Treated Wastewater as an Unconventional Water Resource: Examples from MENA Region

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Abstract

Water is a scarce resource in the MENA region. However, quantity is not the only threat to the region's fresh water. Overexploitation, poor water related infrastructure and contaminations, which are common across the region, represent additional challenges to the quality of the water and its suitability for drinking and agricultural uses. In light of growing demands for water, a comprehensive management strategy should be implemented in order to reduce water consumption, improve quality and mobilize new sources of water. There has been a great deal of interest in the mobilization of new unconventional sources of water in order to preserve the natural sources. Treated wastewater can serve this purpose when being reused for irrigation, landscaping or aquifer recharge. It is needless to say that national quality standards, economical, social and environmental factors should be considered in order to ensure the best possible usage of reclaimed wastewater.

Introduction

The availability of water is of primary concern in the water scarce MENA region. A condition of severe water scarcity is looming over the countries in the region with the per capita share projected to be no more than 500 cubic meters compared to a world's average of 6,000 cubic meters [1]. Demand for water has alarmingly increased in the last years mainly due to the high rate of population growth coupled with changing use patterns [2]. As a result of climate change average global precipitation is predicted to decrease, paralleled by an increase in evaporation [3], also seasonal precipitation patterns are likely to change [4], resulting in additional deficits in national water balances and extra strains on the water resources management. Management of water resources is challenged, among others, by overexploitation, leakage through ill-maintained drainage and distribution pipes, increasing dependencies on larger centralized water production facilities (desalination) and related distribution networks, limited sanitation services, lack of proper wastewater treatment, and contamination [5].

Among the innovative approaches to develop and use new and unconventional water resources, attention has focused on producing new water by desalination, harvesting water and reusing treated wastewater. The treatment and adequate management of wastewater is of great importance to the issue of environmental safety and human health. Similar to modern solid waste management approaches [6, 7], wastewater management ideally also follows a "3R approach"; (a) reduce the total volume of wastewater that requires treatment, (b) reuse any centrally treated wastewater at locations as close as possible to the treatment or (c) recycle by reintroducing the treated wastewater e.g. through infiltration or injection into fresh water bodies such as rivers, aquifers, groundwater reservoirs, i.e. returning it to the hydrological cycle for further use at a later stage or other location. Reducing the production of wastewater can be achieved through managing demand for water consumption, water conservation or by decentralized water treatment and reuse options, such as household grey water use [8]. The Arab region produces approximately 10.85 km^3 of wastewater annually, two-thirds of which goes through treatment [9]. The treated wastewater can be reused in several water applications, including household grey water use, greening, landscaping and irrigation. The latter represents by far the main consumer of treated wastewater [9].

With almost 60% of the Arab population expected to be living in cities by 2020 [10], it is essential to explore the various ways in which wastewater can be treated and reused for an efficient management of urban water. This paper discusses how wastewater is successfully reused in MENA countries, based on the presentation of selected examples from the United Arab Emirates, Morocco, Jordan, Tunisia and Oman.

“Reducing” demand for centrally treated wastewater using reed bed treatment

Demands for water are continuously increasing in Dubai, **United Arab Emirates (UAE)**. A decentralized treatment of wastewater via reed beds is being implemented, as a coping strategy. Reed bed treatments consist of wastewater passing through a soil filter planted with wetlands vegetation, such as Phragmites communis (reed bed) [11]. The filtration of wastewater through the reed bed occurs in tandem with chemical and physical precipitations as well as microbial processes ensuring the removal of water pollutants. Subsequently, the treated water can be collected in tanks via drainage pipes and reused for car washing, fish ponds and irrigation of flowers, palm trees and gardens which are located in close proximity to the reed bed treatment facility [11].

A great advantage for using reed beds in wastewater treatment is that they can be set up locally: in offices, car washing facilities, private villas, and municipal properties. Therefore, they do not require specific large sewage networks and infrastructure or heavy maintenance [11]. This reduces the volumes of wastewater for central treatment as well as the costs for investments, operation and maintenance of large wastewater collection systems. It also reduces the environmental and health risks generally associated with a sewer pipe leakage or a system overload during the transportation of wastewater to a central treatment plant. Another important benefit is that the treated wastewater does not necessitate any additional treatment and can be reused directly, reducing the local demand for fresh water [11].

