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THE INCREASING DEMAND FOR DESALINATION

by

T.A. Dabbagh and A. Al-Saqabi

Award

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THE INCREASING DEMAND FOR DESALINATION

T.A. Dabbagh and A. Al-Saqabi
Kuwait Fund for Arab Economic Development*
P.O. Box 2921, Safat
13030 Kuwait

ABSTRACT

Desalination techniques have usually been utilised in arid zone countries with high incomes arising mainly from oil production. Potable water provided to the public by desalination has to be heavily subsidised by the governments concerned.

In reviewing the alternative water resources available in other arid and simi-arid zone countries when appraising water sectors for providing aid for development, it becomes increasingly evident that there will be a greater demand for desalination by the turn of the century. In fact, desalination has already imposed itself on some developing countries, in spite of its high capital cost and the subsequent subsidies required, since the only alternative may be to convey water for long distances, possibly from other countries.

The paper reviews the cost of producing water in developing countries and points out that when it comes to providing water the price will be paid, however high it may be. Reducing the cost of desalinated water, however, is not only dependent on improving desalination technology, but also on improving the management of the conservation and utilisation of desalinated water. The paper therefore emphasises that when desalination is proposed it is important that it should be carried out in conjunction with improving the efficiency of the water supply system, re-using sewage effluent and substantially increasing storage capacity.

* The views expressed in this paper are not necessarily those of Kuwait Fund for Arab Economic Development.

Finally, the paper attempts to indicate areas where further research is required and to show the need for collaborative action by arid zone oil-producing countries in setting up an institutional framework that would enable their extensive experience with desalination to be shared, and permit the establishment of a body of expertise that could work towards reducing the present, often prohibitive, cost of desalination.

1.0. BACKGROUND

1.1. The history of large-scale desalination can no longer be considered short; forty years have elapsed since it commenced in the early fifties. During this period technology in other more challenging fields has leapt forward and spread worldwide. Yet large-scale desalination, a basically simple process, has been confined to certain areas of the world, eventhough the demand for water has never been greater.

1.2. Despite major developments in the technology of desalination, the old multi-stage flash distillation process (MSF), still predominates for sea-water desalination, amounting to nearly 62% of the plants in the world. The next most successful process, reverse osmosis (RO), accounts for nearly 25%. The remaining 13% consists of various systems which are of more limited usage, less well developed, or still at the experimental stage (Ref.1).

1.3. Desalination technology has been associated mainly with wealth as it has only been used extensively in arid oil-producing countries and to a lesser extent in some industrial countries and arid islands. The development of this technology has been stimulated and encouraged by oil-producing countries since their oil incomes have enabled them to use desalination as their most reliable solution to the problem of providing water when surface and groundwater are very limited or negligible. Since the inception of the desalination industry the capacities of installed desalination plants have increased enormously.

Figure (1) shows the cumulative increase in capacity over the last three decades. Following a slow increase in the adoption of desalination technology, a rapid change started taking place in

