Desalination and Water Treatment
www.deswater.com

doi:10.5004/dwt.2017.21026

79 (2017) 87–92
June

Overview of sustainable water management in the MENA green industries

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Received 14 April 2015; Accepted 31 January 2017

ABSTRACT

Water is a key ingredient in many industrial processes and supporting activities. Considering the extreme water scarcity and the rapid rise in demand in the Middle East and North Africa (MENA) region, it is paramount that industries in the MENA region place as a top priority sustainable management of water resources and the reduction of the impact of their operations on the environment in general and fresh water bodies in particular. This paper discusses these water-related issues in the MENA region, which is at the core of the UN green industry initiative. The paper explores the range of industries, technologies, initiatives and governance issues in the MENA region where water plays the central or a significant role through greening existing industries or in creating new green industries. In particular, the paper discusses backed by case studies water conservation in industry, industrial infrastructure, desalination using renewable energy, research and development and governance. The study shows that the region is witnessing increasing use of renewable energy – particularly solar energy – in desalination. However support of research and development in increasing water use efficiency and reuse is still lacking. Although several countries in the region have strict laws and regulations with respect to wastewater treatment and reuse they are not adequately enforced. The study recommends adopting water and energy pricing schemes that properly capture the real cost of these scarce resources and send clear signals to the industrial sector to adopt more effect water conservation and reuse measures. The region should also increase their investment in research and development in the green industry sector.

Keywords: Green industry; Water; MENA; 3Rs; Sustainability; Wastewater

1. Introduction

Water plays a key role in a wide range of industries with varying levels of water quantity and quality requirements. It acts as a medium for transferring heat (cooling or heating) and removing waste. Water is also used in many industrial processes and ends up as a component in final products. Despite its importance, water is considered a secondary input in many industries owing to its generally low cost as compared to other operating costs such as wages, energy and input material [1]. In developed countries popular and formal concern over unsustainable utilization of natural resources, particularly water have dramatically reshaped how industry manages its water use and waste disposal. Developing countries – including countries in the MENA region – however are still lagging behind.

Several UN initiatives have evolved over the years to help developing countries achieve sustainable development and eradicate poverty while maintaining the integrity of ecosystems and the viability of their natural resource for future generations. More recently the UN introduced the Green Economy as a development paradigm that calls for the sustainable utilization of natural resources that achieves economic growth while reducing environmental pressures [2]. As a component of the Green Economy initiative, United Nations Industrial Development Organization

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(UNIDO) has advocated the Green Industry concept to galvanize efforts in bringing industry in line with sustainable development.

The green industry concept is a recent articulation of several decades of policy and philosophical discourse on sustainable development. The green industry concept as advanced by UNIDO addresses realigning industry from two perspectives: revamping existing industries – "Greening the Brown" (GtB) –, and creating new green industries – "Growing the Green" (GtG) [3]. The Green economy is anchored on the decoupling concept, whereby economic growth is not achieved at the expense of exerting additional environmental pressures. The ultimate objective is to produce more with less resources, waste generation and pollution. The well-established 3 R's (Reduce-Ruse-Recycle) approach is a key to achieve this objective.

This paper discusses the role of water in green industries, provides an overview of current water related industrial applications in the MENA region, and discusses opportunities for future growth in the green industrial sector. There is a wide range of industries, technologies, initiatives, policies and regulations where sustainable water management is a central issue. These can be categorized into the following:

- Water conservation in industry;
- Industrial infrastructure;
- Desalination using renewable energy;
- Research and development in support of water use in green industries; and
- Governance of industrial water use and wastewater management.

These water related green industry issues are discussed in the following sections and illustrated with case studies from MENA countries.

2. Water conservation in industry

The 3R's (reduce, reuse and recycle) approach has long been established as the ideal resource efficiency process. Reducing the use of a resource involves improving its use efficiency in industrial activities. Reusing a resource refers to using it again – with or without treatment – within the same facility. In comparison recycling is the process of treating the waste to a level suitable for other uses including other industrial processes, municipal applications or environmental services. Although all three steps should be considered, reducing the use of a resource is considered more optimal than reusing it which in turn is more optimal than recycling.

In designing a 3R's process in industrial water conservation, it is important to have in place an auditing procedure that accurately captures all water uses, quantity and composition of wastewater, alternative wastewater treatments and water quality requirements for reusing and recycling. A cost/benefit analysis can then assess the feasibility of alternative water conservation alternatives. Costs generally include capital investments and operating costs. Benefits include savings in water use and wastewater generation in addition to the potential added benefit of material recovery. Incremental economic analysis is generally applied to prioritize water conservation measures. For example, cost per unit for mechanical treatment of wastewater is greatly less than that for biological treatment.

