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ScienceDirect
Desalination 220 (2008) 150–164
DESALINATION
www.elsevier.com/locate/desal

# A new approach to meet the growing demand of professional training for the operating and management staff of desalination plants

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Received 28 September 2006; accepted 3 January 2007

**Abstract**

For the expected installation and operation of additional seawater desalination plants, manpower is needed. Besides the financing and the manufacturing of these plants, the training of the future staff is a big challenge. It is assumed that in the MENA region each year more than 1000 people will have to be trained. The present and future problem at seawater desalination plants, i.e. the lack of experienced personnel, is also a lack of instructors. There are already existing institutions and facilities in various countries carrying out well-organized training programs at site. In addition, there are many excellent short courses and workshops organized by organisations like EDS or MEDRC — nevertheless, the crucial question remains whether these structures are strong enough to meet the growing demand for professional training in the future. When talking about training programs, the question of how to finance these measurements emerges directly. The solution can be found in an improvement of the availability of the plants. A higher availability resulting in a higher fresh water production rate could be obtained by well-trained staff able to react in a proper way to any disturbances or unstable operation modes of the plant. The so-called "Twinning-Model" could be a suitable approach to meet the demand for professional training. A central training facility called TFEU (based in Europe and affiliated to an existing university or a technical school) is one of the twins and plays the part as developer of training programs (curricula), as instructor for the trainers and as trainer for advanced and simulator courses. Following the curricula, additional experts from other universities or companies are integrated in the team. After an initial phase needed for the training of the trainers, the local "twin" called TFLO is responsible for the fundamental and main training program. A board comprised of participants from all parties involved (i.e. TFEU and TFLO, the manufacturers as well as the operators) surveys the curricula and examination procedures.

*Keywords:* Operation; Availability; Staff; Training; Curricula; Twinning-Model

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*Presented at the conference on Desalination and the Environment. Sponsored by the European Desalination Society and Center for Research and Technology Hellas (CERTH), Sani Resort, Halkidiki, Greece, April 22–25, 2007.*


doi:10.1016/j.desal.2007.01.029

## 1. Introduction

It is undisputed amongst international experts, that the importance of seawater and brackish water desalination for the fresh water supply will increase as a result of the worsening shortage of renewable water resources in Southern Europe and the MENA region. For the expected installation and operation of additional desalination plants, well-trained personnel is of vital importance.

That said, several questions pop up immediately:

(1) How can the money needed over the next decade be raised for the manufacturing of the desalination plants?
(2) Who has the qualification to design, manufacture and erect these plants in a reasonable time frame?
(3) Who is able to operate these plants so that the preset conditions of the cost-benefit calculation are fulfilled?
(4) Where will the personnel needed for a proper operation of the plants be recruited from?

The primary focus of this paper is to discuss the last two points above. Points 1 and 2 will surely be discussed in further sessions of this conference. Thus we are searching for answers regarding how to recruit the appropriate staff of desalination plants.

As we immerse ourselves into this quite generally posed question we will face the following problems:

- What number of personnel are needed for managing and operating a desalination plant at a given capacity?
- What should the employees' structure look like?
- What kind of entry qualifications should be requested?
- How will we accrue people needed for this job and where will they come from?
- Should we train these people ourselves and if "YES":
  - Who should know what?
  - Where could the training be held?
  - How much would the training cost?

Regarding these questions posed, the paper is divided into 3 main chapters:

After finishing this introduction we will discuss staff requirement and employees structure of a typical seawater desalination plant. Which entry qualification for the training program is requested from the trainees and which skills are needed for the individual job on the plant will be subject of the following chapter. Before we present a new approach to meeting the growing demand on professional training the present situation in the training market will be explained and assessed.

To avoid questions out of the readership such as "And what about the costs? This subject will be discussed as always at the end of the paper where we will get a nasty surprise!", this here is a preliminary remark to this crucial point.

In order to be able to calculate the production cost of 1 $m^3$ of fresh water by desalination an availability of the plant has to be assumed (sometimes by experience, sometimes by wishful thinking). According to the definition of availability the total number of operating hours at full load have to be compared to the total number of hours per year. To obtain as high an availability as possible, a lot of money is spent for process equipment, process automation and process control systems. This will help to avoid unsafe operation, trips and damage of the plant equipment. Nevertheless, unforeseen events could cause a lot of trouble, such as shutdown of the plant causing a standstill period, which would really hurt. Despite all the high-sophisticated hardware, avoiding such events and proper trouble shooting is in the end a matter of the staff. In Germany for instance, the essential part of the training program for power plant operators is dedicated to this subject, this means simulator training at best equipped work places.