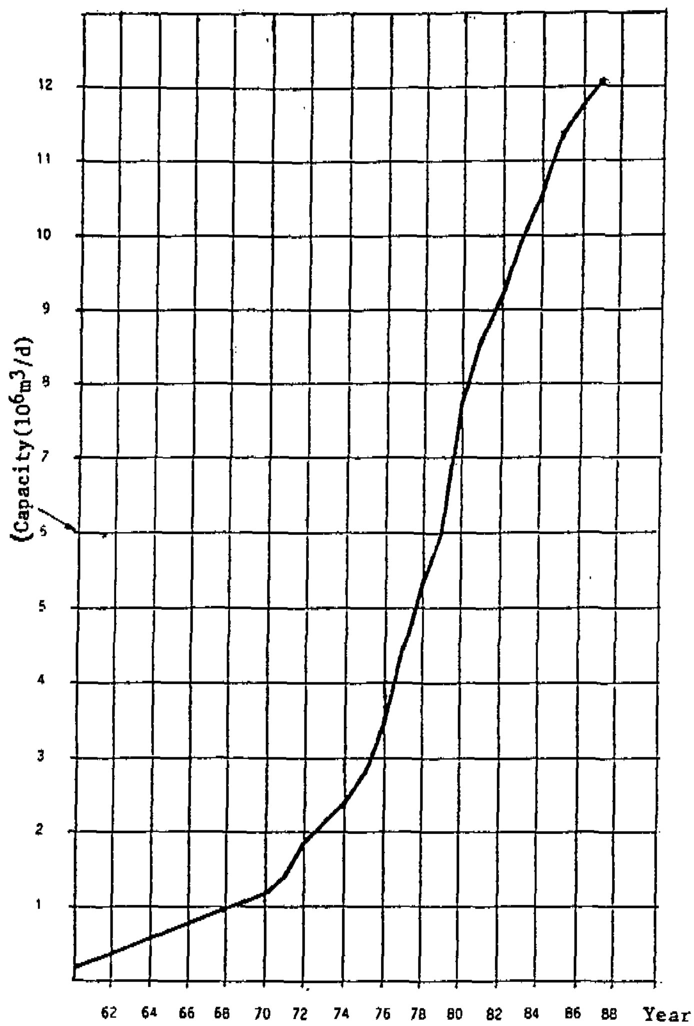

Figure 1 - Cumulative Capacity of all Land-based desalting plants capable of producing more than 100 m^3/unit of fresh water daily against contract year.

Source: Wangnick K Consulting, 1988 IDA Worlwide Desalting Plants Inventory, Gnavvenburg Germany, 1988.

the sixties when the average increase in cumulative capacity was in the region of 46 million m3 per year (10 billion gallons per year). This trebled between 1970 and 1976 and has since increased six-fold to an increase in cumulative capacity of about 283 million m3 per year (62 billion gallons per year).

2.0. WATER DEMAND IN ARID AND SEMI-ARID ZONES

2.1. Many arid and semi-arid countries face shortages of potable water available from natural sources. The Arab World is representative of such countries. It covers an area of about 14 million square kilometres and includes 22 countries with a present population of about 200 million estimated to increase to 280 million by the turn of the century. The average annual rainfall generally varies between 100 and 250mm and in most Arab countries not only are there no rivers or lakes but groundwater often lies at a considerable depth below the surface and suffers from a lack of substantial natural recharge. To make matters worse, many aquifers in the Arab World are of high salinity or suffer from increasing deterioration of water quality as a result of increased water abstraction.

2.2. The water resources in the Arab World in 1985 were estimated to be about 172 billion m3, while the water demand for domestic, industrial and agricultural purposes was estimated to be about 305 billion m3, leaving a deficit in the region of 133 billion m3 (Ref. 2). With an estimated population increase of around 2.5% annually, the deficit is expected to remain nearly the same until the year 2000, provided that the development of water resources takes an increasingly high priority in the development plans of all the regions and that adequate financial allocation is made to carry them out.

2.3. Within each region of the Arab World there will be major differences. The situation, for instance, in Somalia and Djibouti is expected to be substantially worse than in Egypt and Sudan. In the eastern region, the development of water resources in Jordan will be far more difficult than in the other countries while, in the western region, Tunisia, Libya and Mauritania will have greater difficulty than, say, Morocco or Algeria. In the Arabian Peninsula, water shortages will be the problem of the region's non-oil-producing countries, since the oil producers will increase their reliance on desalination. Kuwait, for example, already has desalination capacity of about 250 mgd (1.14 million m3/day) to meet the water demand into the next century, even if a proposal for conveying water from Iraq does not become a reality. Considerable variation also exists within each Arab country and is likely to be accentuated in future. Sudan, for instance, although it enjoys the Nile, has serious water shortages in its arid areas.

2.4. The lack of water for the development of arid and semi-arid regions is becoming a crucial issue. Indeed, the situation could become a key factor in confrontations over political frontiers (Ref. 3). According to the Centre for Strategic and International Studies regarding U.S. Foreign Policy on Water Resources in the Middle East, the Middle East is on the brink of another major natural resource crisis so that before the twenty-first century, the struggle over limited and threatened water resources could break already fragile ties among regional states and lead to unprecedented upheaval within the area (Ref. 4).

