watersum

BACKGROUND DOCUMENT

for the REC's MENA Water World Café 2017 at World Water Week 2017

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Contents

Introduction

In response to the rapid depletion of water resources, deterioration in water quality, increased water demand, and changes in water endowments that are affecting environmental quality, food security, municipal infrastructure and economic development in most societies in the Middle East and North Africa (MENA), the Regional Environmental Center (REC, www.rec.org) is implementing the project "Sustainable Use of Transboundary Water Resources and Water Security Management" (WATER SUM) (www.watersum.rec.org). The project is funded by the Government of Sweden (Swedish International Development Cooperation Agency [Sida], contribution ID 52030234) and is being implemented between April 2014 and March 2018.

The overall objective of the project is to promote and enhance sustainable water resources management and to foster a comprehensive and integrated approach to water security and ecosystem services for sustainable development in beneficiary countries in the MENA region in order to help halt the downward spiral of poverty, biodiversity loss and environmental degradation.

The project is divided into two components: "Water Resources Management Good Practices and Knowledge Transfer" (Water POrT); and "Water and Security" (WaSe). The goal of the Water POrT component is to accelerate the more sustainable use of the region's water resources and to promote a strategic approach to climate change adaptation. The WaSe component aims to foster a comprehensive and integrated approach to water security and ecosystem services for sustainable development in eight selected local communities in Jordan and Tunisia. The WaSe component is a part of efforts to combat water scarcity and increase overall human well-being within the wider context of ensuring regional peace and stability.

The MENA Water World Cafe 2017 at World Water Week (WWW) brings together representatives of central and local governments, regional bodies, NGOs, academia and businesses from the region for lively discussions in a pleasant atmosphere related to the overarching theme of the WWW, namely: "Water and waste: Reduce and reuse". Using a modified World Cafe Method (www.theworldcafe.com/method.html), this event (https://programme.worldwaterweek.org/event/7018-mena-focus-mena-water-world-cafe-2017) will kick off with a brief plenary session, during which discussion topics will be outlined and participants divided into three working groups.

The present background document comprises three articles prepared by experts and addressing the topics of the three working groups: Rethink before use (Group 1); Climate change and the water-waste cycle (Group 2); and Water quality management (Group 3). The working groups will rotate at intervals of 25, 20 and 15 minutes, while facilitators will remain in the respective area during the entire process and later support the summary of outcomes. Expected discussion outputs among others are: list of barriers and constraints related to the reuse and recycling of wastewater, identified good practices and case studies, list of challenges and needs related to water quality at all levels, draft recommendations for improved water quality management in the MENA region and discussion on practical responses and adaptation measures to climate change from the water-waste cycle perspective.

1. Rethink before use: wastewater as a resource to be reused and recycled for irrigation and domestic use

MENA Water World Cafe 2017 Background Paper, Working Group 1

András Kis, Regionális Energiagazdasági Kutatóközpont (REKK)

Introduction

As one of the most water scarce regions in the World, the countries of the MENA need to rely on all possible sources of water. Most water resources are fully utilized, some of the non-renewable or slowly renewable sources, especially ground water, are overexploited. While in many other parts of the World treated wastewater is simply discharged into nature, within the MENA region the value of water is so high that wastewater is frequently used again.

The most common form of the utilization of treated wastewater is irrigation in agriculture. This is partly because agriculture is the biggest user of water in most countries (the MENA average is 86%[1]), and partly because irrigation does not require the same quality of water as most other uses – while there are various irrigation water quality standards depending on the land use or crop choice, these standards are attainable through advanced wastewater treatment. Sometimes blending with fresh water is also necessary.

Besides crop production, treated wastewater can also be used elsewhere, such as urban parks, wetlands, golf courses, forests, fish farming and industrial uses. The direct domestic use of treated wastewater is possible only when the water is treated to the extremely high standard of drinking water, which is an expensive technology that is only applied in a few locations in the World, most prominently in Singapore. Wastewater reuse, however, indirectly contributes to the enhanced supply of domestic customers, since it replaces some of the fresh water use of agriculture, making the saved water available to higher value domestic uses. Aquifer recharge, indirectly and on a longer time frame, also contributes to improved water sources for urban water uses.

While the MENA region is one of the most advanced in the field of wastewater utilization, there is still room for expansion. In this paper, we seek to understand how a higher level of wastewater reuse is attainable. Our assessment starts with a review of wastewater utilization in the region. Then we inspect the barriers and constraints that inhibit increased use of treated wastewater. Next, good practices will be briefly described, both from within MENA and outside the region. Lastly, a short analysis will be devoted to those measures and instruments that could contribute to enhanced use of treated wastewater.

[1] https://water.fanack.com/specials/wastewater-treatment-reuse-mena-countries/wastewater-reuse-important-mena-countries/

Characterization of wastewater reuse in the MENA region

Current level of wastewater utilization

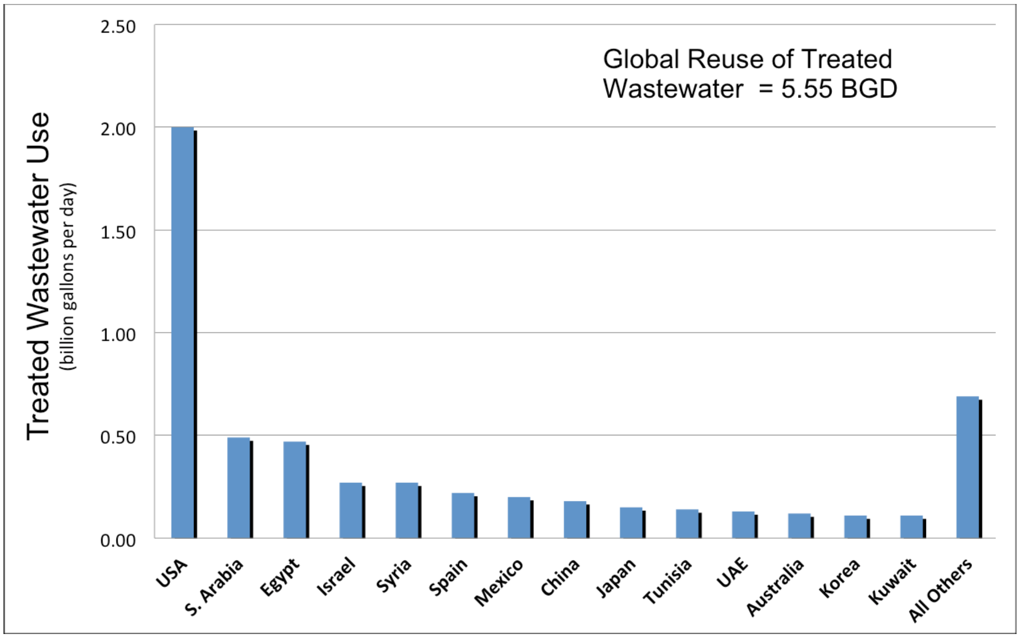
As the two figures below illustrate, the MENA region utilizes a higher than average share of its wastewater. According to Figure 1, this region makes use of about 1.2 km^3 per year of wastewater, or about 20% of the overall global figure. This reflects the scale of water scarcity in North Africa and the Middle East – what may seem like a cliché in much of the World ("every drop counts") is the harsh reality here.