The reed bed treatment of wastewater is also financially beneficial for companies through the reduction of the cost and amount of energy required for treatment [11]. It is worth mentioning that besides their role in saving on water resources by providing a new source of water, the reed beds help save on other natural resources as well. The reed plants can be harvested and used in the production of bioenergy and biomaterials such as paper and reed concrete [12]. This contributes to a greener economy and green job creation and reduces the emission of greenhouse gases. In summary, reed bed fields play a dual role: (i) provide decentralized treatment of wastewater and make the treated wastewater available for local irrigation and other water applications, (ii) serve as biomass for energy and eco-building material production contributing to a greener economy.

"Reusing" treated wastewater at large water consuming facilities

The reuse of centrally treated wastewater in the MENA region can be illustrated with the example of Marrakech wastewater treatment plant and reuse project in **Morocco**. Marrakech is well renowned for its spacious and numerous golf courses which contributed to the city fast becoming an important travel destination. Approximately 24 million m^3 of water are required each year in order to meet the golf courses need for irrigation water [13]. Such an amount places a heavy burden on the country's already limited water resources.

The public water and electricity entity for the city of Marrakech (RADEEMA), in collaboration with the Moroccan government and the golf courses, has initiated a one billion Moroccan dirham (120 million USD) project, which includes a wastewater treatment plant and a reclaimed wastewater distribution network across the city [13]. The project, which started by the end of 2010 / beginning of 2011, aims to provide 33 million m^3 of treated wastewater per year to be directly reused for the irrigation of the golf courses scattered across the city after transfer of the treated wastewater via 60 km of piping. The treated wastewater will also be reused to irrigate the western area of Marrakech palm grove (Oulja) [13].

The Marrakech wastewater treatment plant project helps mobilize a new unconventional source of water supply and sustain the golf tourism in Morocco i.e. reduce its fresh water demand. It also secures a large scale environmentally sound management of urban sewage effluents as the wastewater undergoes three consecutive treatments, ensuring a water quality in accordance with the WHO guidelines [13]. The main challenge, however, is the demand for trained personnel and substantial technical knowledge in the operation, maintenance, transfer and distribution processes. However, this can also be seen as an opportunity for local green job creation and a contribution to green economy.

The facility also encompasses anaerobic reactors for the treatment of the sludge after separating it from wastewater. The fermentative digestion of the sludge generates methane biogas which is then recovered and used for energy production. The produced bioenergy satisfies 33% of the total energy requirement for the operation of the wastewater treatment plant and allows for the recycling of methane, reducing as a result the emission of greenhouse gases into the atmosphere [14].

Ranking amongst the world's poorest countries in water resources, **Jordan** took a major leap in wastewater treatment and reuse. One example is the city of Aqaba and the reuse of treated wastewater by Aqaba Water: approximately 25% of the annual water supply is generated as reclaimed wastewater by the Aqaba city treatment plants [15]. The agricultural and industrial sectors consume, respectively, 57% and 33% of the treated wastewater [15]. Al-Haq farms project, Palm tree forest project, Aqaba city greening project are examples of some of the projects that have been implemented, all aiming at reusing the treated wastewater from the Aqaba treatment facility for irrigation, greening and landscaping [15].

Jordan has been one of the pioneers in the region in reusing treated wastewater for industrial purposes. Water scarcity has been a hurdle in the way of industrial development in Jordan [16]. The reuse of treated wastewater mainly for cooling and less so for power generation might be a way forward for industries to overcome water limitation [16]. Industries often require a constant high quality of treated wastewater. This is reflected in the higher cost of wastewater treatment for industrial use vs. agriculture [17]. National policies, regulations, and guidelines were drafted in order to firmly set the standards to which treated wastewater should adhere. The cost-benefit assessments seem to be in favor of reusing treated wastewater by industries such as the Jordan Phosphate Mining Company [18].

"Recycling" treated wastewater by re-introducing it into the hydrological cycle through managed aquifer recharge, aquifer storage and recovery

All the examples discussed so far represent cases of a direct reuse of wastewater treated either locally or centrally. However, treated wastewater can be reused indirectly through reintroducing it into water "reservoirs". This applies to the case of the Korba managed aquifer recharge in **Tunisia**. Korba aquifer is located in the Northeast of Tunisia, a region classified as semi-arid. It encompasses over 90% of the region's groundwater [19]. Analyses of groundwater samples collected from the Korba aquifer, prior to its artificial recharge, suggested that it suffered from deterioration in water quality and quantity [20]. In addition to the decrease in the groundwater level, overexploitation of the coastal Korba aquifer has led to seawater intrusion, resulting in high water salinity. If used for irrigation, this water can contribute to the salinisation of agricultural soils. Bacterial contamination was also found in the groundwater, compromising further its use for irrigation. However, due to the lack of alternative water sources in the area, farmers carried on using the aquifer's contaminated water to irrigate their lands, putting their health and the environment in peril [20]. Korba aquifer also contained high levels of nitrate caused by an excessive use of fertilizers.