3.0. **ALTERNATIVES FOR DEVELOPING WATER RESOURCES**

3.1. Hence there is an urgent need to increase the rate of development of water resources in the Arab World in particular and in developing countries in general. The difficulties encountered will be substantial. Apart from oil-producing countries, the investment required is not readily available and must be obtained as technical assistance or loans from Arab development institutions or from industrial countries or their development institutions. They need to be convinced of the economic viability of the possible alternatives. However, by the turn of the century, some developing countries will have so depleted their natural resources that they will be forced to consider the alternatives of importing water from neighbouring countries or desalinating sea or brackish water.

3.2. Importing water from neighbouring countries by pipeline or tanker is not a new idea, but has been promoted more widely recently. Turkey has proposed a "Peace Pipeline" for sharing its abundant water resources with neighbouring countries. Europe has frequently promoted the shipment of water from southern Europe to North Africa and other developing countries (Ref. 5). Preliminary studies have been made for conveying water by pipeline from Pakistan to the Arabian Peninsula. But one of the most serious of all these proposals involves bringing water from the Shatt Al Arab in Iraq to Kuwait. The idea goes back to the early fifties, but has taken since then to reach the drawing board. If this is so for one of the simplest propositions, then it is not surprising that other more complicated projects, which involve crossing seas, mountains or other countries, never reach even this stage. The successful transportation of water has generally only been carried out over relatively short distances, as between Malaysia and Singapore or China and Hong Kong.

3.3. In spite of the reluctance of financing agencies to consider desalination as a viable alternative because of its high capital and running costs, it has, however, been imposing itself as a reliable and strategically safe solution. It has already been chosen by some developing countries as a main source of water in some of their towns and industrial or touristic centres. Table (1) shows the total capacities installed in some developing countries which are not major oil producers.

3.4. The operation and maintenance of some of these plants has not been easy. Cape Verde, for example has experienced numerous difficulties operating the plants which it has been using for the last 20 years. Nevertheless it will be increasing its capacity in 1990 by constructing two small additional plants with the assistance of foreign aid. Mauritania, on the other hand, had to close down its desalination plant near the capital Nouakchott after a few years owing to the high cost of operation and maintenance. Instead, groundwater is now pumped from a well field, but at the cost of depleting the aquifer, increasing sea water intrusion and provoking an even more serious water shortage in the future.

Table (1)

Desalination Capacities in Some Non-oil Producing Countries of the Third World

Country	Capacity (1) m3/day	Capacity (1) MGD	GNP/Capita (2)
Cape Verde	5,363	1.2	500
Chile	13,240	2.9	1,310
China	11,768	2.6	300
Columbia	7,465	1.6	1,220
Cyprus	7,710	1.7	5,210
Ecuador	5,604	1.2	1,040
Egypt	52,510	11.5	710
India	214,443	4.7	300
Jordan	6,861	1.5	1,540
Malaysia	6,968	1.5	1,800
Malta	66,254	14.5	4,010
Mauritania	4,654	1.0	440
Peru	14,852	3.3	1,430
Philippines	3,787	0.83	590
Singapore	16,500	3.6	7,940
Syria	5,623	1.24	1,820
Tunisia	20,370	4.5	1,210
North Yemen	2,053	0.5	620
South Yemen	3,161	0.7	420

Source : (1) Wangnick Consulting, 1988 IDA Worldwide Desalting Plants Inventory, Wangnick Consulting, Gnarrenburg, Germany, 1988.

(2) World Bank, The World Bank Atlas 1988, Washington D.C.

3.5. Desalination has also been increasingly resorted to by industrial countries, particularly Spain and the U.S.A. Between 1986 and 1987 Spain's capacity increased by about 85,000 m3/day (18.7 mgd) representing 12.3% of the desalination plants sold in that year, and making Spain the third major buyer after Saudi Arabia and the U.A.E. In the same year the U.S.A. increased its desalination capacity by about 52,000 m3/day (11.5 mgd) representing 7.65% of the desalination plants sold.

3.6. While efforts have been made to improve the utilisation of natural water resources, they have not been very effective because of the difficulties encountered in changing consumer habits, even in industrial countries with efficient managerial capabilities (Ref. 7 & 8). The result has frequently been over-exploitation of aquifers and deterioration in their quality. At the same time surface water has been utilised extensively by the construction of dams on most rivers in the world. Transporting water from water-rich regions has proved to be both exorbitantly expensive and beset with institutional obstacles (Ref. 7). Consequently, the demand for desalination has gone beyond the provision of water for domestic or industrial use. The U.S. Bureau of Reclamation is already constructing the world's largest R.O. plant of about 272,000 m3/day (60 mgd) capacity in Arizona to desalinate irrigation drainage. In addition, desalination is being considered as part of the process of refining sewage effluent to make it drinkable (Ref. 10).