2.1. Water uses and potential conservation in industry

Water use varies by industry and by the processes employed within each industry. Petrochemicals, oil, energy, steel, textile, paper and bulb and food processing are the major industrial users of water in the MENA region. Although a portion of the water is "consumed" through evaporation and incorporation in final products, the bulk of water used by industry is returned as a wastewater with varying composition of pollutants. Consequently, level of treatment would vary by industry and by the quality requirements by the users of reclaimed treated wastewater.

In terms of industrial processes cooling and heating are the most water intensive processes. In open ended systems, wastewater is treated – internally or externally – and then released to the environment. More ideally, a closed loop system should be employed where wastewater is treated and reused several times. This process would increase water productivity.

Cooling towers are the most common and most water intensive systems used in industry. In a typical cooling tower, warm or hot water is cooled by evaporation with heat released to the atmosphere. Water consumption is attributed to evaporation, bleeding and makeup (partially replacing water with freshwater to reduce accumulation of total dissolved solids (TDS)), and losses due to air drifting, wind and leakages. Useful best-practice procedures for water conservation in cooling towers can be found in [4].

Quite commonly water losses occur throughout the industrial and housekeeping activities. Water losses can be substantial. However, simple measures such as fixing leaky pipes, raising awareness among staff, and water saving devices can significantly reduce losses. Consequently, investments in these measures have high returns in water savings.

The Arab Forum for Environment and Development (AFED), a non-governmental organization, developed a water efficiency handbook that provides guidance on water conservation in the industrial, municipal and agricultural sectors [5]. The handbook emphasizes seeking support from management and staff, developing a baseline on current water use, identifying and prioritizing water saving options, and setting up a system for monitoring progress. The handbook also provides a summary of water saving options in industrial processes and related activities.

The World Business Council for Sustainable Development (WBCSD) has released a software tool – Global Water Tool for Power Utilities – to help companies in the power and utilities sector assess their water use and consumption and benchmark them using a set of water use efficiency metrics against local, regional and international levels [6].

2.2. A case study – water conservation in paper production

This case illustrates not only the potential of major reduction in industrial water use, but it also presents an industry that was developed to utilize treated municipal wastewater to recycle waste paper. The Middle East Paper Company (MEPCO) started operation in Jeddah in 2002 to produce paper products from waste paper using treated wastewater from the Khumrah wastewater treatment plant in Jeddah. Production was 100,000 tons/year at a water use of 20 m^3 per ton of product with a total water use of 2 million m^3/year. In less than five years the company over-tripled its production to using close to 7 million m^3/year [7].

Faced with limited availability of water, the company carried out a systematic analysis of their water use to identify water use efficiencies and alternative efficiency measures. A system of screens, drum filters, air floatation units, gravity filters, and a reverse osmosis unit were then installed to treat and reuse effluent which dramatically improved water use efficiency to 8 m^3/ton amounting to water savings of 4.2 million m^3/year. The water use efficiency measures had the added benefit of increasing efficiency of fiber recovery from 80% to 90%. Water use efficiency reduced company's operational cost by over $ 400,000/ year at a lump investment cost of $ 870,000 with a 2-year payback.

Further assessment showed that biological treatment of effluents can improve water use efficiency to 6 m^3/ton at an additional investment of $ 2.7 million. Additional water savings would be around 1.2 million m^3/ year equivalent to operational cost savings of $160,000. Incremental cost of these additional savings is therefore quite high and require 16 year to payback investment.

2.3. A case study – dairy producer

As reported by [8] the largest Ultra High Temperature (UHT) milk processer in Saudi Arabia with a production of 400,000 liters of milk per day has revamped its water use to achieve a significant reduction in water use. Prior to implementing water use efficiency measures the company used over 2000 m^3/day and discharged over 1400 m^3/day to external sewage system. Through a combination of measures including reusing cooling water, reducing waste in cleaning and repairing leaks, the company managed to reduce water use per liter of milk from 4.26 liters to 3.33 liters which amounts to over 160,000 m^3 of water per year. Water savings were worth $153,000 per year at an investment cost of $120,000 (Payback period = 9 months.) Additional water conservation measures would yield another $40,000 at the cost of $45,000. Factors that facilitated the implementation of water conservation measures include securing buy-in from management, installing monitoring system, training and developing a culture of water conservation among the employees.

