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Recent developments in water desalination

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Abstract

The paper presents a global overview of the desalination of seawater. Lessons learned from success stories in the field are critically examined to indicate the potential of these initiatives to be treated as best practice initiatives for their possible applications in Mediterranean countries. Results from some interesting case studies elsewhere and from Libya are briefly given. An example from studies initiated at the Tajoura Engineering Academy indicating solar distillation as a promising alternative for saline water distillation that can partially support needs for fresh water with free energy, simple technology and a clean environment particularly in remote/rural communities are discussed. A plan to ensure the availability of high-quality water in coastal areas is presented to seek venues of possible cooperation amongst potential interested agencies in Mediterranean countries.

Keywords: Developments; Desalination; Seawater; Case study; Remote/rural communities; Mediterranean countries

1. Introduction

Desalination of seawater in coastal areas is increasingly becoming feasible and in some situations very much cost effective. Development of appropriate technology for the desalination of seawater in coastal communities where two-thirds of the world population lives thus poses one of the biggest challenges of the new millennium. The development, supply and use of seawater desalination technology in rural and remote coastal areas have generated great interest in many coastal countries. Like many of the southern European states bordering the Mediterranean sea, i.e, Cyprus, Malta, Spain and Greece, Libya is also looking towards seawater desalination to cover some of its water needs.

2. An appraisal of water supply and desalination technology in Libya

Over 80% of Libya's population resides along a thin strip of its 1900-km-long Mediterranean

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coast, which also contains most of the country's agricultural farms and major industrial units. In recent years a rapid increase in population and water consumption rates for domestic, industrial and agricultural purposes have had a significant impact on the country's water resources — mostly ground aquifers — which suffered serious depletion and deterioration. This situation combined with severe droughts and uneven population distribution have prompted a search for new and unconventional sources including large water transfer schemes [The Great Manmade River Project (GMMRP)], water desalination, and wastewater conservation through recycling and reuse. This has prompted the authorities to review the best available technology not entailing excessive cost (BATNEC) for water desalination and water reuse and to make recommendations in terms of benefits to the integrated water resources planning and management, as is evident from the recently held ICEWD2000 in Tripoli. The conference indicated that in recent years there is a niche for solar stills at low capacities [1,2]. For large capacities the trend is away from solar stills. This is because of several contributing factors such as the cost of large tracts of land, no money to be made from solar stills, too much optimism among researchers, and the technology used is not off-the-shelf equipment.

It is recognized that an intensive effort is needed to overcome the difficulties facing the wide-spread utilization of seawater desalination technologies. This would, in turn, require the development of appropriate infrastructure and related institutional settings.

3. A global overview on water and seawater desalination

An appraisal of the achievements made during International Drinking Water Supply and Sanitation Decade (IDWSSD) and beyond [2] shows that the total global annual funding of US $10 billion had only succeeded to some extent in introducing low-cost technologies and focusing attention on the user communities in Asia, Africa and Latin America as active participants in the development processes. Some progress has been made in developing models for the sustainable development of water in rural and peri-urban areas of developing countries. The plan for providing reliable water services which involved distribution of technologies, e.g., high technology for urban areas, intermediate technologies for peri-urban areas and low-cost technology in rural areas did not attract the requisite funds. Thus there is a clear need for much greater efforts to translate these models into workable approaches in view of the magnitude of the crisis, which is clearly seen by the fact that every year humans around the world use 160 billion tonnes more water than is replenished, yet 1.2 billion people lack access to safe drinking water, and annually there are 250 million cases of water-borne diseases with 10 million reported deaths.

An overview of progress achieved in Africa [1,2] showed that the continent which counts for some 30 of the world's 42 heavily indebted poor countries (HIPC) has suffered acute water problems associated with drought. Most countries fell significantly short of their targets for the 1980s and 1990s.

As per one estimate [2], 97.5% of the total water on the earth is salt water. Much of the remaining 2.5% is locked off in glaciers, meaning that only a small fraction of world's fresh water is available for use. Around 300 major river basins and many under ground aquifers cross national boundaries. Many of the world's fresh water resources are shared. For example, the Jordan River passes through, or is on the border of, Syria, Lebanon, Jordan, Israel and Palestine. The Nile River is also shared by 10 nations. In addition, there is a gradual depletion of the world's fresh water supplies mainly because of pollution brought on in part by population growth. Huge amounts of water disappear from city systems due to theft, inadequate metering and poor billing practices.