4.0. <u>THE COST OF WATER</u>

4.1. The unit cost of water production in different countries varies considerably, as can be seen from Table (2) which gives the cost in a number of countries who replied to a WHO questionnaire received in December 1985 (Ref. 9). Their per capita incomes varied between US$ 1,362 to US$ 14,764 and the most striking observation is that some developing countries pay far more to produce their water than industrial countries or, indeed, than oil-producing countries such as Saudi Arabia which rely basically on the desalination of sea water. Although this is the exception rather than the rule, it nevertheless shows that when it comes to the provision of water the price will be paid however high it may be.

TABLE (2)

Unit Cost of Water Production in US$/m3 in Countries of varying GNP/Capita 136 to 14764 US$

Country	Cost $/m3	GNP/Capita $	% Cost to percapita
Cape Verde	4.65	317	1.5
Cayman Is.	2.75	13000	0.02
Cameroon	2.00	800	0.25
Mexico	1.50	2080	0.07
Argentina	1.50	1929	0.08
Netherland	1.25	9290	0.01
Zambia	1.05	390	0.3
Saudi Arabia*	1.00	8850	0.01
Sierra Leone	0.90	200	0.45
Tonga	0.80	354	0.23
Botswana	0.75	840	0.09
Togo	0.66	300	0.22
Suriname	0.60	3030	0.02
Seychelles	0.60	2250	0.03
Malawi	0.60	170	0.35
Papua New Guinea	0.55	649	0.09
Tunisia	0.50	1277	0.04
Cook Islands	0.40	7170	0.006
Cyprus	0.40	3572	0.01
Djibouti	0.40	480	0.08
Rwanda	0.40	280	0.14
Bahamas	0.37	7556	0.005
Laos	0.35	100	0.35
Barbados	0.34	4889	0.007
Ghana	0.35	420	0.08
Burundi	0.35	230	0.15
Mali	0.33	142	0.23
Switzerland	0.33	14764	0.002
Afghanistan	0.30	163	0.18
Mauritius	0.29	1020	0.03
Burma	0.25	188	0.13

Singapore	0.24	7420	0.003
Spain	0.22	4256	0.005
Vanuatu	0.22	529	0.04
Zaire	0.22	271	0.08
Hungary	0.23	1909	0.01
Finland	0.21	10531	0.002
Thailand	0.21	729	0.03
Hondorus	0.20	720	0.03
Republic of Korea	0.19	2032	0.009
Haiti	0.18	320	0.06
Malaysia	0.18	2033	0.009
Costa Rica	0.17	1300	0.013
Madagascar	0.17	240	0.07
Angola	0.15	560	0.03
Nicaragua	0.14	770	0.02
Morocco	0.14	512	0.03
Chile	0.12	1430	0.008
Peru	0.12	1010	0.012
Iraq	0.118	2964	0.004
Bangladesh	0.09	136	0.07
Ecuador	0.09	1160	0.008
Western Samoa	0.09	660	0.013
Panama	0.07	2100	0.003
Philippines	0.05	585	0.008

* It is not clear whether 1 $/m3 quoted for Saudi Arabia is for water obtained by desalination alone or includes abstraction of ground water as well. In Kuwait, however, the average cost is 1.6 $/m3 of desalinated water.

Source : World Water/WHO, The International Drinking Water Supply and Sanitation Decade Directory, Edition 3, Thomas Telford Ltd. London, 1987.

4.2. The high cost of production of water is not necessarily due to a lack of local resources. Singapore has no rivers of any significance, and barely any ground water to exploit, but instead has to rely on harvesting rain water and importing water from the neighbouring Malaysian mainland. Even so, the unit cost of water production in Singapore is one of the lowest in the table, that is $US 0.24/m3. By contrast, Cameroon with abundant rainfall and surface water has one of the highest costs of water production, that is $US 2.00/m3. This phenomenon can be attributed to many causes, the most important of which is the efficient utilization of the sources avalable; a major feature of Singapore Water Management is its high degree of efficiency.