Let us assume that for an economic efficiency calculation the availability $f$ of a desalination plant has been preset to 0.95, i.e.

$$f = \frac{\text{operating hours}}{\text{hours per year}} = \frac{\text{OH}}{8760\ \text{h}} = 0.95$$

Thus the number of operating hours at full load is:

$$\text{OH} = 0.95 \cdot 8760\ \text{h} = 8322\ \text{h}$$

Or vice versa, the number of non-operating hours (NOH), i.e. plant standstill, is:

$$\text{NOH} = 8760\ \text{h} - 8322\ \text{h} = 438\ \text{h} = 1825\ \text{d}$$

The standstill period includes both regular shutdowns (i.e. for maintenance, repair and overhaul purposes) and unforeseen events. Regarding a desalination plant with a nominal capacity of 40,000 $m^3$/d a standstill period of one day results in a loss of 30,000 €, assumed that the specific prize for fresh water produced by the plant is 0.75 €/$m^3$. If the availability is reduced to 0.9 due to unforeseen events in combination with non professional action of the staff, the additional standstill periods leads to a total deficit of:

$$\text{Total deficit} = 1825\ \text{d} \cdot 30{,}000\ \frac{€}{\text{d}} = 547{,}500\ €$$

If this scenario takes place every year during a 10 years operation time the deficit compared with the figures of the cost-benefit calculation will accumulate to nearly 5.5 million €! (Plant capacity: 40,000 $m^3$/d, specific fresh water prize: 0.75 €/$m^3$.)

This calculation procedure sets the frame for the overall budget sum when discussing training programs and costs. An improvement of the availability by only one percentage point, i.e. 3.65 days per year additional full water production, would result for our exemplary desalination plant in an additional revenue of more than 1 million € over an operation time of 10 years.

At the end of the paper fees and supplementary costs for training programs will be presented in order to be able to evaluate the individual case.

## 2. Personnel on desalination plants — demand and structure

In 2003 the two consultant companies WANGNICK and S.T.E.P. conducted a comprehensive survey in behalf of the German Gesellschaft für Technische Zusammenarbeit GmbH (GTZ). This survey discussed the personnel situation at the existing and planned future desalination plants in the MENA countries. According to the biannual IDA Inventory Report [1], a questionnaire mailed to plant operators, consultants and manufacturers, and a model developed by WANGNICK (taking into account such parameters like population growth, gross national product and renewable water resources) the future desalination capacity could be estimated for each individual country of the MENA region. As Fig. 1 shows the mean value of the contracted and installed desalination capacity can be approximated by means of an exponential function of time resulting in a doubling of the desalination capacity for the next 10 years (i.e. 2015/2016). Knowing that the today's installed capacity is about 40 million $m^3$/d additional 40 million $m^3$/d have to be installed!

In order to obtain the future personnel demand it was first necessary to analyse the situation on plants in operation. Based on the above mentioned questionnaire and on published data combined with the expertise of the two consultant companies an employees structure shown in Table 1 was developed. The structure and the numbers are valid for desalination plants with a capacity of 50,000 $m^3$/d up to 60,000 $m^3$/d per unit. The same procedure was applied to different unit sizes (6 classes from small, i.e. 1000 $m^3$/d to large, i.e. >50,000 $m^3$/d).

In a following step the staff which need desalination technology orientated training has been defined. The table indicates that 77 persons have to be trained (about 35% of the total staff of the desalination plant). To determine the future demand of personnel needed to be trained it was assumed that the distribution of the plant size for the future plants (in all countries with a large demand) should correspond to the size distribution of the existing plants. Combining the forecast model of the future desalination plant demand with the personnel structure of the respective plant the total demand of personnel could be estimated. The result of this procedure for each individual country of the MENA region is shown in Fig. 2.

When considering the enormous desalination capacity which is installed and planned in Saudi Arabia and in the United Arabian Emirates, it is not surprising that both countries have an exposed state in regard of the staff needed to be trained. As can be seen from Table 2 the estimated demand of personnel to be trained during the next 10 years adds up to 3500 each ($2 \times 25\% = 50\%$ of the total of the MENA region).

Using a rough approximation of a linear distribution of the trainees over the years, when broken down by year a total number of 1450 persons have to be trained in the MENA region, respectively 350 in Saudi Arabia and in the Emirates.

These figures represent the forecasted situation at the new plants. However in our opinion the managers and operators of running plants need continuous upgrading, too. We have estimated that in the MENA region an additional 20,000 persons (Saudi Arabia: 10,000) should go through an annual or biannual training program to improve their knowledge and to train trouble shooting procedures.

As illustrated in Fig. 3 the personnel on desalination plants can be allocated to 6 groups:
(1) Management
(2) Administration
(3) Operation
(4) Maintenance & repair
(5) Laboratory/safety
(6) Training instructors

It is assumed that administration staff do not need desalination technology orientated training. Thus this group is not relevant for the concerns discussed here.

The members of the 5 remaining groups have different jobs that also require different training