Figure 1 Wastewater reuse of major regions in specific regions of the World

Source: http://www.emag.suez-environnement.com/en/wastewater-treatment-aims-challenges-11037

Figure 2 describes daily wastewater reuse figures in a country breakdown. While the US, the biggest economic powerhouse of the World with a dry South-West region, posts the largest volumes, half of the displayed countries are located within MENA or on the Arabian Peninsula.

Figure 2 Daily treated wastewater use of individual countries



http://nas-sites.org/waterreuse/files/2012/09/treated-wastewater.png

Despite the high absolute volume of treated wastewater use, there is much room for further increase: not all wastewater is collected, only part of the collected sewage is treated to sufficiently high standards and even treated wastewater that is suitable for further use is only partly utilized.

According to Jeuland (2015) actual utilization of generated wastewater in most MENA countries is below 20%, but the country specific figures vary widely. For example, it is 12% in Egypt, 40% in Jordan, 14% in Tunisia, 11% in Lebanon and only 1% in Morocco (last column of Table 1).

Table 1 Wastewater reuse rates in MENA countries (Jeuland, 2015)

Table 1. Sewerage coverage in urban and rural areas, and wastewater treatment and reuse rates in the Middle East and North Africa

Country	**Sewerage rate to piped network** (% of households connected)			D. **Treatment rate** (% of collected wastewater by volume)	E. **Treatment rate** (Est. % of wastewater by volume)[a]	F. **Reuse efficiency** (% of treated wastewater by volume)	G. **WRI** (Est. % of all wastewater by volume)[b]
	A. Urban	B. Rural	C. Overall				
Algeria	92	50	77	46	40	Na	Na
Bahrain	Na	Na	77	73	49	16-20	10
Egypt	74	18	42	57	52	24	12
Iran	39	5.3	30	78	21	Na	Na
Iraq	39	3.3	28	30	17	Na	Na
Israel	99.5	95	98	Na	90	99	89
Jordan	67	4.0	56	98	53	76	40
Kuwait	Na	Na	>99	Na	78	63	49
Lebanon	Na	Na	66	81	23	50	11
Libya	54	54	54	24	13	100	13
Morocco	86	2.8	53	20	18	6	1
Oman	53	17	44	34	27	66	18
Palestine	67	12	54	Na	Na	Na	Na
Qatar	Na	Na	78	100	78	50	39
Saudi Arabia	44	7	37	93	69	40	27
Syria	96	45	72	Na	40	78	31
Tunisia	79	8.9	54	77	68	20	14
UAE	93	63	87	Na	87	25	22
Yemen	42	0.4	12	66	8	40	3

Notes:
Na: Data not available
[a] Estimate from Aquastat (2014) data: Wastewater volume treated / Wastewater produced; If estimates were not available, this is estimated as Sewerage rate*Treatment rate (Column D), assuming that production rates are similar across connected and unconnected households.
[b] Authors estimate: Wastewater volume treated)*Reuse efficiency (Column E)*(Column F).
WRI = Wastewater Reuse Index.
Sources: Authors' calculations using data from Aquastat database (FAO 2014), Kfouri et al. (2009), Jimenez and Asano (2008), *Global Water Intelligence* (http://www.globalwaterintel.com), and country reports from the JMP (World Health Organization and UNICEF 2014).

Barriers and constraints for enhanced utilization

Some MENA countries have a big gap between current and potential wastewater reuse, as shown by the Wastewater Reuse Index (WRI) in Table 1. The biggest single reason is lack of infrastructure for wastewater collection, treatment and distribution of treated wastewater. The more of this chain of infrastructure is absent, the more expensive it is to increase the level of WRI.

In many locations assets are in place, but they are inadequate, especially old, poorly maintained wastewater treatment plants that cannot treat sewage to a quality suitable for further utilization of the discharged wastewater. The level of treatment directly impacts the potential use of wastewater: produce that is directly consumed (e.g. vegetables) requires better quality sewage than other crops that need to be processed before consumption (e.g. cereals), or fruit trees where water is not in direct contact with the fruits. These requirements are usually codified in the form of standards or regulations.

Transferring the treated wastewater to the location of use is frequently made difficult by the distance between cities, where sewage is generated, and farms, where wastewater could be used for irrigation. To remedy this problem, either channels/pipelines need to be constructed or a local use need to be found for the wastewater, e.g. irrigation of public parks.

Another barrier is the availability of fresh water to blend with treated wastewater when blending is necessary to reach the quality standards set for wastewater reuse.

When sewers are absent, it may still be possible to make use of domestic wastewater for local crop production, but this entails the introduction of local treatment technology and a willingness of the population to make use of wastewater. The less fresh water is available, the more flexible the attitude of households will be toward this option.

In some cases, proper quality of treated wastewater is available close to farms, but the farmers refuse to use the wastewater for irrigation as they are afraid that this practice will result in soil degradation (e.g. salination), a decline in the quality of the crops they produce, possibly creating a health risk to consumers, or simply creates a bad image to their produce. Whenever fresh water is available in sufficient volume and at an affordable cost, farmers prefer to use it over treated wastewater, while farmers facing severe water shortage have no real choice but to apply wastewater (or a mix of fresh water and wastewater) to their land. In some cases, the alternative to treated wastewater is untreated wastewater which is freely available. In this case farmers may be hesitant to pay for treated wastewater when the alternative– although a lower quality – requires no payment.

Good practices examples

Despite the difficulties described in the previous chapter, there are numerous good examples of wastewater reuse both within MENA and in other regions. We briefly describe several cases in this chapter, as they can guide decision makers toward new instruments and measures that would enhance wastewater reuse and thus contribute to an improved water balance in their countries. We restrict ourselves to cases from the MENA region, as they are more relevant to policy makers in these countries, while many of the case studies from outside the region, such as the NEWater case of Singapore[2], represent a substantially different economic and institutional environment.

Wastewater reuse policy of Jordan

As Table 1 depicted, within the MENA region Jordan has an outstanding wastewater utilization rate of 40%. This figure is surpassed only by oil-rich gulf states (and clearly, financial resources are elementary in wastewater reuse), while other MENA countries are characterized by figures that are typically below 15%. The remarkable achievement of Jordan is the result of setting wastewater reuse as one of the key pillars of the national water strategy, and supporting this priority with regulations as well as investment priorities.

As in other countries, drinking water supply preceded the construction of sewers in Jordan. By the middle of the 20th century, a lot of Jordanian towns were characterized by septic tanks and cesspits, with gray water often discharged to gardens. This practice resulted in major environmental problems, especially groundwater pollution. The pollution problems were augmented by rapid urban growth. This was the original driver of building sewage collection lines.

Modern technology to collect and treat wastewater was introduced in the late 1960s when the first collection system and treatment plant was built at Ain Ghazal utilizing the conventional activated sludge process. The system consisted of a sewage network that runs by gravity to the lowest point in Amman,

[2] https://www.pub.gov.sg/watersupply/fournationaltaps/newater

where the treatment plant was located and built. The design effluent standard was BOD5 (20 mg/l). The treated effluent was discharged to Wadi Al-Zarqa.