An appraisal shows that in 1930 the world's population was 2 billion. On October 12, 1999, it became 6 billion. As per UN estimates, by the end of the first century of this new millennium, the population is expected to be about 12 billion. Presently, there are 300 million people living in areas with severe water shortages. As per another estimate, the number is expected to increase to 3 billion by 2025. UN estimates show that about 9500 children die around the world each day because of the poor quality of drinking water. Middle East and North African countries have a combined population of about 285 million, about the same as North America. However, the net annual renewable water resources are only 7% of those of North America. Some of the regions in the Middle East such as the West Bank and Gaza face acute shortages and are provided with only 2.6 gal of water daily, i.e,. one-fifth of international standards. It is feared that in the Middle East water is going to be the catalyst for war. In the Far East the situation is similar. For example, China, with 22% of the world's population, has only 7% of the world's fresh water.

Many experts feel that in the short term the global water crisis problem can be resolved by better water management, i.e. conservation, realistic pricing, and some necessary regional shifts in agriculture. For instance [2], to produce a pound of beef it takes 7 lbs. of grain; this in turn takes 7000 lbs. of water. This same amount of water, if treated, is enough to meet one person's basic needs for about 6 months.

3.1. Best practices initiative in Libya

The Best Practices Programme (BPP), initiated during in 1999 in Libya, to collect, validate and maintain lessons learned from proven practices worldwide for its potential application in developing countries is gaining recognition. The objective is to repeat tried and true techniques that work to avoid repetition and monotony in industrial technology. "Best practice" can be defined as a recorded experience of proven value in conducting future activities. It pertains to actions, initiative, or projects that have led to tangible improvements in quality of life and the living environment of people through sustainable industrial development. The purpose of BPP is to provide means to systematically access, scrutinize and choose from the past experiences those lessons we can apply in a new situation with a high probability. The objective is to ensure that their use will result in a better course of action and results than would have been expected without their use. The aim is to stimulate thinking regarding the most effective use of lessons learned and to identify some potential pitfalls to avoid when considering the use of a demonstrated course of action in a new situation.

The Office of Scientific Activities (OSA) based initiative and methodology described elsewhere [2] gives us the lessons learned in various sectors of economy, including the water industry. It has helped to assess the current use of lessons learned and suggest guidelines for analyzing and applying best practices learned successfully in both in Libya and abroad.

Consequently, each BPP initiative considers alternatives and plans courses of action which serve as a subset of one or more models for the service of industry. Presently the OSA is engaged in designing interactive simulation models by a team of experts in statistics, related engineering disciplines, computer scientists and specialists in charge of relevant services. Typical suggested guidelines in the form of a questionnaire for the application of lessons learned from BPP initiative include the following:

- What is the credible model of system which is capable of describing the inter relationship of the major elements?

- What is the relationship between input and output of a required system?
- Is the problem thoroughly identified and defined?
- What are other available systems to resolve similar problems?
- What is different about the other system and how will those differences affect our application of the other programme solution?

4. Some results from typical case studies

Results from typical case studies pertain to water supply problems in many parts of the world, especially in an arid or semi-arid regions, with increasing population, opposition to dams, increasing agricultural requirements and opposing political viewpoints. Water resources in the study region are uneven in both time and space. Case study considers the six Gulf Corporation Council (GCC) members including Bahrain, Oman, Qatar, Kuwait, Saudi Arabia, and the UAE as arid to semi-arid. Most parts of Iran are also arid to semi-arid; 50% of it is mountainous. These countries are characterized by scanty rainfall. They suffer from a high rate of evaporation and consumption leading to deficits in their water projects. The expanding population, especially in remote areas in these countries, suffers from a great scarcity in per capita annual water resources. The socioeconomic development in these countries since the 1970s, especially after the oil crisis, has magnified the problem. Presently 90% of the water requirements are met by ground water. Desalinated water is 7.5% and the remaining 2.5% is obtained by treated waste water. The recycling of treated waste water, mainly introduced in 1980s, is gaining attention of the planners.

Ground water aquifers contained within the deep geological formations are major sources of water in most of the Middle Eastern countries such as Saudi Arabia, Bahrain, Qatar, Kuwait and Iran. This water source is also used for agriculture in addition to household requirements and drinking purposes. The salinity of these ground water is different from place to place. As per an estimate [2], the ground water sources in the Arabian Peninsula are 20×10^{12} m^3. However, the renewable resources are very limited due to the limited recharge, i.e., about 3000 Mm^3/y. It is further estimated that about 4000 Mm^3/y are available as surface water. This shows that water is being abstracted from storage at a faster rate than the recharge, resulting in gradual depletion of storage. The result is a continuous decline in the ground water levels and quality deterioration due to the encroachment of seawater.