2.4. A case study – olive oil extraction

Olive oil extraction produces substantial wastewater – referred to as olive mill wastewater (OMW) – which is highly toxic and has a high organic content. 1.2 to 1.8 m^3 of OMW is produced per ton of olives [9]. Morocco is one of the largest producers of olive oil in the world. The National Cleaner Production Centre in Morocco has supported local industry in adopting a new olive oil extraction system which reduces water use and waste production. The new system achieve 95% reduction in water use, produces virtually no solid waste and saves 15% of energy requirements by using solid waste as a fuel [10].

3. Industrial infrastructure

Organizing industrial activities through Industrial parks has been a preferred approach to managing industrial development as it facilitates better regulation and supporting services, and can be situated away from residential areas. However, concerns over industrial resource waste, pollution and the social implications of industrial development led to a global interest in the industrial ecology (IE) concept which calls for organizing industry to mimic the natural ecosystem in which material and energy is cycled through a series of species where waste generated by one species is utilized by another. IE advocates developing symbiotic relationships among industries to facilitate exchange of inputs and outputs that will lead to more efficient use of resources and reduction of environmental impact of industrial waste. For example, wastewater treatment facilities in one industry can be designed and managed to produce treated wastewater with quality specifications that match those of input water for another industry.

Due to its logical appeal and congruence with the concept of sustainability, there has been great enthusiasm in implementing the IE approach mostly in form of developing – or reorganizing current industrial parks into – Eco-Industrial Parks (EIP). However, assessment of EIPs give mixed results. The experience has not been positive in the USA or Britain due to a range of reasons including restrictive regulations on reuse of hazardous waste and the lack of incentive in forging networking among industries [11]. In contrast the South Korean experience has been reported to be quite beneficial both economically and in reducing environmental impact, a success mainly attributed to strong backing from the government both financially and in developing an effective institutional structure that facilitated active participation from the industry [12].

As shown in the case study below Saudi Arabia has been a leader in the MENA region in adopting principles from the IE concept in the development of its two main industrial cities: Jubail and Yanbu. In both industrial cities common industrial infrastructures have been developed to provide water supply, cooling requirements and wastewater treatment.

3.1. A case study – industrial utility

The two largest industrial companies in Saudi Arabia (SABIC and ARAMCO) and two public agencies have entered into a one-billion USD joint venture in 2003 to form Marafiq as an industrial utility to provide central power and water services for the industrial cities of Jubail and Yanbu. Marafiq collects and treat – separately – industrial and domestic wastewater. It supplies through extensive networks treated wastewater for irrigation and industrial customers. It is estimated that in 2011 Marafiq treated 160,000 m^3/day and 55,000 m^3/day from Jubail and Yanbu, respectively. However, only 50% was reused mostly in irrigation with only a small fraction (around 5,000 m^3/day in total for both cities) was reused by industry mostly for cooling, heating and landscaping [13]. It is not clear from the reference the destination of the balance. Consequently, treated wastewater is greatly underutilized by industry.

3.2. A case study – district seawater cooling

The North Shore District Cooling Network uses seawater to provide cooling requirements to the Bahrain Financial Harbor business complex. In addition of virtually eliminating requirements of fresh water – mostly obtained via desalination – for cooling, this central cooling system is expected to reduce peak power demand in Bahrain by 400 MW by 2020, deferring costly capital investment to expand power generation capacity [14].

4. Desalination using renewable energy

Desalination systems using renewable energy can be generally categorized into thermal and electrical types [15]. The first type relies on utilizing heat generated by a renewable energy source (RES). An example is a multistate flash desalination system using reject heat from a concentrated solar power system (CSP). The second type is based on using RES-generated electricity. An example is a reverse osmosis (RO) plant that uses electricity generated by a solar photo-voltaic (SPV) system.

The German Aerospace Center (DLR) has conducted a comprehensive feasibility assessment of solar power (CSP) seawater desalination in the Middle East and North Africa (MENA) region. The study concluded that within 20 years CSP desalination would bring cost down to \$0.6/m^3 making it competitive with freshwater supplies particularly in coastal cities [16].

4.1. A case study – Desalination using solar and geothermal energies

A small solar desalination system was tested in southern Algeria to desalinate brackish groundwater for remote communities. The system is a multi-effect solar still with thermal storage. The combined use of thermal storage and geothermal water as a feed resulted in desalination productivity of up to 20 liters per m^2 per day in comparison to 5 to 6 liters per m^2 per day by a regular solar still. The system developed can be constructed using local material and does not require high skill to operate and maintain [17].