Since the year 1980, Jordan carried out significant and comprehensive plans with regard to wastewater management primarily related to the improvement of sanitation. About three-quarter of the urban population and half of the total population have access to wastewater collection and treatment systems. This raised the sanitation level, improved public health, and strengthened pollution control of surface and groundwater in the areas served by wastewater facilities. Lastly, the treated wastewater became available for irrigation. Importantly, this source of water is independent of the season, unlike surface freshwater resources.

In 2014 in total over 120 million m^3 of treated wastewater was utilized for irrigation, contributing about one-quarter of all water used for irrigation in Jordan. Most of the treated wastewater originates from the As-Samra wastewater treatment plant that serves the Greater Amman area as well as large part of Zarqa. With respect to official plans, the government is planning to construct 14 new plants by 2020 and all plants together will be expected to treat 262 million m^3/year.

Despite the success of this unconventional supply of water, some problems also arose. Some of the WWTPs are overloaded with utilization rates reaching even 2-3 times of design capacity, which would imply that the plants are not achieving their design treatment standards and/or the excess sewage is being diverted into by-pass channels without receiving any treatment. Therefore, there are questions about the appropriate quality of the released wastewater for irrigation purposes, mainly because the characteristics of wastewater in Jordan are somewhat different from other countries. The average salinity of municipal water supply is 580 ppm of TDS, and the average domestic water consumption is low. This results in very high organic loads and higher than normal salinity in wastewater. This is particularly applicable to wastewater treated in waste stabilization ponds (85% of the total generated wastewater), where part of the water is lost through evaporation, thus increasing salinity levels in the effluents. In addition, high organic loads impose operational problems where the plants become biologically overloaded with only a portion of their hydraulic loads.

Most of the treated wastewater is mixed with fresh water in reservoirs before making it available for irrigation. This practice is important for at least two reasons. 1) As mentioned above, the quality of treated wastewater is not always appropriate for irrigation, but blending improves the quality to the desired level. 2) In part of the Jordan Valley this is the only source of irrigation water, farmers do not have a choice between fresh water and blended water. In locations where such a choice exists, farmers usually prefer fresh water, thereby reducing the demand for wastewater, which is one of the barriers mentioned in the previous section.

In line with the widespread use of treated wastewater in agriculture, Jordan introduced a standard on substance concentrations for various uses (Jordanian Standard JS893/2002 dealing with "Water-Reclaimed Domestic Wastewater") as shown by Table 2. The effluent of most wastewater treatment plants comply with the Jordanian standards for restricted irrigation and violate the standards for unrestricted irrigation. Blending with fresh water, however, generally achieves the needed improvement to allow unrestricted irrigation.

Table 2 Jordanian Standard for the use of effluent from wastewater treatment plants

	BOD5 mg/l	COD mg/l	TSS mg/l
Vegetable eaten cooked	30	500	150
Fruit, forestation, industrial crops and grains	300	500	150
Discharge to wadis and catchments	60	150	60

The better the quality of the discharged effluent, less fresh water is required for mixing, saving valuable water for other uses, most importantly the supply of drinking water to cities. Therefore, the efficiency of wastewater treatment is a critical component of the successful implementation of the Jordanian water management strategy.

Wadi Shallalah WWTP, Jordan

The case of Wadi Shallalah wastewater treatment plant illustrates the implementation of the above described policy, the wastewater reuse component of the National Water Strategy of Jordan.

The plant is in Northern Jordan, about 8 km North East of Irbid City. It receives wastewater influent from the Eastern parts of Irbid City as well as from Sareeh, Howara, Sal, Bishra and Mughaier towns. Wadi Shallalah is a modern plant with three stages of treatment (primary, secondary, and tertiary) supplemented with biogas generation and combustion. It started to operate in 2013. The plant design capacity is 13,600 m^3/day, currently underutilized at a rate of about 50%. As the sewer network in Irbid expands, the amount of treated water at Wadi Shallalah will also rise, up to the full capacity. Originally full capacity was projected to be reached in 20-25 years, but due to the influx of refugees to Jordan, most treatment facilities reach their design capacity beforehand. In case of the Wadi Shallalah WWTP full capacity is currently forecasted to be reached in 10-12 years.

While by law it is not compulsory to connect to an operational sewer, experience shows that most people are in favor of connection, as releasing wastewater into the sewer is cheaper than paying for truck based wastewater collection (except when a leaking cesspit stores the sewage, but even in that case the convenience of the sewer may compensate for the cost difference).

The wastewater of Irbid is mainly of domestic source, it does not contain industrial pollutants. At the end of the technological chain a sand filter and UV treatment are dedicated especially to ensure inactivation of pathogens and to render the discharged effluent to be utilized for irrigation without the risk of contamination.

The treated water is pumped to the Central Irbid wastewater treatment plant, from where together with the treated wastewater discharged by that plant (about 8,000 m^3/day), the wastewater is further transported. Together with effluent from the Wadi Al Arab wastewater treatment plant a total volume of about 27,000 m^3/day reaches the Wadi Arab dam. Here the wastewater will be blended with freshwater for further use of irrigation within the Jordan Valley. The exact mixing ratio is not yet determined, as this project is still under implementation, but it is likely to be between 1:5 and 1:8, meaning that each m^3 of wastewater requires 5 to 8 m^3 of freshwater to become suitable for the irrigation requirements of the Jordan Valley, where fruits and vegetables are produced. Regardless of the exact blending ratio, it can be assumed that each m^3 of utilized wastewater will replace one m^3 of fresh water in irrigation supply, making the saved fresh water available for urban consumption.

A cost-benefit analysis (Kis et. al., Nov. 2016) of the investments needed to ensure irrigation water for the Jordan Valley (sand filter, UV treatment, pipelines, pumps) concluded that the cost of „freeing" fresh water for urban use is about 1.4-1.6 JD/m^3, which is below the marginal cost of water supply in highly arid Jordan.

Pilot project of graywater irrigation in Tafilah and Karak governorates, Jordan

During the year 2000, the International Development Research Center (IDRC) supported Inter-Islamic Network on Water Resources Development and Management (INWARDAM) in conducting a comprehensive evaluation of the potential for graywater reuse in rural areas of Jordan. This evaluation resulted in initiating Phase I of graywater research project which was implemented in Ein Al-Baida, of Tafilah Governorate, southern Jordan, from May 2001 to May 2003. Phase I resulted in developing and evaluating five distinct types of on-site greywater treatment units. Two out of the five units were selected as potential units for further improvement and scale-up. In Phase II, the designs were further developed to make them more practical and less costly to operate. These are units that can be installed on the household level to ensure that the graywater produced by the households becomes suitable for irrigation of the garden.