Recharging the Korba aquifer with treated wastewater collected from the Korba wastewater treatment plant was successful in restoring the quantity and improving the quality of the groundwater in the aquifer [21]. "Recycling" the treated wastewater through infiltration into the aquifer created a hydraulic barrier against seawater intrusion. This consequently lowered the salinity of the water making it better suited for irrigation and less ecologically damaging.

Reintroducing the treated wastewater into aquifers can also offer a more environmentally-safe way for the elimination of treated wastewater. The treatment of the wastewater in the Korba wastewater treatment plant proved to be insufficient as the treated wastewater still contained substantial bacterial and chemical pollutants. While ideally the treatment should be improved, it was found that the infiltration of pollutant-rich treated wastewater into the aquifer comprises a relative lower risk [20]. If discharged directly into the sea, this water would have adverse impacts on human health, fish and the marine ecosystems. From a purely economic perspective, the indirect reuse of the treated wastewater for irrigation can reduce the costs associated with the use of fertilizers as this water retains a high concentration of nitrate and other crop nutrients [20].

Salalah, one of the major cities of **Oman**, relies entirely on its coastal aquifer for water supply [22]. In 2005, 9% of the groundwater in the aquifer derived from treated wastewater injected into the aquifer [23]. A 3D flow model coupled with experimental work suggested that injecting treated wastewater into the aquifer can halt aquifer depletion [23]. This is supported by monitoring results showing that the groundwater levels in 2005, when the injection process was operational, were higher than in 2000 [22].

The model also argued that recharging the aquifer with treated wastewater can reduce the salinity in the aquifer caused by seawater intrusion [23]. This will not only improve the quality of the groundwater but also reduce the need for additional desalination plants [24]. It is imperative to note that the success rate of the aquifer recharge in preventing water depletion and salinisation is directly proportional to the aquifer abstraction rate. There is real concern that even with the treated wastewater being injected into the aquifer, the rate of the aquifer recharge from natural and treated wastewater sources will be lower than the abstraction rate, if restrictive measures are not taken [23]. In this case seawater will keep moving into the aquifer and impacting on the groundwater quality. Agriculture, amongst other sectors, consumes the largest share of water from the aquifer. 'Recycling' treated wastewater via injection into the aquifer will enable the indirect reuse of treated wastewater as irrigation water, narrowing therefore the gap between water demand and availability.

Conclusions and outlook

An appropriate treatment and reuse of urban wastewater can help: (a) preserve natural water resources, (b) supply the water scarce MENA region with new sources of water, (c) reduce adverse ecological impacts and health risks associated with the direct discharge of untreated or poorly treated wastewater into the environment, (d) reduce the volumes of centrally treated wastewater and the charges for large wastewater networks and infrastructure, (e) reduce pollution and cross-contamination caused by the infiltration of wastewater from overloaded or leaking pipes, (f) prevent contamination by seawater intrusion into coastal aquifers, (g) promote safe agricultural practices, (h) diminish the use of fertilizers and increase profits, (i) promote green economy, (j) create green jobs, and (k) increase green spaces in cities.

A high level of political and public commitment must be ensured for any sustainable wastewater management strategy. Wastewater management generally involves several governmental and private institutions which should be clearly recognized for the purpose of improving accountability. Better transparency and compliance with standards can equally be attained by setting up a qualified independent regulator.

Conducting a thorough assessment of the quality of the treated wastewater is needed in order to ensure that the quality of treated sewage effluent (TSE) is in accordance with the national quality standards for TSE utilization, taking into consideration that the quality standards may vary depending on the intended use. Social, economic and environmental cost factors should be taken into account when assessing the cost-benefit ratio to determine the most appropriate use for TSE. It is recommended that countries aim for (1) local wastewater treatment and reuse options, reducing the need for large scale infrastructure, (2) high quality sewage treatment facilities, networks and infrastructure in order to optimize the plant performance in terms of energy consumption and operating costs, (3) improvement of the treatment process to ensure consistently high quality of TSE and reduction of leakages.

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