4.3. Over the last forty years there has been an overall reduction in the cost of desalination. This has been presented graphically, based on extensive sources of information, by the U.S. Office of Technology Assessment (Ref. 10). The Graph, reproduced in Figure (2), shows that whereas higher oil prices affected the cost of desalinated sea water using distillation, the cost using RO was not substantially affected. Nevertheless, the cost of distillation is decreasing at a steeper gradient

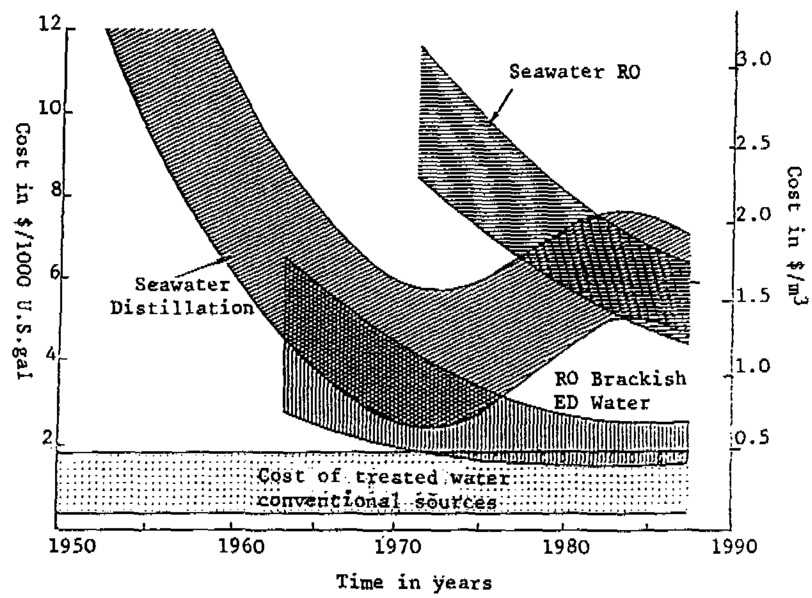

Figure 2- Approximate Desalination Costs(in 1985 $) for Plants Producing 1 U.S.mgd(4500 m^3/day) to 5 U.S.mgd(23000 m^3/day)

Source: Using Desalination Technologies for Water Treatment, Background Paper, U.S.Office of Technology Assessment, 1988, P.25

than RO and it has been shown to be the most cost-effective technology for producing large amounts, that is over 1 mgd (4,500 m3 per day), of desalinated water. When using brackish water of salinity up to about 10,000 mg/l, however, RO and ED are more cost-effective, particularly for small communities. In fact, these systems have become competitive with conventional methods of water treatment as shown in Figure (2).

4.4. In comparing the cost of sea water desalination plants for developing countries, the most important factors are operational simplicity and the availability of spare parts, whether, for instance, they can be manufactured locally or in neighbouring countries. bearing this in mind, distillation, particularly MSF, is more suitable for developing countries than RO which requires more careful control of the pre-treatment process. If this is disrupted it can lead to fouling of the very expensive membranes which have to be imported from abroad from a limited number of manufacturers. India can manufacture membranes, but they are not yet suitable for desalinating sea water.

5.0. REDUCING THE COST OF DESALINATION

5.1. In attempting to reduce the cost of desalination two aspects need to be looked at: firstly the technology and secondly the management of the production and conservation of desalinated water. Technological efforts must concentrate on reducing the capital, operation, maintenance and, above all, the energy costs. Managerial efforts must concentrate on maximising the conservation of desalinated water by reducing unaccounted-for water, reusing sewage effluent and increasing storage capacities. The need to tackle both aspects together is illustrated by Table (3) which gives a break-down of the cost of producing and distributing one metre cube of water in Kuwait in 1983/1984. It hows that whereas the cost of energy accounts for 65.5% of the cost of water production, leakage repairs account for 51.75% of the cost of water distribution.