4.2. A case study – Hybrid wind/solar seawater greenhouse

A hybrid wind/solar seawater greenhouse was developed as a test pilot in Oman to assess its technical feasibility in supplying desalinated water for greenhouse crops [18]. The system is based on a humidification/dehumidification process where seawater is first pumped from a well – to filter out suspended solids – into a storage tank and then through a condenser to cool it. Seawater is then blown by prevailing winds through an evaporator into the greenhouse. The incoming moisture laden air then gets dehumidified by the condenser and freshwater is collected and used to irrigate crops. Solar photo-voltaic units are used to power the pumps and fans. The greenhouse measuring 16 meter wide and 60 meter long generates 297 liters/day. The system relies on on-line measurements of meteorological conditions. An interesting feature of the greenhouse is the using of specially designed roof elements to filter out sun radiation allowing only the part required for photosynthesis and consequently keeping the air cool in the greenhouse without reducing plants photosynthesis requirements.

4.3. A case study – mobile solar-powered desalination unit

A company – SPX Global – founded by an Iraqi entrepreneur has designed a trailer-mounted desalination unit that uses solar power to run an ultrafiltration (UF) membrane system. In comparison to RO membranes, UF membranes have larger pore sizes and consequently much lower pressure is required [19]. SPX Global has delivered 325 units to the Iraqi Ministry of Municipalities and Public Works worth \$17 million. Unit capacity range from 1 to 5 m^3/hour at a cost around \$2.65 per m^3 based on a 10-year life span. The company is currently developing a new line of solar-powered RO units for desalinating brackish water. The units will use a tracking system to keep solar panels optimally oriented towards the sun.

4.4. A case study – solar-powered desalination

As a joint venture between the King Abdulaziz City for Science and Technology (KACST) and IBM a solar-powered desalination plant was developed in Al Khafji, Saudi Arabia. The plant utilizes ultra-high concentrator photovoltaic (UHCPV) technology to produce 30,000 m^3/day of desalinated water equal to the demand of 100,000 people [20].

5. Research and development

Countries in the MENA region have some of the lowest rates of spending – in terms of percentage of GDP – on research and development. This also applies to research and development on industrial water use. The industry in the MENA region generally prefer to import rather than develop technology. Key research issues for the region relate to exploring solutions to enhance water use efficiency, reduce water pollution and facilitate more effective exchange of inputs and outputs among industries. These research issues transcend all water use sectors including urban and agricultural sectors. Water pricing policies for example targets reducing water use and enhancing water use efficiency. Research in wastewater treatment and reuse would also need to consider addressing matching wastewater treatment levels and costs with the need of end users in industry and agriculture. In following sections we present some of the few research activities in the region that address water use and production in the industry.

5.1. The Middle East desalination research center

The MEDRC has funded several research activities on using solar energy for desalination including for example [21]:

- Development of a hybrid fossil/solar still-based desalination unit which can be built and maintained using local materials and skills;
- Development of a decision-support system for assessing and selecting most optimal renewable energy desalination solutions; and
- Development of a RO desalination unit powered by a combined PV/diesel engine.

5.2. Development of an integrated seawater system

Masdar institute has entered into a joint research and development venture with Etihad Airways, Boeing and UOP Honeywall to develop an integrated agriculture/aquaculture seawater system [22]. The research is based on refining a system originally developed in the USA and implemented in Eretria and Mexico. In this system seawater is pumped into fish and shrimp ponds. Runoff from these ponds is then used to irrigate fields of high salt-tolerant salicornia. Feces from shrimp and fish supply nutrients to salicornia. Prior to releasing it to the sea, runoff from salicornia fields is sent to a mangrove forest which acts as a filter of pollutants and as a feed to animals and fish.

The oil-rich salicornia seeds are harvested and processed to produce oil that can be modified for blending with jet fuel. Salicornia's other parts can be processed into liquid fuel or used as a biomass fuel to generate electricity.

5.3. SABIC support of research at KAUST

SABIC (Saudi Basic Industries Corporation) – the largest petrochemical manufacturer in Saudi Arabia – has entered into agreement with the KAUST (King Abdullah University of Science and Technology) to develop a research center at a cost of $150 million and sponsor 10 to 15 researchers for five years. This research center will focus on renewable energies, desalination and treatment in addition to research on industrial processes [23].