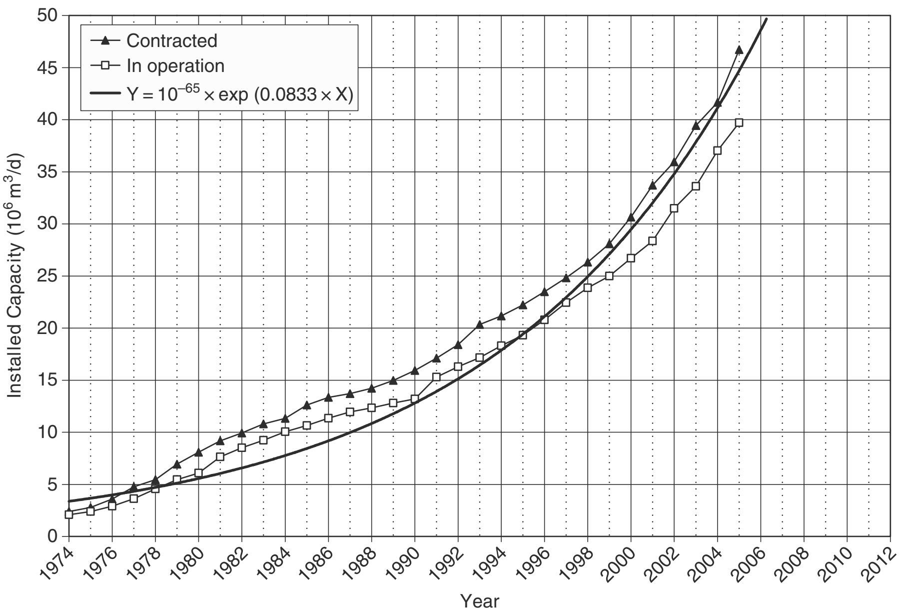


Fig. 1. Worldwide operational and contracted desalination plant capacity [1].

Table 1
Employees structure of a desalination plant larger than 50,000 m$^3$/d

| Management | f |
|---|---|
| A Superintendent | 1 |
| A Ass. Superintendent | 1 |
| A Senior Desal. Engineer | 1 |
| A Planner | 1 |
| A Material Specialist | 1 |
| Secretaries | 1 |
| **Total** | **6** |

| Administration | f |
|---|---|
| Manager | 1 |
| Accountants | 3 |
| Accounts Clerks | 8 |
| Wages Clerks | 4 |
| Secretaries | 4 |
| First Aid Nurses | 2 |
| Store Keepers | 3 |
| Ass. Store Keepers | 6 |
| Stores Clerks | 1 |
| Drivers | 4 |
| Labourers | 2 |
| Groundmen | 7 |
| Cleaners | 7 |
| **Total** | **52** |

| Operation | f |
|---|---|
| A Operation Manager | 1 |
| B Shift Engineers | 5 |
| C1 Control Room Operators | 12 |
| C1 Local Operators | 11 |
| B IT Specialist | 2 |
| Helpers | 15 |
| **Total** | **46** |

| Maintenance | f |
|---|---|
| A Maintenance Manager | 1 |
| **Electrical Equipment** | |
| B Electrical Engineer | 1 |
| C1 Electrical Foreman | 3 |
| Electricians | 4 |
| Labourers | 5 |
| **Mechanical Equipment** | |
| B Mechanical Engineer | 1 |
| C2 Mechanical Foreman | 3 |
| Mechanical Fitters | 4 |
| Pump Mechanics | 3 |
| Welders | 2 |
| Labourers | 5 |
| **IT + Instruments** | |
| B Instrument Engineer | 1 |
| C2 Instrument Technicians | 3 |
| B Computer Programmers | 1 |
| Labourers | 7 |
| Helpers | 15 |
| **Total** | **59** |

| Training, Safety, LAB | f |
|---|---|
| **Laboratory** | |
| B Chemists | 2 |
| B Assistant Chemists | 4 |
| **Chemicals** | |
| C1 CD Foreman | 3 |
| C1 CD Labourers | 6 |
| **Safety** | |
| Fire Fighting Foreman | 1 |
| Fire Fighters | 4 |
| Security Guards | 12 |
| **Training** | |
| D Training Instructor | 4 |
| D Ass. Training Instructors | 8 |
| **Total** | **44** |

| | |
|---|---|
| **Grand Total** | **207** |
| **Grand Total to be Trained** | **77** |

regarding learning targets, content of the program and duration. It is however not appropriate to design a special training program for each group, but more suitable to allocate the members to 3 training categories A, B, C as shown in Table 3. The complexity of a large desalination plant is reflected in these categories.

Based on this discussion the requirements for personnel training of seawater desalination plants can be defined as follows:

- Various professionals must be trained (engineers, technicians and craftsmen).
- The training must cover various aspects of engineering and various professions.
- The complexity of the plants must require a high level of special knowledge and a high standard of training.
- All aspects of the training as well as the certification must be recognized without reservation by the plant operators.
- A good basic knowledge in chemistry and physics must be required from the outset.

The last point in this listing addresses the entry qualification of the trainees. It is quite evident that the operator and/or the manufacturer of a desalination plant should not be responsible for the vocational education of engineers or