The units were installed at 110 low-income families. This pilot project was successful in several aspects. It lowered the demand for drinking water and for pumping sewerage from septic tanks, it provided additional income for participating households through improved crop yield, and it continues to serve as an example for other locations. While the households enjoyed the benefits of this technology, it is uncertain if they themselves would be able and willing to invest into it without external support, and the long-term sustainability of the solution (post-pilot project maintenance and use) has not been tested. Nevertheless, the pilot project proved that even in locations without a sewer it is possible to make use of wastewater.

Wastewater Reuse at the Jordan University of Science and Technology, Jordan

The Jordan University of Science and Technology (JUST) has a large campus (11km^2) and has reused water from the university wastewater treatment plant for almost 20 years. Another source of effluent water is located off campus at the Wadi Hassan area, about 4 kilometers South of the university campus. There are two storage lakes on campus: a 132,000m^3 lined pond, and a 110,000 m^3-capacity reservoir. These sources of effluent water and the existing infrastructure have encouraged the university to irrigate additional portions of the campus and to support the production of cash crops, field crops and forest trees by reclaimed wastewater. The project had two main goals, both successfully achieved: 1) to demonstrate that wastewater reuse is feasible for irrigation purposes; and 2) to evaluate the efficacy and economics of growing new types of crops in the Northern area of Jordan, utilizing the flow from the existing JUST WWTP as well as the Wadi Hassan WWTP. As a pilot project, the JUST case provides a valuable example which can be followed by other sites in Jordan and the region.

Beqaa Valley, Lebanon

The Beqaa Valley in Lebanon is an important agricultural area that - similarly to most of the Middle East - faces problems of water shortage. This situation may be eased using treated wastewater for irrigation purposes. Between 2011 and 2015 a pilot project was implemented by FAO to research the use of treated wastewater from the Iaat wastewater treatment plant. The project concluded that wastewater is an important source for irrigation in the area, it can even enhance yields, but in order to use it for vegetable and fruit production, some precautionary measures are needed on the part of farmers, and more advanced treatment of the wastewater at the Iaat plant would also be desirable.

The main result of this pilot project is the experience gained, based on which guidelines are developed for the future use of treated wastewater for irrigation, contributing to a large-scale safe utilization of sewage. The project showed that food safety considerations are relevant, and both improved wastewater treatment, and the education of farmers are necessary for a higher level of wastewater utilization.

Diverse use of wastewater in Tunisia

Tunisia is in a relatively advantageous position within the MENA region with respect to its water resources. The country is better supplied with water than, for instance, Jordan, and makes good use of its resources through a sophisticated infrastructure of dams and connecting canals as well as a sensible water policy. One of the consequences of this situation is that demand for treated wastewater is low, even though it is readily available as annually about 240 million m^3 of sewage is collected and treated in 110 wastewater treatment plants around the country. Of the total agricultural area equipped for irrigation only about 2% makes use of treated wastewater. However, in Tunisia effluent discharges are also used to water green spaces (such as golf courses, an important category of land use in Tunisia where tourism is a key economic sector) and to recharge ground water and wetlands. Recharge is important not only for ecological reasons, but it also helps to keep the water cycle in balance, with ground water resources replenished to some extent. The authorities are currently developing a new project in the perimeter of Mornag funded by KFW that includes annual groundwater recharge of about 5 Mm^3 following a tertiary treatment process.

It should be noted that there is still much water, about 70% of all treated wastewater that is released into water courses or the sea without actual utilization. Not all released effluent is suitable for further use, improved treatment is one of the preconditions to a higher rate of utilization.

Table 3 Volume of treated wastewater reuse (1998-2010)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2010
Production of treated wastewater	129	135	156	170	174	188	193	201	217	225	240
Quantities reused in public irrigated areas	21	21	23,5	24,5	23,5	26	25,5	30	37	34	37
Quantities reused in green spaces	6,5	7	8,5	8,5	9	9	10	12	11	14	15
Groundwater and wetland recharge	1,5	5	7	8	16,5	15	16,5	16	17	17	11
Total of wastewater reused	29	33	39	41	49	50	52	58	65	65	63
Reuse rate	22,5	24,4	25	24,2	28,2	26,6	26,9	28,9	29,9	28,9	26,3

Source: Système hydraulique de la Tunisie à l'horizon 2030, Tunisian Institute for Strategic Studies, 2014.

Reforestation in Luxor, Egypt

In the Egyptian desert, the sun shines with an intensity of about 2,200 kWh per m^2. Since virtually no rain falls in the Egyptian desert, without regular watering, any tree would quickly dry out and die. When it was decided to reforest Luxor, piped treated wastewater was selected as the most suitable option for watering.

Within the case study the area of an irrigated forest was expanded from 40 feddan (160,000 m^2) to 1,700 feddan (6.8 million m^2) within 10 years' time, starting in 1990. The effluents of the Luxor wastewater treatment plant were utilized for this purpose. The practice helped in greening the desert and in producing Jatropha and Mahogany trees.

The ground under the trees is covered with a layer of dry fallen leaves that capture the sunshine and power the growth of the trees. Additional fertilizer is not necessary - the effluent water delivers all the nutrients that the plants need.

Before implementing the project, groundwater samples collected from a 20-meter deep (production) well, located 1 km west of the demo site, and near the forested area indicated no fecal contamination. After two years, Coliforms were present in some of the samples taken at the on-site well. The count ranged from 0 to 800 CFU/ml.

The Jatropha plantation in Luxor has a high rate of growth and productivity. Shrubs produce seeds after 18 months of planting seedlings compared with 3 years in other countries. The average yield of one tree is 3-4 kg after 2 years and the older the tree grows, the more the yield increases until it reaches 12-18 kg per tree. Forest grows four times faster than a European forest. Over a period of 15 years, they have already almost reached their maximum size – this takes over 60 years in France.

The biodiesel oil produced and extracted from Luxor Jatropha seeds was refined in UK laboratories and it was proved that it has a higher productivity level than its counterpart in other countries.

To ensure the applicability of the practice in other areas, a nursery for producing Mahogany tree seedlings at Luxor Forest was constructed and it produces around one million seedlings per year.

Based on the Luxor case it can be assumed that the use of effluent can generate economic gains not only in agriculture, but also in forestry.

Lake Manzala Engineered Wetlands, Egypt

As described in the previous section on barriers and constraints, increasing the rate of wastewater reuse is a costly endeavor when the necessary assets (sewers, treatment plants, distribution networks) are not yet available. The moderate income level of most of the MENA countries requires lower cost solutions. Egypt has successfully experimented with natural wastewater treatment which have substantially lower costs than technology intensive solutions.

As part of the Lake Manzala Engineered Wetland Project (LMEWP) a wetland was created specifically to clean and reuse polluted drainage waters for productive purposes. This low-cost technology is already used elsewhere in the Middle East, but it was the first of its kind in Egypt. LMEWP was designed in 2004 by the Tennessee Valley Authority and executed by Egyptian counterparts.

Experience shows that effluent concentrations are successfully reduced with the dual application of a sedimentation pond and the wetland treatment system. The removal rate, depending on the pollutant, varies from 5% (lower bound for Organic N) to over 95% (TSS). The reduction of heavy metals concentrations also greatly varies, from 26% (mercury) to 99% (zinc).