6. Governance

Although literature review returns no specific legislation or regulation in MENA countries that target the issue of water in green industry, there are references to regulations and government initiatives in Saudi Arabia that emphasize water use efficiency by industry. For example, the Ministry of Water and Electricity (MoWE) in Saudi Arabia launched in partnership with the private sector Wafeer as an industrial water conservation initiative in the country [24]. The initiative aims at improving water use efficiency in the industrial sector. [25] provides a summary of Saudi Government and Aramco wastewater reuse regulations.

One of the regulations that is worth considering by governments in the MENA region for encouraging water savings in industry is the water management action plan (waterMAP) by the State of Victoria in Australia. Under this regulation, industrial and non-residential customers who are using more than 10,000 m^3/year are required to submit a detailed plan showing their current water uses, water saving targets, potential water-saving activities and implementation of these activities, monitoring system and progress status report [26]. Industries in the region can benefit from these by at least voluntarily considering this approach in their internal water-saving programs.

An important aspect of facilitating effective governance of water in industry is designing water pricing schemes that can adequately capture the social opportunity cost of water resources which tend to be quite high due to the region's extreme water scarcity conditions. Quite often however water is significantly subsidized discouraging industry to undertake water conservation measures which as indicated above can be quite costly. Similarly energy subsidies should be reduced to encourage investment in using renewable energy for desalination.

Determining the real cost of water is quite complex as it involves assessing the social discount rate, demand by other sectors and the highly variable natural water stock levels. [27] developed a hydroeconomic simulation tool designed for use by policy makers to assess the social value of water in the Amman-Zarqa aquifer, which is a strategic water supply for Amman, Jordan. The tool helps users to assess alternative policies for allocating water among industrial, municipal and agricultural users.

7. Conclusion and recommendations

This paper has looked at how water is being addressed in the industrial sector in the MENA region from the perspective of the green industry concept. Pressed by water scarcity, some industries in the MENA region are taking measures to enhance water use efficiency particularly in the water intensive petrochemicals, textile, food processing and pulp and paper sectors. Case studies show that these measures not only significantly reduce water usage, but they also cut down on wastewater releases and their associated adverse impacts on the environment and improve industrial material recovery.

Literature indicates that industrial infrastructure provides an efficient and cost effective means to collect, treat and reuse wastewater by matching quality and quantity requirements among several industrial users. The limited experience from the region indicates a great potential of reusing vast amounts of treated wastewater that are currently underutilized.

Considering the high and rising dependency on desalination among several MENA countries, several efforts have been reported on exploring the use of renewable energies in desalination. The focus is mostly on utilizing solar energy, which is quite abundant in the MENA region. Several approaches are being considered: using reject heat from concentrated solar power (CSP) systems, using electricity generated by a photo-voltaic (PV) or CSP system to run membrane filtration desalination units, and using enhanced solar still systems.

With few exceptions, research and development in water related green industries are insignificant. This is a serious issue considering the high demand by the sector for technology and expertise which are currently met by external resources.

Although many MENA countries have legislations and regulations that address wastewater treatment, very few deal with reusing wastewater particularly in the industrial sector. Even when well-designed regulations exist they are generally not adequately monitored and enforced.

Industrial water pricing in the MENA region do not reflect water social opportunity cost or even costs of delivery and wastewater treatment. Consequently, the cost of water is not properly factored in the cost/benefit analysis of water conservation measures thus reducing the incentive to implement these measures.

Overall, the industrial sector in the MENA region is slow in acting to enhance water conservation, reduce environmental impacts of wastewater, utilize renewable energies and invest in research and development. This is despite the risks posed by severe water scarcity conditions and mounting wastewater-related environmental pressures to the region's socio-economic development and growth, which are in turn the key determinants of success for the industrial sector. This problem is partially a result of short-sightedness of most industries, and a lack of clear public industrial policies on sustainable water resources management. Several policy recommendations are suggested to move forward:

- Develop legislations and regulations backed by effective enforcement to specifically target industrial water conservation, wastewater treatment and reuse and utilization of renewable energies;
- Design industrial water and energy pricing schemes that accurately reflect their real costs to encourage investment in water conservation and using renewable energy for desalination;
- Develop – in cooperation with the non-governmental sector – capacity in industrial water conservation, use of renewable energies in desalination and other supporting activities;
- Invest and encourage private industrial investment in research and development, particularly in establishing excellence centers, supporting researchers, and funding technology incubation programs and individual entrepreneurs.

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