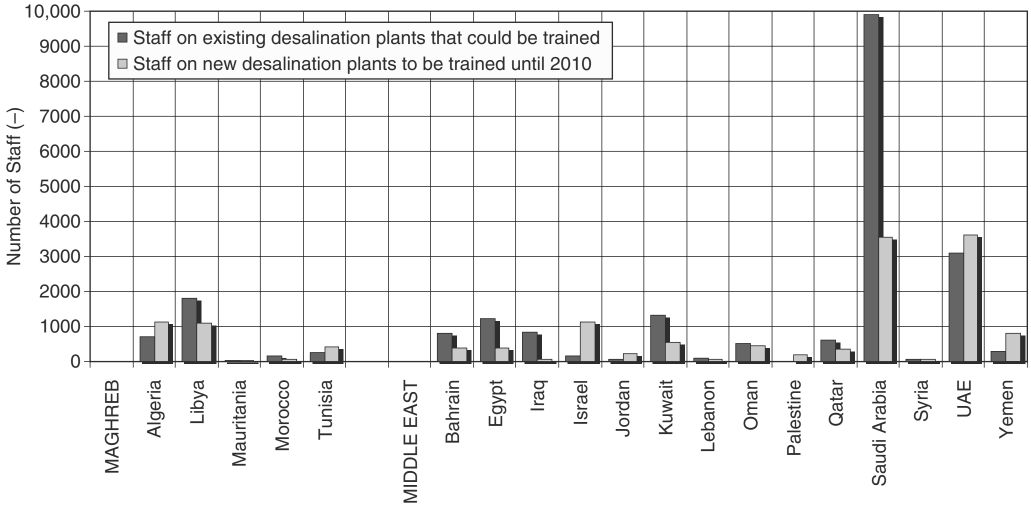


Fig. 2. Staff on existing and future desalination plants to be trained.

technicians — this is the original task of the national educational system. Hence the entry qualification of the trainees should be proved by an university diploma, i.e. "Engineer" or a master craft's diploma or comparable.

However, it is well-known that so-called "dual vocational training systems", i.e. theoretical and parallel practical training, are not yet fully installed in the relevant countries. The crux of a safe and reliable fresh water supply leads to the reasonable conclusion that private or parastatal operators should cooperate with governmental authorities in order to establish and to perform suitable training programs — springing from the idea of "Cooperative Capacity Building".

A very interesting and successful example of such a cooperation comes from Germany. The erection and the operation of nuclear power plants are strictly regulated by law. Among other things, the issues of staff training are also exactly defined by the regulations of this law. Thus for instance an operator has to perform a certain number of simulator training hours each year. All simulators (each nuclear power station has a tailor-made simulator) are installed in a simulator training centre operated by the KRAFTWERKSSCHULE E.V. (PowerTech Training Center [2]). Fig. 4 shows a picture of a typical simulator training room. In order to generate an economical operation of this center training courses are offered continually with fees fixed in a long-term contract between the operators of the nuclear power plants and the training centre.

Thus the German Government takes special care for the health of the citizens by ensuring that the nuclear power stations are being operated by well-trained staff.

It's surely worthwhile to seriously check into the possibility to bringing this approach to the

Table 2
Present and future personnel on desalination plants in the MENA region

| | | |
|---|---|---|
| Total number of staff on plants in operation | 56,000 | |
| Total demand for new plants (next 10 years) | 36,000 | |
| | 10 years | 1 year |
| Staff to be trained (new plants) | 14,500 | 1450 |
| Saudi Arabia | 3500 | 350 |
| VAE | 3500 | 350 |

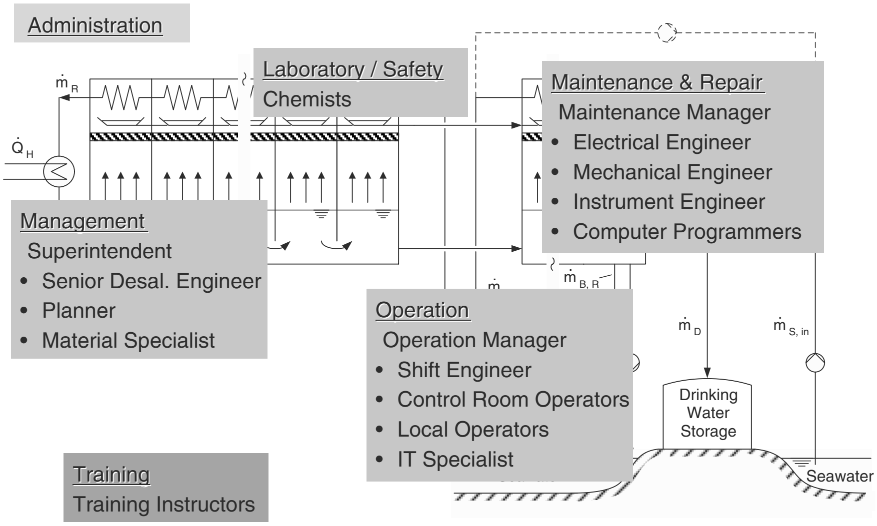


Fig. 3. Allocation of the personnel of a desalination plant.

countries suffering from severe water scarcity. Before we will discuss a new approach, a short glance at the present situation on the "Training Market" should be taken.

## 3. Assessment of the present training situation

In order to be able to assess the present training situation we have to distinguish between

(1) Local training performed by operators and manufacturers or third parties

(2) Training abroad

In several of the concerned countries, local training programs have already reached a high level. In 1987, Saudi Arabia as the country with the world's largest desalination capacity founded a Research and Development Centre based in Al Jubail. The centre includes five basic laboratories that are equipped with the most modern devices and experimental stations. The Saline Water Conversion Corporation (SWCC), a government owned company, which operates the center, has given top priority to the process of training and rehabilitation as well as to the process of Saudisation of jobs.

