

Industry has been traditionally an important user of desalination, for process water or for the use feeding boilers or refrigeration towers. This application in general has been the most innovative in terms of incorporating the new developments in technology as the Electrodesionization for demineralized water, UF and MF as pretreatments, etc.

Industrial plants have too other important specific characteristics, based always in a basic principle; it can't fail, because the whole production of the industry (products, energy, etc.) depends on water production and quality. For this reason this plants have a high automation level, all equipment with standby units, etc. This situation causes too that industry is predisposed to pay the price of water even more expensive if it represents guarantee of supply.

To mention some interesting experiences in the plants listed, we can remark the following;

- Sedebisa plant is fed by superficial water with high loads of organic matter and suspended solids. A pressurized Ultrafiltration was installed, although it was necessary to install later a previous sand filtration due to the high level of SS. As innovative design it was installed too a brine concentrator (RO system processing the brine from the main double RO system), getting in this way a very high recovery.
- García Carrion plant is a part of a project including an effluent treatment plant using MBR. The brine from the RO plant is blending with the MBR permeate producing a very high quality water used in the irrigation of orange and lemon trees planted surrounding the factory (fruit juice factory) in a kind of Zero Liquid discharge system. The RO plant has a design that produces 2 different qualities of water for the factory (< 50 µS/cm and < 500 µS/cm) for different applications and with 90% recovery.
- Plant installed in 1997 in Basrah Refinery treating Shat Al Arab river was very problematic due that the very high difference in temperatures from day to night and the bad quality of river water. It was solved by means of individual isolation of pressure vessels, adjusting the number of vessels in operation depending on the temperature. The situation of the surrounding environment (embargo) and the difficult to find materials and tools in the location it was not the best for the complex installation of this plant.
- Sidmed plant is an example of the very problematic treatment of tap water by means of RO systems, due to the presence of Aluminium (sometimes iron) used as coagulant in the drinking water treatment plant that causes fouling in the membranes, in this case aggravated for the use of polyacrilamides as antiscalant. With the use of more conventional (in this time, not in 1995) polyphosphonates this problem was avoided.

VI. DESALINATION OF BRACKISH WATER FOR OTHER APPLICATIONS

Desalinated water using membranes have broad possibilities for its use. Next we described some of them in the next table 4.

Table 4. Examples of desalination plants for other applications

	1	2	3	4
Plant	Xeresa Golf	Alicante University	Granada Airport	Parque Hort de Torrent

				
Owner	Xeresa Golf	Alicante University	AENA	Ayuntamiento San Vicente del Raspeig
Erection (year)	2003	1996	1999	1998
Capacity (m^3/day)	5,000	450	200	100
Technology	RO	RO	RO	RO
Raw water	Wastewater	Groundwater	groundwater	groundwater
Salinity	3,400 µS/cm	6,400 µS/cm	1,800 µS/cm	8,500 µS/cm
Product water requirements	< 600 µS/cm for green irrigation	Water for irrigation of gardens and parks	Drinking and services water	Water for park and urban services irrigation. < 250 µS/cm
Physical Pretreatment	Double stage filtration (sand + sand/anthracite) + cartridge filters + UV disinfection	Sand filtration + cartridge filters	Sand filtration + cartridge filters	Sand / anthracite filtration + cartridge filters
Chemical pretreatment	Antiscalant	Antiscalant, NaClO, $NaHSO_3$	Antiscalant, NaClO, $NaHSO_3$	Antiscalant, NaClO, $NaHSO_3$
Postreatment	Blending	None	None	None
Technical innovations	Wastewater treatment with conventional pre-treatment without chemicals	One of the first plants in Europe with low pressure membranes. Research centre for boron removal		
Difficulties	Very bad water quality	High level of boron		
Electrical consumption (kWh/m^3)	0.85	1.1	1	1
Operational costs (€/m^3)	0.29	0.22	0.18	0.25

It seems clear that the recreational and municipal uses will be an important user of desalination, many times using wastewater (reuse) or well water, reducing in this way the drinking water consumption.

In the case of treatment of wastewater by RO (or other membrane technologies) it represents some difficulties due to the membrane fouling. In the case of Xeresa Golf, we designed the plant with conventional pre-treatment (double stage filtration, cartridge filters and UV disinfection) and incredibly the plant was operating for more than one year without chemical cleaning using antiscalant as the only chemical (no coagulants, no chlorine, no acid). The experience was very interesting because we tried some other innovative decisions as the use of reused old membranes in the first position of each pressure vessel (as "fuse"), 4" "sacrifice" membrane at the inlet of RO train and in the outlet of brine, etc.