5.2. The capital cost of a desalination plant is directly related to its life span. Technological improvements in plant design, heat transfer technology, corrosion protection and chemical selection have lead to extended life spans and reduced operation and maintenance costs, so that the life span of some MSF desalination units may exceed 15 years. However, the life span of a conventional water treatment plant is still much longer being normally taken as 30 to 40 years. Nevertheless, innovations are still being made, even with the long-established MSF process. Trials in the mid-eighties, for instance, concluded that one anti-scaling chemical, Belgard EVN, despite its high unit price was more cost-effective than other lower cost chemicals. Other developments have enabled plants to be operated at lower temperatures using a wider range of chemicals, thereby reducing scale formation, increasing longevity, and minimising plant shut-downs for maintenance operations.

TABLE (3)

Cost of Production and Distribution of Water in Kuwait in 1983/1984

1) Production of one m3 of Water

	Cost US$/m3	Percentage
Capital cost	0.188	12.0
Operation	0.126	8.0
Fuel	1.029	65.5
Maintenance	0.063	4.0
Administration and Overheads	0.084	5.4
	1.49	
Mixing with Brackish Water	0.08	5.1
Total Cost of Production	1.57	100.0%

2) Distribution of one m3 of Water

Capital Cost	0.156	18.7
Consumers Services	0.192	23.1
Administration and Overheads	0.054	6.5
Leakage repairs	0.431	51.7
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Total cost of Distribution	0.833	100.0%
Total cost of Production and Distribution	2.403 $/m3	

Source:- Ministry of Water and Electricity, Proceedings of Seminar on Water Resources in the Arab World and Extending their Utilization in the Arab World (Arabic), Kuwait (1986) 338-359.

Note:- Figures used are converted from cost of 1000 Imp. Gal. in KD.

1 KD = 3.5 US$

5.3. One technological approach is to try to use alternative energy sources such as solar and nuclear energy. Saudi Arabia has already established the Solar Village north of Riyadh (Ref. 13) while Israel has already used nuclear energy for desalination (Ref. 10), but very little information is available about the outcome. Energy requirements have, however, been reduced for many years by using a dual system of sea water desalination and electricity generation resulting in a cost reduction of about 25% in comparison with separate systems. One of the disadvantages is that the two systems are interdependent and thus tend to suffer suffer from a lack of flexibility. Excess electricity cannot be stored and excess water can only be stored for limited periods since extensive storage capacity reservoirs are expensive and it may develop odour. Excess water may, however, be produced because, typically, treatment and desalination plants have been designed to meet maximum demand, which may exceed average demand by a factor ranging from 1.3 to 2.0 or even higher, and also to meet future peak demands. Consequently, a large investment in peak capacity may be rarely utilized.

5.4. For fuller utilization of desalinated water, and hence further cost reduction, greater water storage capacity is required. To this end, Aquifer Storage Recovery (ASR) could be used. This is a relatively new system which has been developed and used successfully in the USA to improve the use of water supply and water treatment facilities. It involves the use of injection wells for the underground storage of treated drinking water in a suitable aquifer when the capacity of water supply facilities exceeds the demand and its subsequent recovery from the same well to meet seasonal, peak, emergency or long term demands. Figure (3), ASR may be used to store surplus water in this way. When electricity

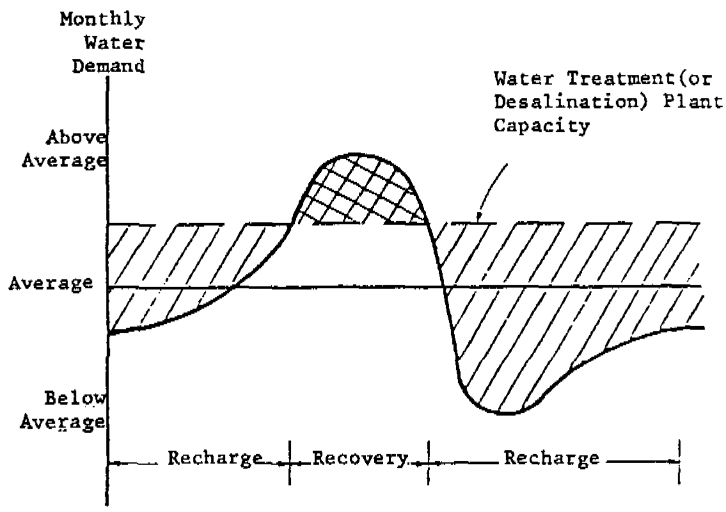

Figure 3 - Typical Aquifer Storage Recovery Operating Schedule

Source: R.D.G. Pyne, Aquifer Storage Recovery: A New Water Supply and Ground Water Recharge Alternative, CH2 HILL, Inc, Consulting Engineers USA, Post 1985, Particulars N.A.