Table 3
Allocation of personnel to different training categories

| Category A | Category B | Category C1 | Category C2 | Category D |
|---|---|---|---|---|
| Superintendent<br>Assistant superintendent<br>Senior desalination engineers<br>Planners<br>Material specialists<br>Operation manager<br>Maintenance manager | Shift engineers<br>IT specialists<br>Electrical engineers<br>Mechanical engineers<br>Instrument engineers<br>Computer programmers<br>Chemists<br>Assistant chemists | Control room operators<br>Local operators<br>Electrical foremen<br>Chem. Dos. foremen<br>Chem. Dos. labourers | Mechanical foremen<br>Instrument technicians | Training instructors<br>Assistant training instructors |

It is assumed that desalination facilities have not yet been possible to establish in the Emirates, besides Abu Dhabi and Dubai. Abu Dhabi Water & Electricity Agency (ADWEA) owns the shares of certain companies that operate in the area of production, transmission and distribution of water and electricity. ADNOC, one of these companies, who owns desalination plants, seems to train their staff in a professional manner and be very well organised. ADNOC requires their operators to go through 2400 h of training, 50 of them solely on desalination technology.

Dubai has also installed a considerable desalination capacity. The plants are mainly owned by the Department of Electricity and Water Authority (DEWA) and the aluminium factory DUBAL. DUBAL offers a comprehensive career development program, which the company developed for its local employees. The program concentrates for 52 weeks on selection, how to train, and the who, what and why of performance before they start on-the-job training (another 20 weeks). The main emphasis is placed on English, Water Chemistry, Thermodynamics, Basics of Desalination and more Chemistry. The graduates get certificates after shadowing an operator for 24 weeks, rotating in areas such as seawater, turbines, and blending etc. DUBAL also offers its staff members a chance to take continuing education courses through its partnership with a technical college. They can get a H.Sc. on the job. At the end of six months in the control room, they must pass a competency test given by the engineer in charge. Training never stops until they earn their degree 3 years later. Each employee has a personal file with all his achievements and is well aware of the next job he is training for. It is no wonder that DUBAL has a very efficient plant. In DUBAL, one operator runs three units in comparison to other plants which need one operator per unit.

Fig. 4. Simulator training room at PowerTech Training Center, Essen/Germany [2].

Kuwait was the first country to implement the MSF process (1956). Already at a very early stage, Kuwait took on consultancy services for their desalination projects from external companies, i.e. consultants in the UK, Germany and USA, and had such services performed by personnel of the Ministry of Electricity & Water. They developed their own tenders with attached technical specifications, and these technical specifications represented the state of the art at that time.

Parallel to that, research and development of desalination processes were performed in the Kuwait Institute for Scientific Research (KISR). It is assumed that the training of desalination personnel is performed in-house, the practical part within the desalination complexes, the theoretical part in the KISR.

The listing might be topped off by more examples. However, according to our personal assessment the decisive point remains that training programs that are fully developed, well organised and efficient only exist within private companies or facilities which are closely related to a desalination plant complex. As soon as state-run research or training facilities are examined it is very difficult to obtain reliable information about level and content of training programs and whether these programs are active or not.

Besides the above mentioned local training programs many short courses, intensive courses, workshops and conferences are offered on the free market to upgrade ones knowledge in the field of thermal and mechanical desalination process technologies. The excellent work of EDS in cooperation with universities and research facilities like L´Aquila or CERTH and the activities of MEDRC should be awarded here in particular. The courses are being taught by experienced members of consultant or manufacturing companies and/or teachers from universities. It may be of interest to look at the target group of such an intensive course called “A 4-day intensive course on RO, NF and Membrane Filtration Technology for Potable Water Applications”:

*The course is directed to professionals who are familiar with membrane technology, with the objective of providing practical information on commercial products, the design process, operation conditions of membrane systems and economics of membrane desalting and water treatment applications.*

That the preferred participant should be a “Professional” is evident, since it is not possible to acquire basic knowledge about membrane technology in a course with a duration of 4 days. As important and essential such courses might be, the crux of the fast growing desalination market is in finding these professionals, in other words: the crux is in becoming a professional in the field of desalination technology if your entry qualification is new graduate engineer.

Before introducing an approach to cope with this task we would like to discuss an example from another industrial branch, the car industry. This is the so-called Trinidad Twinning Model [3].

## 4. The Trinidad Twinning Model

In Trinidad, as in many other developing countries, there is no educational system comparable to the German dual training system. This system is based on hands-on experience in companies as well as theoretical instruction in vocational technical schools. To a certain extent, there are state-governed vocational training colleges, but these are without hands-on training and therefore cannot be compared to German training facilities. German companies that want to invest and establish production facilities in Trinidad encounter the problem of finding qualified employees on the domestic labour market.