VII. ECONOMICAL FEASIBILITY OF DESALINATION OF BRACKISH WATER

It is clear due that the extension of the application that the desalination technology is clearly feasible for the production of water with quality for many applications (even from seawater), including some like the agricultural irrigation, that are very exigent about the cost of water; in the case of Spain with an economical (phychological?) limit for its use at > 0.3 €/m^3.

Other applications as industrial, drinking water or golf courses irrigation evidently can be assume the costs of desalted water, and then, perhaps is better to use seawater always if it's possible, leaving the brackish water applications for inland applications.

As a conclusion of these 14 years of experience treating brackish water, we can extract some conclusions:

- Evidently desalination of brackish water is cheaper than seawater but it rides accompanied of some problems as groundwater exhaustion, difficult to manage brines, problems with different water components (organic matter, suspended solids, sulphates, silica, aluminium, etc.)
- About technology in Spain has been predominant RO, although in the past some EDR plants were installed in Canary Island and more recently, in mainland. The higher cost of this technology accompanied with a monopoly the manufacture of EDR membranes caused in the past a lower extension of this technology.
- The use of nanofiltration has been reduced due that in comparison with the RO systems there are not too much difference in energy consumption compared with the better quality of product water
- In general conventional pretreatments has been used, leaving the Ultrafiltration systems for industrial applications due to the high cost of this technology; it seems that this is changing although slowly
- Agriculture in Spain has been traditionally benefited by the use of desalination as a new resource of water at a competitive cost. Many plants has been built in the last 20 years for this application.
- At the current situation, the construction of big seawater plants by the Spanish government has finished the use of brackish water desalination in coastal areas, maintaining only plants where there are not other possible resources
- It seems clear that, practically finalized the seawater desalination program in the coast, the future of the technology in Spain will be focused to increase the quality of drinking water inland (by means of RO, NF, EDR or even MF or UF technologies), as well as for reuse applications.

VIII. THE PROBLEM OF BRINE DISCHARGES IN BRACKISH WATER DESALINATION

One of the most important parts of the desalination projects is the environmental impact of this technology, particularly in the brine discharge to the sea.

For seawater projects it seems that problem is solved or, at least, controlled, by means of the usual practices (environmental studies dilution previous to the discharge, uses of diffusers, location of the brine discharge).

In the case of brackish water, the brine discharge is a very important problem with a no clear solution. The main solutions for these plants are:

- discharge to the sewer nets (with the associated problems at the recipient WWTP)
- deep well injection
- Zero Liquid Discharge (ZLD) system based mainly in evaporation-cristalization technologies
- Blending with other discharges (for example wastewater)
- Sea discharge, in coastal areas

Another additional problem is due that the composition of brine from brackish water desalination plants is not basically sodium chloride (as it is in SW plants), including other components like sulphates, nitrates, silica, and it can generate problems with the nutrients (N and P).

At this time it seems that the main R&D projects in desalination are focussed about energy consumption as well as brine impact reduction. In the case of Valoriza Agua we could remark a R&D project in development about innovative solutions for the brine discharges. I this project we are working to develop systems with less environmental impact and in technologies about recover of salts from brines. On this study, composed by 5 subprojects, with an investment of more than 6 million €, are involved 4 Spanish universities as well as other 3 companies lead by Valoriza Agua. The project involved a patent for the technology and important subsides from the Spanish Ministries of Industry and Environment.

Other additional environmental problem that is interesting to mention is the exhaustion of groundwater due that the extensive use in some areas that could produce important damages.

The project in under development and due that the interesting results obtained, it will be published in future presentations.

IX. CONCLUSIONS

The main conclusions obtained during this experience are indicated next.

- Water scarcity in many countries has brought about significant progress in the use of non conventional resources (Desalination and Reuse)

-Water from distinct origins may be used for desalination purposes (seawater, brackish water and wastewater)

-Spanish experience has demonstrated that desalination is a feasible alternative and can be incorporated in overall production costs (even for private initiatives)

- Cost of desalination of brackish water is very competitive and can be assumed by all the end-users, even the agricultural industry.

- Desalination of inland brackish water raises problems even not well solved due to the brine discharges or brine disposal, and it’s necessary to research more about this important topic.