is in low demand it can be used to inject desalinated water into the aquifer. Such seasonal storage may reach millions of cubic metres through a single well, *compared to a few hundred thousand* cubic metres stored in conventional ground or elevated storage tanks to meet demand variations.

5.5. By making more efficient use of existing water supply systems, including desalination plants, ASR can reduce capital costs by as such as 50% (Ref. 14). Treatment of the recovered water is generally unnecessary apart from disinfection. Should brackish water be already present in the storage aquifer it may be possible to use wells with horizontal screens to spread the desalinated water over it. The technology for constructing such wells has developed extensively and they can be far more efficient for rapid aquifer recharge than ordinary tube wells (Ref. 15, 16, 17 and 18).

5.6. Maximising the utilization of available water is the first line of attack when resources are scarce or water is expensively obtained. Records for unaccounted-for water in oil-producing countries of the Middle East are very hard to obtain, but there is evidence that they are in the region of 30% to 35% of the water produced. They indicate the amount of water produced but not paid for. There are two main types of losses included in unaccounted-for water. The first are financial in that the water is used but is not paid for, as in fire fighting, watering parks, faulty water meters and inefficient tariff collection etc. The second type are actual in that the water is wasted through the leakage of pipes, maintenance operations and the overflow of water tanks. In industrial countries unaccounted-for water can vary from as little as 2% to 40% or even more (Ref. 19), but since the value of the water may be very low, it does not encourage extensive renovation and repairs to the distribution network. On the other hand, when the cost of water is very high, it is essential to determine the unaccounted-for water and to reduce it by carrying out repairs or introducing improvements to the distribution system or the management procedure.

5.7. The re-use of sewage effluent is an important source of water in arid regions and it should always be considered when desalination is adopted. A great deal of doubt has been generated with regard to its impact on health, while social pressures and customs have constituted further barriers against its utilization. This has led to the adoption of sophisticated sewage treatment facilities which are both extremely costly and difficult to operate and maintain. The present treatment of sewage in Kuwait and Saudi Arabia, for example, provides a safety margin much larger than is justified by epidemiological evidence and greater than can be afforded by most countries (Ref. 20). Only this year, WHO has clearly stated that tertiary treatment is not necessary in any country and also that "in arid and semi-arid regions especially and also in other areas, it is imperative that re-use be taken into account as a feasible option for the disposal of collected wastewaters rather than as something that is possible only under exceptional conditions" (Ref. 21).

5.8. WHO's new approach greatly widens the scope for re-using sewage effluent especially in countries where desalination is used. Not only can the cost of treatment be minimised but utilisation can be maximised by recharging ground-water. This is particularly important when brackish ground water, used for blending with desalinated water, is being depleted. The artificial recharge of sewage effluent can provide major benefits: improving the quality of the effluent and, if recharging wells are used, reducing evaporation losses.

6.0. DEVELOPMENT OF DESALINATION TECHNOLOGY

6.1. The technology of desalination expanded in unusual circumstances with demand mainly limited to a certain zone where the oil boom made money readily available. The subsequent relative recessions in the oil-producing countries had repercussions on the manufacturing industry which, having expanded rapidly, had to shrink fast. This affected the availability of funds for research and development since, surprisingly, during forty years of desalination, progress has depended mainly on research carried out by manufactures. Industrial countries, apart from the USA, have shown little interest in allocating funds to develop a technology which they regard as having little importance for furthering their economic prospects. The USA was attracted by the industry in the sixties, but lost interest in the eighties, allocating no more than a few million dollars per year for research (Ref. 10). By contrast, in a field regarded as vitally important, the reduction of oil consumption, the industrial countries concentrated on research and reduced consumption significantly within a few years of oil prices being increased.