A major economic gain of this project is revived fish farming due to better quality and increased volume of fish produced with use of the treated effluent, while fresh water use declined as wastewater replaced some of the previous fresh water use. Farmers also benefitted from the availability of more water. Some adjustment of farming (e.g. crop choice) was needed to be in harmony with the quality of the supplied treated wastewater.

LMEWP, as a pilot site, offers opportunities for research and capacity building for local, national as well as international participants.

Instruments and measures promoting the enhanced reuse of wastewater

The instruments and measures detailed below are based on the previous good practice cases as well as a general policy analysis of the wastewater reuse situation in MENA countries. They are not universally applicable under all circumstances, rather, they comprise a simple "catalogue" that can be browsed in search of potential solutions.

Investment into the wastewater collection and treatment infrastructure

As described under the previous section on barriers and constraints, one of the difficulties surrounding wastewater reuse is the absence of sewers, suitable wastewater treatment plants and networks for the distribution of the treated wastewater. Targeted investments into these facilities can increase the availability of reclaimed water. Following the physical path of wastewater, intervention can take place in different phases:

- Improved collection of wastewater (primarily through sewers, but given the topographical and other conditions, also by trucks)
- Improved treatment of wastewater to make it suitable for further use
- Blending with fresh water if needed and if possible
- Delivering it to the location of use (e.g. farms, golf courses, ground water recharge points)

The further along this path a country is located, i.e. the higher the sewer penetration and the ratio of treated sewage, the less costly it is to increase the share of wastewater reuse. It makes sense to start on this chain backwards: where there is already sufficient treatment of wastewater, linking it to agricultural fields is relatively inexpensive. Upgrade of existing wastewater treatment plants is another relatively cost-effective solution. Building new infrastructure, including both wastewater treatment plants and sewers, is obviously the costliest intervention that generates treated wastewater at the highest unit cost: according to Jeuland (2015), the average cost level of wastewater collection and treatment is about 1.1 USD/m^3.[3]

These investments can be financed from donor funds, the domestic budget and the revenues of the water utility company:

- Donor funds, when available, are the most convenient source of funding from the perspective of MENA countries, as long as the selected technology suits local conditions and can be operated at an acceptable cost level.
- The domestic budget (state budget) is usually overburdened. Nevertheless, given the strategic importance of maintaining a water balance in arid countries, and the public benefits associated with the use of treated wastewater, spending on such infrastructure can be reasonable. Obviously, before major investment decisions, at least a cost-benefit analysis should be carried out to ensure that financial resources are used efficiently.
- In most locations water and sewage tariff revenues are not sufficient to cover major new investments without substantially raising their level. Since these tariffs are often below the level of cost recovery, a tariff increase is justified from the perspective of economic efficiency, leading

[3] Of course, there are great differences among individual locations depending on topography, population density, and other factors.

to more rational use of water, but often hindered by political considerations and issues of affordability.

When a wastewater treatment plant is already in place, but it is sub optimally operated, a pollution tax may provide the necessary incentives to improve operations and thereby reduce the pollutant concentration of the effluent discharge, so that it becomes more suitable for irrigation.

Price differentiation between fresh water and treated wastewater

When farmers have a choice between fresh water and treated wastewater, they will consider the quality, availability and the price of both options. Treated wastewater is often considered to be of inferior quality and therefore farmers are willing to pay less for it than for fresh water. If both types of water are available in sufficient volume, only a substantial price difference will influence farmers to choose reclaimed water, otherwise this source of water will be underutilized. Given that the price of fresh water for irrigation is often subsidized in MENA, raising the price will not only divert farmers toward the use of treated wastewater, it will also provide a price signal to the farmers to use fresh water more sparingly.

Producing treated wastewater is often more expensive than the abstraction of fresh water, e.g. pumping ground water for irrigation. The latter cost, however, does not include the “scarcity premium” which in the MENA can be substantial, much higher than the direct cost of accessing the water. The full social cost of water that also includes the scarcity premium should be charged to farmers if a socially optimal price signal is to be provided.

While the benefits of drinking water services are directly felt by the population and therefore they are willing to pay a relatively high price for drinking water, the benefits of sewerage and especially the benefits of subsequent treatment are appreciated by households to a lower extent, and their willingness to pay for this service is also lower. Since the benefits of sewerage services accrue to the larger community in the form of improved health, less pollution and saved water resources, from the perspective of public welfare it makes sense to subsidize sewage services and offer treated wastewater to farmers at a subsidized price that is below the level of costs.

Education of farmers

Farmers frequently believe that treated wastewater is considerably less suitable for irrigation than fresh water due to soil contamination and degradation, potential decline of the quality of the crop and health risks for farm workers and consumers. This is a perception which may or may not be true, depending on the quality of the wastewater, soil attributes and crop type.

It is important to educate farmers on the benefits and disadvantages of using treated wastewater so that they have a balanced view of this resource. Benefits include the nutrients within the wastewater stream that can partly replace fertilizers, while dependability of supply may be equally important, since seasonality does not affect treated wastewater the same way as the availability of fresh water for irrigation.

It also helps if the quality of treated wastewater is consistent.

Attitude of farmers toward wastewater reuse greatly improved for the last 15-20 years, probably due to water scarcity.

Monitoring and better enforcement of illegal water abstraction

If illegal water abstraction is an option for farmers, they will continue to pursue it instead of the use of treated wastewater. Better monitoring and enforcement of regulations has an indirect impact on the demand for treated wastewater. Even without consideration of wastewater utilization, reducing illegal abstraction is an important goal on its own.

Blending of treated wastewater and fresh water

As the experience of Jordan shows, blending of treated wastewater with fresh water, and providing the resulting mix as the only available solution to farmers leaves no choice between fresh water vs. wastewater. Use of water for irrigation in such a location inevitably creates a demand for treated wastewater at the same price as the price of the blended water. This measure is available in locations where farmers do not have alternative sources of supply, only the one provided by the state.

Use of low-cost natural treatment solutions

One of the biggest obstacles to enhanced utilization of wastewater is the lack of advanced wastewater treatment, a costly technology. When funds are not available for technological upgrade in the foreseeable future, decision makers may consider low-cost nature based treatment technologies like in the case of the Lake Manzala Engineered Wetlands. The resulting wastewater may still not be suitable for irrigation, but it may be used for other purposes, such as afforestation or ground water recharge.

Monitoring and better enforcement of legal disposal of truck collected sewage

Septic tanks can be emptied by pumping to trucks that collect wastewater. This wastewater should in principle be delivered to wastewater treatment plants, but one can suspect that a large share of truck-collected sewage is dumped into nature as this is a lower cost solution. Therefore, improved monitoring and enforcement of this activity can also contribute to higher volumes of available treated wastewater while also protecting the environment. Compared to some of the other measures the impact of this intervention is probably minor, but in locations with substantial illegal dumping it can generate noteworthy benefits.