The industry initiated the development of a model that ensured the training of qualified personnel for the long term. The Twinning Model (Fig. 5) consists of a two-step training toward a Master Craftsman in Electrical/Electronic Engineering, which takes place in both Trinidad and in Germany. During a period of 6 months, the trainees go through two training phases “Basic

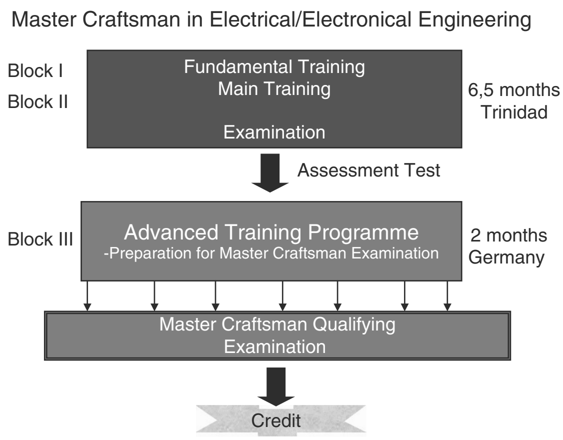


Fig. 5. Structure of the Trinidad Twinning Model [3].

Training" and "Main Training", after which they have to pass an examination. This is followed by a two-month "Advanced Training Programme" in Germany that is concluded with a Master Craftsman Examination.

To implement this model, an institute was established in Trinidad and supplied with the equipment necessary for the relevant training covering the first two phases "Theory" and "Practical Experience" of the above-mentioned model. In addition, two so-called "Examination Boards" were created that are supposed to administer the examinations. As shown in the table below, these boards are comprised of representatives of all parties involved in the project.

| Trinidad examination board | German examination board |
|---|---|
| • Energy Institute | • Chambers of Commerce |
| • Ministry | • Industry |
| • Industry | • University |
| • Schools/University | • Vocational Training Consultant |

Organization and procedures of the examination have been established in accordance with German standards. Consequently, the examinations have been recognized by the industry, especially by foreign companies interested in locating in Trinidad. In this context, the cooperation of the Chamber of Industry and Commerce is absolutely essential.

Upon successful completion of the examination and under consideration of the performance results compared to German standard, the certificates are co-signed by the German representatives. Here, especially the signature of the representative of the German Chamber guarantees the comparability of the Trinidadian vocational training with the German standard. After passing the examinations, the local boards of examiners receive a confirmation of this certification by a German "Chamber Document".

The Chamber Document establishes a form of "credit". Its validity is determined by the Trinidadian and the German part with specification of the precise conditions (e.g. 3 to 4 years). During this period of time, the certificates for the above-named target groups will be co-signed by the German representatives without the necessity of participation of German bodies (Chambers among others) in the local examination boards.

After the fixed duration of validity of the Chamber Document has expired, it is intended to have the comparability of the examination newly examined by the German bodies. Based on this, the period of "credit" will be extended or newly determined.

The project has been successful for several years. As a result, the youth unemployment in Trinidad has decreased noticeably and it has met the increased demand for (qualified) labour by the German industrial firms with activities in Trinidad.

Considering the positive results of the Trinidad Twinning Model the following question arise:

Could we transfer this model to the situation in the desalination market and how could an appropriate Desalination Twinning Model look like?

### *4.1. A new approach to professional training*

Based on the discussion in the last chapter additional requirements for the training of the personnel of seawater desalination plants can be defined:

- The training has to follow a "dual system", i.e. theoretical and hands-on training should be closely related and executed in parallel.
- A close cooperation between plant constructors, plant operators and local universities is necessary to meet the requirements of the market.
- It is essential that the initial knowledge is continuously broadened and kept up to date by way of further continuous training.

- The close combination of special knowledge and solid basic knowledge in engineering places high demands on the instructors.
- For this training programme, experts with various qualifications are needed.

Following the Trinidad Twinning Model especially the last two points concerning the qualification (and number) of the instructors lead to a network structure of local organisations and facilities linked with a central institution. According to the scheme shown in Fig. 6 the core of the structure is a pair or a twin of a local organisation or training facilities (called TFLO) and a central institution placed in an European country, i.e. Italy, France or Germany. The European Training Facility TFEU should be associated to an existing organisation. This could be a university or a technical school. Thus it is possible to use not only the existing infrastructure (i.e. seminar rooms, laboratories, apartment hotel) but also the teachers who are within this organisation.

An internationally accepted expert in the area of desalination and water treatment should act as head of the TFEU. He should be the person who is responsible for the development of the training programs, i.e. curricula and the recruitment of the teachers, and give the essential lectures concerning the desalination technologies by himself.

Within the scope of the complete training program (local and abroad) TFEU will organise and carry out the "Advanced Training Program" and the part "Train the Trainers". Additionally the curricula and the teaching material should be prepared by TFEU. The centralisation of these tasks has the advantage that the training programs and the certification will be recognized without reservation by the plant operators and the manufacturers — one of the essential requirements to each training. Thus the job market will become clearer since it will be sufficient for an applicant looking for a job in a desalination plant to show his TFEU — Certificate in order to prove his qualification as operator or shift-charge engineer.

The scheme in Fig. 7 indicates that within the complete training program the performance of "Fundamental Training" and "Main Training" should be the original task of TFLO. After finishing these two training phases and after successfully passing the assessment test the trainees could be registered for an advanced course. Due to the relatively high costs of a several-week training course abroad (we will discuss this subject later) this procedure is appropriate for all parties involved.