6.2. Compared with conventional water treatment industries, desalination tends to have been a province limited to interested specialists. The topic has, moreover, not been widely taught at Universities. Some research centres have been established by oil-producing countries, such as the Water Resources Development Centre in Kuwait and the Saline Water Conversion Corporation in Saudi Arabia which has recently established a research, development and training institute in Jubail. Clearly, to avoid duplication of research and to co-ordinate development, an institutional set-up needs to be established. In the late seventies an Arab Centre for desalination of water was discussed during the Arab World-Europe dialogue conducted then, but no agreement was reached (Ref. 22). Today, the timing of such a venture may be more appropriate since there is an increasing number of highly qualified personnel in the oil-producing countries.

7.0. INTERNATIONAL INSTITUTIONAL SET-UPS

7.1. The research carried out by the existing institutional set-ups in the major oil-producing countries has led to improvements in manufacturing standards, particularly with regard to protection against corrosion, optimum operating procedures, and the use of chemicals. The knowledge of such innovations has, however, been confined mainly to the dialogue between manufacturers and researchers who have used it to update technical specifications (Ref. 12). Evidently, there is a need for all the available experience to be co-ordinated so that improvements can be suggested in both the technology of desalination and the management of desalinated water. This could be effected by an international set-up relying basically on the experience available in the oil-producing countries. Substantial financial backing would be needed since no fund has so far been allocated for such research and development. The organization could have the following objectives:

1. Collection of data from all desalination plants in the region, with particular regard to the quality of feed water and product water, energy consumption, performance, main characteristics of operation and maintenance and relative advantages and disadvantages of different procedures.

2. Identification of promising fields of research e.g. construction materials, process chemicals, alternative energy, particularly solar energy and nuclear power, or the use and/or extraction of minerals from brine.

3. Provision of advice by drawing up a roster of specialists to review designs and alternative technologies.

4. Co-ordination of the above activities by contacts with the following organizations:

   A. Governmental Institutions

      a) to subsidise major research together with industrial nations to accelerate the development of promising technology.

      b) to assess the economics of using desalination as part of comprehensive water supply schemes that optimise plant operation, reduce unaccounted-for water, increase storage capacity, use aquifer recharge recovery, and maximise the re-use of sewage effluent.

c) to study the optimum conjunctive use of water, especially in arid zones i.e. desalinated water, brackish water, and sewage effluent.

B. Academic Institutions

a) to identify institutions interested in promoting research related to desalination.

b) to subsidise research

c) to establish prizes for research so as to attract international talent to participate more actively in the development of desalination.

d) to propose desalination syllabi to be included in university courses.

C. Manufacturing Industry

a) to establish standard for all materials and replacement parts.

b) to establish factories in the region or in other developing countries with greater industrial capabilities.

8.0. CONCLUSION

8.1. The demand for desalination is expected to increase as the demand for water grows in areas where the population increase is substantial and natural water resources are both limited and subject to over-utilisation leading to their depletion or quality deterioration. Also, desalination provides a reliable and independent source of water which has strategic advantages in comparison with reliance on outside water resources which requires a considerable investment, prolonged planning, besides the difficulties of implementation and operation procedures.

8.2. Desalination has imposed itself on some developing countries in spite of its high cost.

However, the cost has been reduced substantially and with improvements in technology and management in the desalination industry, it is possible that the cost of producing desalinated water will compare increasingly favourably with conventional means of water production, particularly in arid and semi-arid regions as their natural resources become depleted. The exhaustive utilization of water sources in developing countries could lead eventually to a serious situation that may result in confrontation among neighbouring countries.

8.3. Desalination as a viable alternative water source should be evaluated in the light of improved utilization of the whole water supply system. Major elements in this respect are the reduction of unaccounted-for water, the re-use of sewage effluent and the increase in storage capacity resulting from using aquifer storage recovery. Another prime component of such an assessment is the dual system of desalination and electricity generation.

8.4. Little financial support has been allocated for major research into desalination so that research has relied mainly on the manufacturers who have been at the mercy of a fluctuating market. Hence the importance of establishing an international research set-up with substantial financial backing to look into the technical and managerial factors involved in the desalination of sea water in order to develop it as a reliable source of water that can cater for the increasing demand in arid and semi-arid regions, particularly those with modest incomes.

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