X. REFERENCES

1. D. Zarzo. “Planta desaladora Virgen del Milagro (Mazarron), pionera en España en la desalación con fines agrícolas”. *RETEMA Medio Ambiente, Year IX, pages 13-16, January-February 1996.*

2. M. Rubio, D. Zarzo, S. Gil y J. Gil. “Aplicación de la Desalinización de Aguas para Agricultura. Experiencias en Alicante y Murcia.” *RETEMA Medio Ambiente, Year X, pages.45-50, May-June 1997.*

3. M. Rubio, D. Zarzo, y J. Hernandez “Aplicación práctica de turbinas de recuperación de energía en desalinización de aguas salobres” *INGENIERÍA CIVIL, nº 110, pages. 113-117, April-June 1998. ISSN: 02138468.*

4. M. Rubio y D. Zarzo. “Panorama actual de la desalación y reutilizacion para usos agricolas”. RIEGOS Y DRENAJES XXI*, Year XX, nº 136, pages.22-26, May-June 2004.*

5. M. Ferrer, D. Zarzo y R. Lemes. “Ampliacion de la planta Potabilizadora de Abrera”. *Revista Técnica del Medio Ambiente (RETEMA), nº 124, páginas 26-37, 2008*

6. M. Rubio, D. Zarzo, D. Ribes. "La desalación como complemento a la aportacion de caudales; panorama actual, costes y experiencias”, presented at the Congress; Jornadas *El Agua, Gestión Racional y Solidaria,* organizad by Colegio de Ingenieros Técnicos de Obras Públicas de Alicante, Alicante, Spain, 17-19 October 1996.

7. M. Rubio, D. Zarzo y J. Hernández. “Practical Application of Energy Recovery Turbines in Brackish Water Desalination Systems”. presented at the IDA World Congress on Desalination and Water Reuse, 6-9 October 1997, Madrid, Spain. Proceedings pages. 353-366.

8. M. Rubio, D. Zarzo, R. Sanmartin y C. García “Tratamiento de Aguas Superficiales Procedentes de Drenajes para su uso Agricola. Aspectos Tecnicos y Economicos y Experiencia en Explotacion”. presented at the Congress; I Congreso Nacional de AEDyR (Spanish Desalination and Reuse Association). La Desalacion y Reutilizacion cono Alternativa Real a la Sequía., 28 y 29 de November 2000, Murcia, Spain.

9. C. García, D. Zarzo. “Obtención De Agua Ultrapura Industrial Mediante Osmosis Inversa y Electrodesionizacion. Experiencias De Diseño Y Operación”. Presented at the Congress; III Congreso Nacional de AEDyR (Spanish Desalination and Reuse Association). November 2002, Málaga, Spain.

10. León, C. Otero, A. Zarzo y D. Zarzo. “Problematica De Las Aguas Salobres Con Salinidad Creciente. Caso De La Planta De Osmosis Inversa De La C.R. Cuevas De Almanzora” presented at the Congress; IV Congreso Nacional de AEDyR (Spanish Desalination and Reuse Association). November 2003, Las Palmas de Gran Canaria, Spain.

11. E. López, D. Zarzo y C. Otero. “Ultimas tendencias en el tratamiento de aguas industriales. Proyecto Sedebisa” presented at the Congress; V Congreso Nacional de AEDyR (Spanish Desalination and Reuse Association). November 2004, Almería, Spain

12. D. Zarzo, R. Buendia y C. García "Desalinizacion de aguas residuales urbanas por osmosis inversa con pretratamiento convencional" presented at the Congress; VI Congreso Nacional de AEDyR (Spanish Desalination and Reuse Association). 8-10 November 2006, Palma de Mallorca, Spain.

13. J.J. Rodriguez, A.Gomez, F. Valero, M. Ferrer, D. Zarzo y X. Vives "Proyecto de ampliación de la ETAP de Abrera (Barcelona), mediante electrodialisis reversible de 200.000 m^3/día de capacidad" presented at the Congress; VI Congreso Nacional de AEDyR (Spanish Desalination and Reuse Association). 8-10 November 2006, Palma de Mallorca, Spain.

14. M. Ferrer, F. Valero, D. Zarzo and X.Vives "Abrera (Barcelona, Spain) Drinking WTP Upgrade through Electrodialysis Reversal (200,000 m^3/day)". Presented at the Congress; IDA (International Desalination Association) World Congress on Desalination and Water Reuse, Maspalomas, Gran Canaria, Spain, 21-26 de october 2007.

15. C. García, J.L. Sanchez Lizaso, D. Zarzo. "Spanish Experience about prevention and control of environmental impacts from desalination. A case study". presented at the Congress; De-Salting Conference. Australian Water Association, Perth (Australia), 24-25 de september 2008

16. D. Zarzo, R. Buendia, C. García. "Desalination for irrigation and recreational uses". De-Salting Conference. Australian Water Association, Perth (Australia), 24-25 de september 2008