Concerning the above mentioned requirements of a "dual training system" the problem of hands-on training remains still unsolved. In case

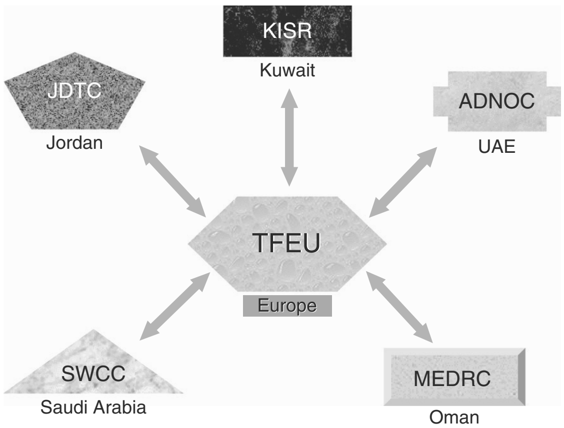


Fig. 6. Structure of the Desalination Twinning Model.

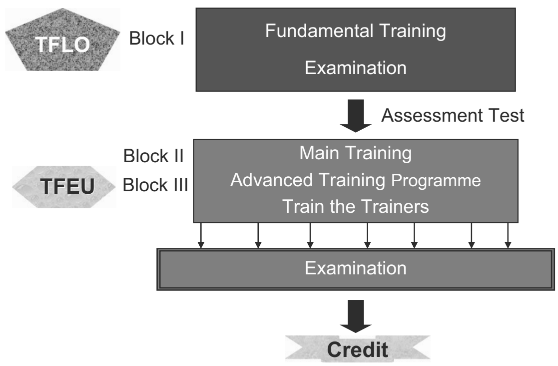


Fig. 7. Structure of the complete training program of TFLO and TFEU.

of a new plant the hands-on training is usually part of the manufacture's services during commissioning and trial run. It is quite comprehensible that the manufacturer who is responsible for the hands-on training is not really interested in running his plants at extreme and unsafe operation modes only to show the trainees how to handle such emergency conditions. That's the main reason why the essential part of the operator training for power plants is performed on computer based simulators. A well-designed simulator shows exactly the same behaviour as the real plant. Hence it is possible to train systematically transient conditions such as load changes or disturbances without the risk of tripping or damaging parts of the plant equipment.

The simulators designed and erected by a team comprised of specialists from the manufacturer and the TFLO can be operated by a group of regular employees of the TFEU. The former operators can be trained at the TFEU in a one- or two-week advanced training course.

With reference to published values [4] the costs for designing a full-scope simulator amounts to 1 to 2% of the investment costs of the plant to be simulated. Regarding for instance a new MSF plant with a capacity of 250,000 m$^3$/d we obtain:

| | |
|---|---|
| Capacity | 250,000 m$^3$/d |
| Specific costs | 1000 €/m$^3$/d |
| Investment costs | 250,000,000 € |
| Simulator costs (1%) | 2,500,000 € |

This value may be transferred now into "fresh water" very easily: Assuming specific production cost of 1 €/m$^3$ of potable water the simulator will be paid off through avoiding 10 days plant standstill caused by poorly trained operators.

The following positive example shows that this approach is not only dry theory.

The French plant manufacturer Sidem is erecting a 40,000 m$^3$/d MED-TVC plant (Multiple Effect Distillation with Thermal Vapour Compression) for drinking water supply of the Libyan town Abutaraba. The training was organised in close cooperation with the General Electricity Company of Libya GECOL and consists of the following phases:

Phase 1 GECOL recruits approx. 100 people from existing power stations and desalination plants (experienced engineers), and directly from University of Benghazi (new graduates).

Phase 2 Sidem performs a preparatory course on site, i.e. Benghazi. Subjects are thermodynamical and hydrodynamical fundamentals, water chemistry and desalination principles. The course is part of the Fundamental Training. At the end of the course the participants have to take an examination. Taking these results into account GECOL prepares a list of 50 people qualified for the next phase. If necessary these people have to take an English language course to reach the level appropriate for the training abroad.

Phase 3 The second part of the Fundamental Training and the main training is performed at Powertech Training Center in Essen/Germany. (Besides the personnel for the existing and future desalination plants GECOL is sending also personnel of its power plants to KWS for training purposes, especially simulator training.)

In charge of KWS the S.T.E.P. Consulting GmbH has the responsibility for preparing and carrying out the courses. If required S.T.E.P. involves external experts for special subjects (i.e. Dr. Heike Glade from University of Bremen for "Removal of Non Condensable Gases").

The courses at KWS have a duration of 5 weeks with the following content:

- Desalination principles
- Physical and chemical properties of seawater
- Fundamentals of evaporation
- Design and operation of multi-stage-flash-plants
- Design and operation of multiple-effect-distillation plants

- Design and operation of thermal vapour compression plants
- Energy consumption/co-generation and steam boiler
- Pretreatment of seawater
- Potabilisation
- Materials and corrosion
- Commissioning and hazard analysis
- Laboratory on programmable logic control system
- Identification system (KKS)

At the end of the course a written test has to be passed. The result of this test and soft factors such as attentiveness, diligence and social behaviour flow into a recommendation which helps each individual trainee to find a job most suitable for himself (shift charge engineer, operator, chemist).