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2. Climate change and the water- waste cycle": climate change effects on water-waste cycle (considering both water extremes and their impact)

MENA Water World Cafe 2017 Background Paper, Working Group 2

Prof. Fayez Abdulla, Jordan University of Science and Technology

Abstract

Climate change is a global issue that has drawn a great deal of attention from nearly all cultural and institutional quarters (e.g. politics, the media, science and academia, and civil society), and the effects of climate change on countries in the Middle East and North Africa (MENA) region are and will be very severe. The MENA region is particularly vulnerable, given already scarce water resources, high levels of aridity, and a long coastal stretch that is threatened by rising sea levels. Natural and physical systems in the region are already facing heavy pressures, and these will only be intensified as temperatures rise and precipitation levels fall. Impacts of climate change and variability on water resource are already evident in the region, and the more frequent occurrence of flood and drought situations pose further challenges to water and waste managers in all MENA countries. The projected impacts of climate change are likely to exacerbate water stresses and shortages in some parts of the MENA region, while increased flooding will affect other parts.

Changes in climate affect the intensity and amount of precipitation, elevate temperatures and related evapotranspiration rates, shift water demand, and alter the intensity and timing of storm runoff. In turn, all these factors have a combined effect on water and wastewater treatment systems in cities.

The aim of this paper is to discuss the effects of climate change effects on the water-waste cycle, with a dual focus on extreme effects and impacts on urban areas in the MENA region. Ideas on practical responses and adaptation measures to climate change are also discussed from a water-waste cycle perspective. It is evident that climate change is currently threatening urban centres, in addition to other threats such as earthquakes, droughts, flash floods, dust storms, heat waves, air pollution, and rapid and uncontrolled urbanisation. Also, previous studies indicate that climate change is expected to significantly affect infrastructure across the region.

Thus, there is a need to develop and implement adaptation measures, ranging from changes in land use and cropping patterns to water conservation and flood warning systems. This paper highlights that climate change adaptation should be prioritised and integrated with other development plans and policies. Specific measures should be considered to reduce water stress and scarcity by improving water availability through different adaptation measures, such as water harvesting, wastewater reuse, desalination and demand management programmes. Urban water drainage and wastewater treatment systems should be improved and upgraded to meet the projected challenges associated with extremes (floods and droughts) and sea level rise. In addition, local government capacities should be developed and strengthened throughout the region.

Introduction

As adopted by the World Bank, the MENA region is a large zone composed of 18 countries that stretches from Morocco in northwest Africa to Iran in southwest Asia. The MENA region is of great political and economic diversity, and includes both oil-rich Gulf economies and resource-poor countries compared to their population (such as Yemen, Egypt and Morocco). Countries in this region occupy arid and semi-arid regions that are characterised by low and limited water resources and high evaporation. The population of the MENA region is about 6 percent of the global population. Oil is the region's main natural resource, with 70 percent of the world's reserves. The MENA region, one of the world's driest and most water-scarce (see Figure 1), draws subsistence from climate-sensitive agriculture and is expected to face severe water shortages in the near future. The current annual amount of per capita renewable water resources is just 1,100 cubic metres (m^3). Fresh per capita water resources are less than 1,000 m^3 per year in nine out of 18 countries, and this limited supply is currently being depleted at a rapid rate because of growing economic development in the region. Projections indicate that water availability will drop by half, reaching 550 m^3 per person per year by 2050 (World Bank, 2006). The Intergovernmental Panel on Climate Change (IPCC) has stated with high confidence that the MENA Region will suffer a decrease in water resources due to climate change (Bates et al., 2008). Many countries in the region (e.g. Yemen, Jordan, Libya, Algeria, and Palestine) are experiencing acute water shortage, with water availability of less than 500 m^3 per capita per year — less than the official poverty level of 1,000 m3 per capita per year. Figure 2 shows the ratio of total water withdrawal to total renewable water resources (FAO, 2009). The entire region's agriculture sector uses nearly 85 percent of total water resources, but generates only 8 percent of regional GDP on average: Oman's 1.5 percent, Jordan's 2.25 percent and Syria's 21.3 percent are representative examples from 2005.

Climate change and its relationship to water and wastewater in cities

Water supply and sanitation has been a primary concern since the dawn of civilisation. In fact, the locations of major human settlements over time has been determined primarily by an abundance fresh surface water, such as rivers, lakes or natural springs. Throughout history, humankind has made sure to invent and develop means of getting water into cities and disposing of or treating wastewater. Without water resources, related infrastructure and sanitation systems, populations are highly vulnerable to disease and dehydration.

In cities of earlier times, water management was not a serious problem if populations were low and not highly concentrated. As overall population started to increase dramatically after the 1950s and the rate of urbanisation began to accelerate, the delivery of clean water and safe disposal of wastewater and storm water for the megacities of developing countries became increasingly costly and complex.

Climate change is no longer the stuff of science fiction. Its existence has been avowed in a vast and growing number of publications from various disciplines since the 1960s, when technological advances allowed researchers to monitor the transformation of CO_2 in the atmosphere and to predict changes in global temperature through computer modelling (Vo et al, 2014).

Today's cities generally include water and wastewater utility systems with large raw-water storage facilities, storm-water collection systems, trans-basin diversion structures, potable and wastewater treatment plant equipment, pipelines, local distribution systems and finished-water storage facilities (Major et al, 2011). Climate change is not only affecting water supply, but the very structures and facilities that have been built to manage the supply. For instance, any significant change in the precipitation rate, temperature and sea level will lead to changes in water availability, which will in turn affect water supply infrastructure. (Verner, 2013)

In general, studies have paid too little attention to the effects of climate change on urban water supply, paying far more attention instead to surface and groundwater resources and their impacts on agriculture, food supply, energy production and flood risk. There needs to be a more balanced focus between these two related, but different, phenomena.

Figure 1: Per capita water availability in the MENA region (*Source: FAO, 2009*)