4.1. Suggested technologies

Most of the countries in the case studies listed above satisfy about 75% of their water demands using non-renewable resources. Barely 25% of the demand is met by renewable conventional sources, desalination plants and recycled waste water. By and large these countries are considered to be leaders in utilizing non-conventional sources of water, especially desalination. Currently there are three major distillation processes: MSF, MED, and vapor compression (VC) which are in use commercially. MED technology is declining, mainly because of operation and maintenance problems due to scaling and fouling, especially at high-temperature operation. MSF plants provide the bulk of the installed capacity. VC small plants are also in operation. In addition, major membrane desalination processes such as reverse osmosis (RO), electrodialysis reversal (EDR) and mem-brane softening (MS) are gaining popularity. However, RO is not generally favoured, especially in locations which have high tempera-tures up to 40°C, high salinity levels, high silt density, high bacteria activity and high pollution, since these require complex pre-treatment. The cost of desalination water varies from US $0.75 to $3/m^3. The typical construction costs of seawater desalination plants range between US $1000–3000/m^3/d of installed capacity depending on plant size, location and design requirements.

The global appraisal of seawater desalination shows that the main problems facing coastal communities in several countries is the development of appropriate technology for seawater desalination. The various problems pertain to and can fall into following categories:

- lack of skilled personnel and appropriate technology
- difficulty in raising the funds required for support activities (resource evaluation, education and training, research, development and demonstration) and investment
- the need for coordination and planning of the action to be taken.

4.2. An appraisal of the present status and some typical results from studies at the Tajoura Engineering Academy

OSA appraisal shows that Libya relies heavily on groundwater for satisfying its ever-increasing water needs with minor contributions (<3%) from springs, wadis, surface run-off and dams. To alleviate the socioeconomic and environmental impacts of excessive mining of the ground water acquifers, the following remedial measures [3] have been taken:

1. Transporting of ground water from the south of Libya, where it is available in large quantities, to the north where it is urgently needed to implement the GMMRP;

2. Protection of current sources from pollution;

3. Development of unconventional water resources, e.g, water desalination and waste water reuse.

An overview of desalination technologies in Libya shows that since the early 1960s, because of its need for oil exploration, the country has over 400 plants with 0.65 MCM/d installed capacity, thus becoming the largest user of these technologies in the Mediterranean basin region. The country uses MSF, MED, EDR, VC and RO technologies in plants distributed geographically and used by all sectors. The largest capacties of over 400 m^3/d are provided by 92 MSF plants located along the Mediterranean coast. Most of the RO with an installed capacity of 135,000 m^3/d uses ground water for its desalination. However, seawater desalination accounts for more than 40% of the total installed capacity of all RO plants. About 75% of this capacity is provided by large- and medium-size plants (>4,000 m^3/d), while about 60% of these capacities are provided by plants that are 17 years old. The small plants, 77% of the total, provide the remaining installed capacity.

In brief, MSF technology provides 70% of the municipal water, 59% of the industrial waters, and 66% of water for other uses. RO technology is the second largest provider of desalinated water, i.e., 18% of municipal, 25% of industrial and 23% of others. EDR is the third largest and other technologies are last. The problems associated with the desalination plants pertain to design, installation, execution, operation and maintenance aspects [3].

Comprehensive studies at the Tajoura Engineering Academy in Libya pertain to solar distillation as a promising alternative for saline water distillation that can partially support needs for fresh water with free energy, simple technology and a clean environment, particularly in remote/rural communities. The results of a recent study [1] pertain to the design and testing of three types of reflectors: conventional galvanized steel, aluminum and mirror solar inside the stills. The theoretical values and experimental measurements [4] in respect to distillate output and efficiency have been compared to further improve the design. The results on aluminum and mirror solar inside the solar stills presented elsewhere [1] indicate an increased efficiency in water flow of the order of 18% and 26% compared to conventional galvanized steel stills.

Further studies on solar water stills at the Tajoura Engineering Academy pertain to the factorial design experiment. This involves the factors of climatic conditions; solar radiation input; still geometry or configuration parameters (length, width, slope, absorber surface area, etc.); water temperature; glass cover temperature; basin liner temperature; mass flow rate; thermal capacity of flowing water in the still; distillate output; efficiency of the system. Efforts to evaluate the impact of several types of reflectors such as conventional galvanized steel, aluminum and mirror solar distillation with a view to evolve an optimal design based upon performance and economic considerations are in progress.

Computer simulations are also in progress to improve performance by making optimum use of the still configuration and its properties. Analysis for enhanced distillate flow systems is being simulated too. Further studies to design a control system capable of monitoring and controlling the operation are in progress.

Computer models and computer-aided engineering are being developed in drafting parts of distillation units, production facilities, electronic systems, cost analysis, processing alternatives. etc.

Finally, expert systems for the diagnosis and support of different operations and controls in distillation plant production is under development. The objective of these expert systems is to engage in real-time monitoring and analyzing processes with values such as temperature and flow data during plant operation. It would be ultimately used to optimize strategies to identify anything out of the norm. It would help to find places of troubles graphically and in giving advice visually and vocally for preventing further trouble. In addition, it would help provide cause detection, counter measures of malfunctions, operational data for optimal operations.