Phase 4 During commissioning and trial run SIDEM performs the hands-on training.

The response of the participants regarding the training program has been very positive. They appreciate obtaining detailed knowledge about the thermodynamical and hydrodynamical processes in desalination as well as the implementation of the theoretical insights into the design and the equipment of a real plant. They have emphasized that this knowledge will surely enable them to act quickly and efficiently regarding any transient condition of the plant. As a result there is an increased availability and a reduction of the specific production costs of desalted water.

## 5. Costs of professional training

At the end of the introduction paragraph of this paper it was shown that an improvement of the availability of a 40,000 $m^3/d$ desalination plant by 1% per year would result in an additional revenue of more than 1.0 million € for an operation time of 10 years.

The total cost of an abroad training program consists of three parts:
(1) travel costs
(2) living costs
(3) course fees

The question about the travel costs can be answered easily knowing the number of trainees (in our example 50) and the flight data for the relevant case so that we will not discuss this subject here in detail. We simply assume travel cost of 1000 € per person. This gives:

$$\text{travel costs} = 50 \text{ participants } \cdot 1000 \frac{€}{\text{person}}$$
$$= 50{,}000\ €$$

However, one should take a look at the living costs and the course fees.

The living costs which include accommodation, meals, local transport and health assurance are the most cost-intensive part of the training performed abroad. Based on the amounts of the above explained example it is assumed that 50 € per trainee and day is a suitable value. The living costs for a five-week training program for 50 participants therefore summarize to:

$$\text{living costs} = 50 \text{ participants} \cdot 7 \frac{\text{d}}{\text{week}} \cdot 5 \text{ weeks}$$
$$\cdot 150 \frac{€}{\text{part} \cdot \text{d}} = 262{,}500\ €$$

(Possible pocket money for the trainees would naturally increase the living costs.)

The course fees on a weekly basis (7 lessons (45 min) per day, 5 days per week) could be set to 20,000 €. This leads to an additional amount of:

$$\text{course fees} = 5 \text{ weeks} \cdot 20{,}000 \frac{€}{\text{week}}$$
$$= 100{,}000\ €$$

Thus the total costs for the 5-week course with 50 participants add up to:

| | | |
|---|---|---|
| (1) | travel costs | 50,000 € |
| (2) | living costs | 262,500 € |
| (3) | course fees | 100,000 € |
| | total costs | 412,500 € |

Even when excluding the other costs that the operator also has to pay for the further training measurements, the gap between the revenue of 1 million € and the estimated costs of about 400,000 € for the training abroad is reason enough to justify the efforts for a professional training.

Although these figures can only provide a guideline (an adjustment will have to be made to each individual case), it has become evident, that the training measurements can be refunded through an improved availability followed by a higher fresh water production rate.

## 6. Conclusion and recommendation

For the expected installation and operation of additional seawater desalination plants, man-power is needed. Besides the financing and the manufacturing of these plants the training of the future staff is a big challenge. It is assumed that in the MENA region each year more than 1000 people will have to be trained. The present and future problem at seawater desalination plants, i.e. the lack of experienced personnel, is also a lack of instructors. The best and most experienced plant operators or constructors are, because of their exposed position, not really interested in turning to teaching. However, there might be a chance that these people are available for a short period of time, i.e. a training course lasting a few days but not for months or years, as would be necessary in a training centre. We are not talking about just a few people, but about 50 to 100 qualified teachers needed.

There are already existing institutions and facilities in various countries carrying out well-organized training programs at site. In addition, there are many excellent short courses and work-shops organized by organisations like EDS or MEDRC — nevertheless, the crucial question remains whether these structures are strong enough to meet the growing demand for profes-sional training in the future.

When talking about training programs, the question of how to finance these measurements emerges directly. The solution can be found in an improvement of the availability of the plants. A higher availability resulting in a higher fresh water production rate could be obtained by well-trained staff able to react in a proper way to any disturbances or unstable operation modes of the plant. Rough calculations prove that prevention of a 4 to 5-day plant standstill each year would bring enough money to pay for the training courses.

The so-called “Twinning-Model” could be a suitable approach to meet the demand for profes-sional training. A central training facility called TFEU (based in Europe and affiliated to an existing university or a technical school) is one of the twins and plays the part as developer of training programs (curricula), as instructor for the trainers and as trainer for advanced and simulator courses. The TFEU recruits his instruc-tors from the staff of the university or technical school. Following the curricula additional experts from other universities or companies are inte-grated in the team. After an initial phase needed for the training of the trainers, the local “twin” called TFLO is responsible for the fundamental and main training program. A board comprised of participants from all parties involved (i.e. TFEU and TFLO, the manufacturers as well as the operators) surveys the curricula and exami-nation procedures.

The current training program for the future staff of the Zuara and Abutaraba Desalination Plants is an excellent example of an efficient coop-eration between the Libyan GECOL as operator of the plants, the French manufacturer Sidem and the German PowerTech Training Center (KWS) assisted by an expert team of S.T.E.P.

Consulting GmbH. Based on the positive experience with this training program, we hope that more and more "MENA — Europe — Twins" will be established to tackle the problem of staff training.

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