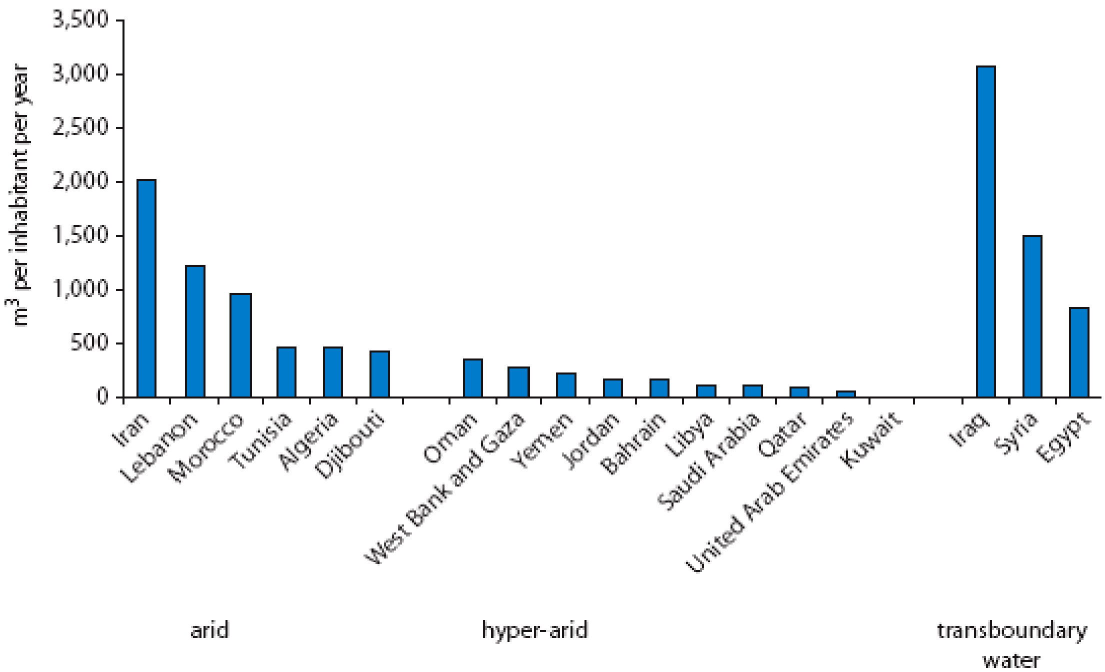
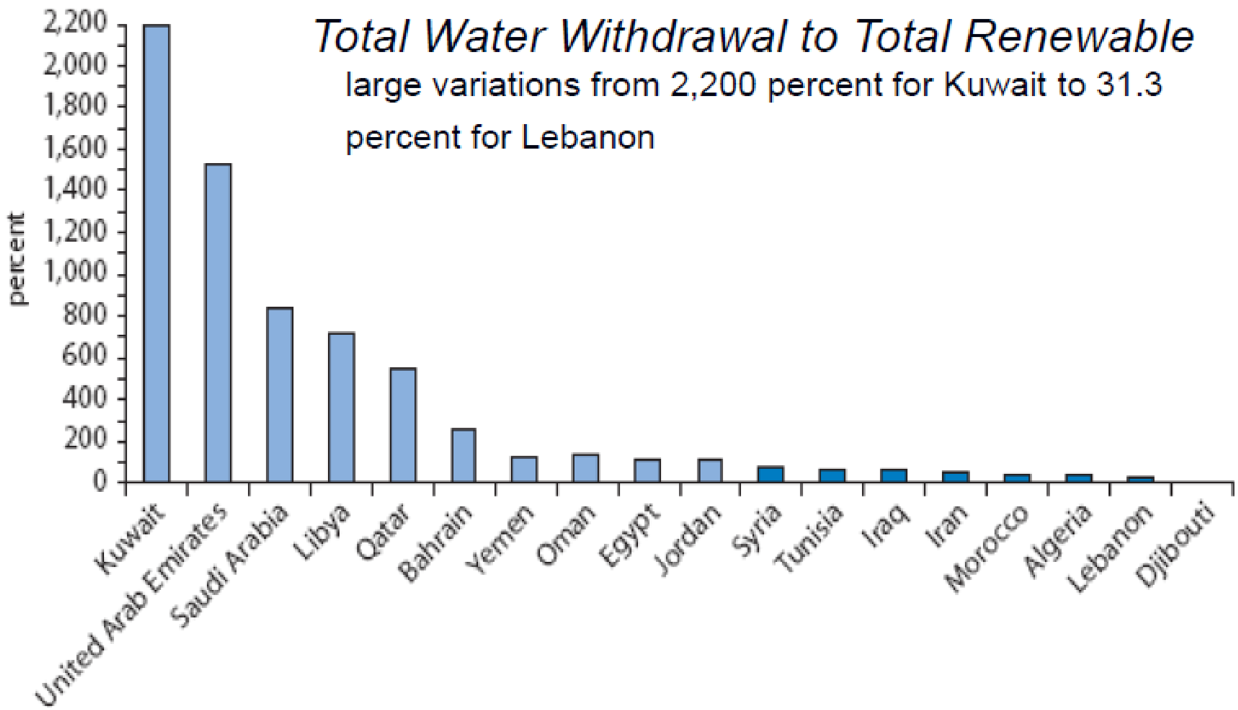


Figure 2: Total water withdrawal compared to total renewable resources (*Source: FAO-AQUASTAT*)



Climate trends in the MENA Region

According to the IPPC (2007b), the linear warming trend over the last 50 years has been +0.13ºC per decade. Furthermore, there has been an increase in the number of heat waves, a reduction in the frequency and duration of frosts, and an increase in frequency and intensity of extreme events in many parts of the world. Regarding these global trends, recent studies have found that the MENA region experienced an uneven increase in surface air temperature, ranging from 0.2 to 2.0ºC, that occurred from 1970 to 2004 (IPCC, 2007a). Earlier studies of weather records in Jordan show an increase in the magnitude and frequency of extreme temperatures (Abdulla and Al-Omari, 2008). The results of these local climate trend studies demonstrate that:

- there is a slight increase in the mean annual temperature; and
- mean annual maximum temperature tends to increase slightly, but the mean annual minimum temperature tends to show a higher increase. (REC, 2017b)

According to Jordan's second and third "National Communication to the United Nations Framework Convention on Climate Change" (UNFCCC), annual precipitation decreased by between 5 and 20 percent at the majority of stations in Jordan over the past 45 years, but very few stations experienced increased amounts of rainfall by between 5 and 10 percent (JSNC 2009 and JTNC 2014). Larger amounts of rainfall with a decrease in the number of rainy days may lead to an increase in daily rainfall intensity, thus increasing the chance of recording extreme precipitation values. On the other hand, many other stations in Jordan recorded increasing trends in relative humidity of about 4–13 percent in last three decades (JSNC, 2009).

According to station readings, winter precipitation in the northern and north-eastern zones of Syria has decreased over the last five decades, while autumn precipitation has increased in north-central Syria. Trend analysis applied to the seasonally average annual temperature series between 1955 and 2006 shows a widespread increase in summer temperatures throughout the entire country, and most notably in the coastal and western regions (FNC Syria, 2009).

All five Maghreb countries depend mainly on rainfall and partly on modest groundwater reserves. Annual average precipitation varies along the Al Maghreb region, but decreases gradually to 300 mm per year as one moves towards the Mediterranean coastlines of eastern Morocco and northern Tunisia. (Laušević et al. 2016).

Drought frequency in Morocco, Tunisia and Algeria has increased over the past four decades. Prior to 1990, Morocco experienced an average of one drought every five years, but now experiences drought at least once every two years (Karrou, 2002; Abbas, 2002; Mougou & Mansour, 2005).

The first signs of changes in this region were apparent through evolutions in temperature and precipitation. In Morocco, for example, an examination of readings taken over three decades (1970–2000) revealed strong evidence of climate change, such as: greater frequency and intensity of droughts, unusually devastating floods, decreased periods of snow cover on the peaks of the Rif and Atlas mountains, modified distribution of spatial-temporal, changes of course and passage dates of migrating birds, and the appearance of bird species in the Rabat region that used to be seen only south of Marrakech. Temperatures increased by 1°C to 2°C during the 20th century.

Registered amounts of rainfall in Morocco show a negative trend on both a national and regional scale. Compared to the 1960s, spring rainfall has declined nationwide by over 40 percent. At the same time, drought has become gradually more persistent. The maximum dry-spell length during the rainy season (February to April) has increased significantly since the 1960s — by as much as 15 days. At the same time, the total number of wet days is decreasing.