5. Suggested plan of action

Cooperation among Mediterranean countries is needed to share the advance knowledge so far gained by the industrialized/developed countries with a view to obtain practical contributions to regional and specific research and the development and manufacture of the new and emerging technologies. The exchange of data, experience and information could be useful in the following areas:

- new technologies and problems related to their manufacture and commercialization
- institutional and regulatory policies related to standardization and quality control
- exchange of design, development and testing engineers to work in joint teams on national projects

Action-oriented cooperation can be developed among several Mediterranean countries in the form of good bilateral and multilateral cooperation with developed countries. These programmes can result in:

- establishment of regional prototype testing facilities for new technologies, especially in the field of seawater desalination
- setting up of demonstration projects in high-priority areas for new technologies related to seawater desalination
- establishing a regional information network on seawater desalination
- establishment of a regional training programme on seawater desalination
- etablishment of a regional technology support programme in the field of seawater desalination, with micro-computer software systems which can be used by all member countries.

The problems identified elsewhere [1] are:

- inadequacy of information and data resource assessment specially related to seawater desalination technology
- lack of know-how and limited technical capabilities

- lack of appropriate national policies regarding seawater desalination in long-term planning and the necessity of establishing adequate institutional infrastructures for the management of the operation of seawater desalination systems
- lack of financial resources for research, development and demonstration.

The problems of water supply in coastal zones can be tackled through concepts such as Integrated Coastal Zone Management as described elsewhere [5]. Such approaches emphasize the systemic nature of the coastal zone and the need to balance development and environment. However, a major missing element in these approaches has been the direct concern for the coastal community. There is an urgent need to improve the livelihood of these communities and to ensure their participation in restoring and preserving coastal ecology.

This would also require promoting and supporting the eco-village concept (5) as a self-contained system, where the outputs of a sub-system become inputs to another sub-system. There is a dire need for Mediterranean rural communities to join the eco-village movement to tackle the issue of water supply in rural areas, which is active around the world; there is even a Global Eco-village Network consisting of Findhorn Community, Scotland; The Farm, Tennessee, USA; Lebensgarten, Steyerberg, Germany; Crystal Waters, Australia; Ecoville, St. Petersburg, Russia; Gyurufu, Hungary; The Ladakh Project, India; The Manitou Institute, Colorado, USA; The Danish Eco-village Association; and Gaia Villages, Denmark, which acts as the secretariat.

6. Conclusions

The paper has presented an overview of water desalination in coastal areas. It has identified numerous difficulties in promoting the utilization and development of seawater desalination technologies.

The review of best practice initiatives shows that currently there are three major distillation processes, MSF, MED and VC, which are in use commercially. MED technology is facing decline, mainly because of operation and maintenance problems due to scaling and fouling, especially at high-temperature operation. MSF plants provide the bulk of the installed capacity. VC small plants are also in operation. In addition, major membrane desalination processes such as RO, EDR and membrane softening are gaining popularity. However, RO is not generally favoured, especially in locations which have high temperatures up to 40°C, high salinity levels, high silt density, high bacteria activity and high pollution, since these require complex pre-treatment. Solar distillation has the potential to become a promising alternative for saline water distillation that can partially support needs for fresh water with free energy, simple technology and a clean environment, particularly in remote/rural communities. Dealing with uncertainty and risk in the water industry needs not only a concerted plan of action but also a daring, caring and sharing approach. Daring without knowledge is risky. Knowledge without daring is fruitless.

There is a vital need to develop new water policys outlining measures to bridge the gap between current policies and those that lead to the sustainable use of the world's water resources. It is recommended that the Mediterranean countries pay new attention to areas including (1) institutional development, reforms and restructuring of water and energy industry and sector planning; (2) the development of greater community awareness and participation including the increase involvement of women; (3) the development and utilization of affordable appropriate technologies for water desalination; (4) research on issues related to sustainable water resources including scientific and engineering concerns on water quantity and quality, water supply and demand, geology, pollution sources, integration of water supply with sanitation and hygiene education; etc; (5) the importance of adequate operation and maintenance of systems; (6) the conservation and efficiency issues in water use; (7) the mobilization of communities through the eco-village movement concept to manage their programs through demonstration and extension services including the development of own cost recovery measures for operation and maintenance; (8) the significance of human resources development through awareness among policymakers, quality education , training and life-long learning; (9) promote and support studies and research and enhanced public understanding specially in the field of water supply using renewable energy like solar stills in remote/rural areas as a strategic priority; and (10) cooperation on water management and demand management practices at region-wide levels.

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