Egypt’s climate has shifted in phase with global changes, but with lower rates of variation. There is a downward trend in maximum temperature over the delta, the northern part of Upper Egypt, and the extreme south of Upper Egypt. The trend ranges from -0.02°C to -0.06°C per year. There has, however, been a marked increase in minimum temperatures. An upward trend is evident in most parts of Egypt, except for a small area in Middle Egypt. The upward trend has culminated in increases of +0.1°C per year in the southern parts of Upper Egypt. The main cause of the rise in air temperature is an increase in night time temperature, at which time temperature rises at a higher rate than at any other time. This upward trend has culminated in increase of +0.05°C per year over the western part of the Nile Delta near the Mediterranean coast. The rise in night time temperature could be the result of greenhouse gases and increased water vapour in the boundary layer. On the other hand, the rise in surface air temperature in Egypt is about 60 percent less than the global rise in surface air temperature. Rainfall has increased over the western coast of Egypt by up to 3 mm per year.

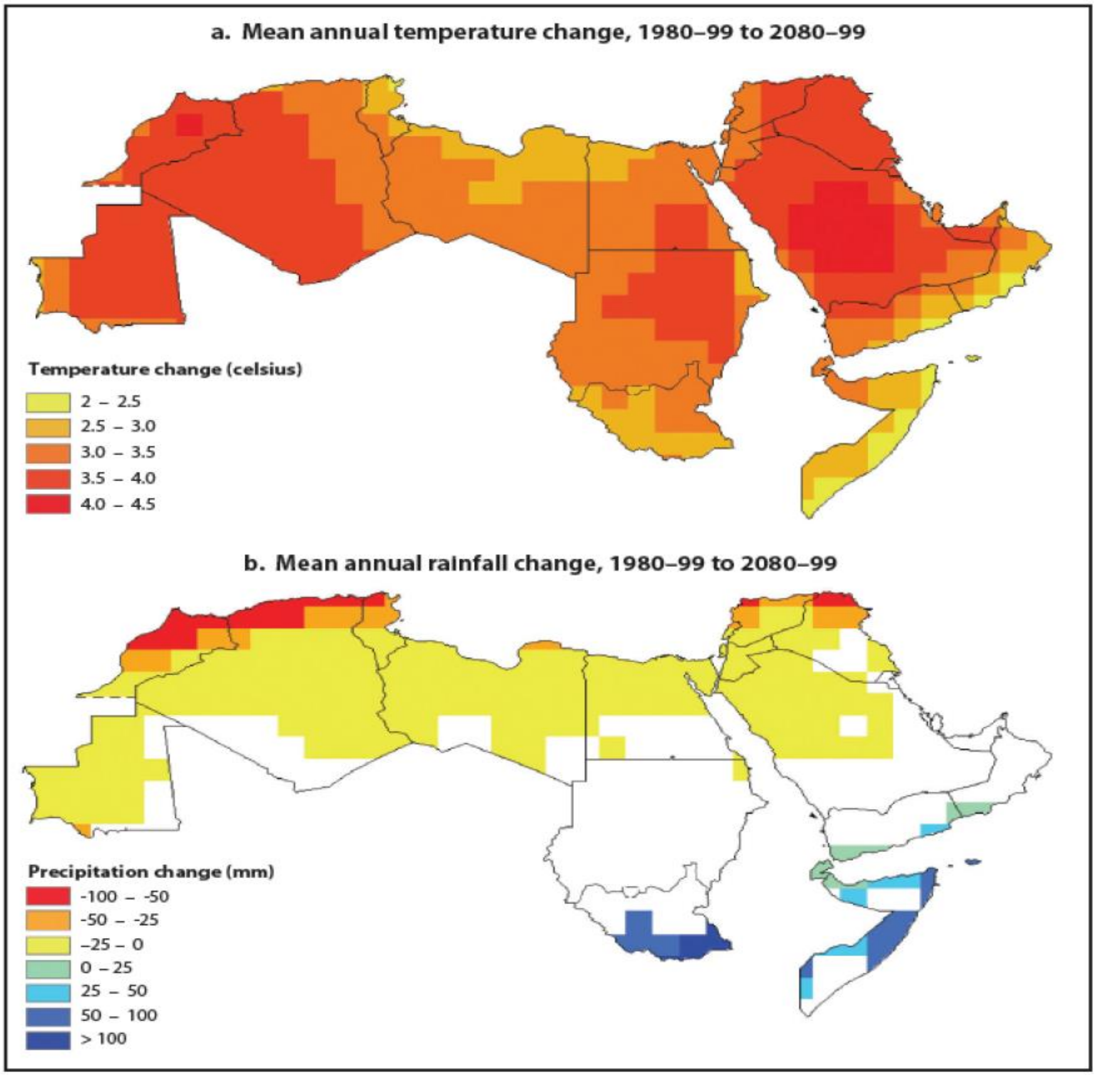
The Arabian Peninsula is the poorest region in terms of water resources, and rainfall is rare by all standards. According to many sources, groundwater in most of the countries in the region is not renewable, and continuous abstraction increases water table depth and, in some cases, deteriorates water quality. The region depends mainly on the desalination of water from the Arab Gulf. Yemen is the only country in the Arabian Peninsula that experiences extremely high summer temperatures, low intensity of rainfall, and declining groundwater table levels due to over-pumping and high rates of evapotranspiration. Meanwhile, average temperatures vary significantly across the region and over time. The annual average temperature for the period of 1970–2001 was around 27°C. Average monthly temperatures for the United Arab Emirates (UAE) for this period show clear trends. The range of monthly temperatures was highest in the summer months, reaching nearly 6°C, while the range of minimum monthly temperatures during the winter months was around 11°C (UAE_INC, 2006).

Climate change projections for the MENA region

The effects of climate change are and will continue to be severe for the MENA region. The region is particularly vulnerable because of already existing water shortages. The region also suffers from aridity and recurrent drought. According to IPCC estimates, most of the MENA region will become hotter and drier. Higher temperatures and reduced precipitation will increase the occurrence of droughts, an effect that is already evident in the region (Verner, 2013). In 2007, the IPCC asserted that climate change in the MENA region will result in an annual raise in temperature of between 2°C and 2.5°C by 2050, while the annual average rate of precipitation is expected to fall by between 10 and 20 percent. In Morocco, Saudi Arabia, Yemen and the UAE, the decrease is rainfall is expected to be 30 to 40 percent.

Also in 2007, the IPCC issued an assessment of projected climate change impacts around the world. This report, the Fourth Assessment Report (FAR), estimates that the average temperature of the Middle East region will increase by about 1–2°C between 2030 and 2050. This would result in higher evaporation rates, causing soil degradation across large areas of land in the region. The MENA region is a vast zone of generally diverse climatic conditions, characterised by very low and highly variable annual rainfall and a high degree of aridity (FAO, 2002b). In a worst-case scenario, average annual temperatures would rise by 1°C to 1.5°C across most of the Arabian Peninsula by 2030; by between 2°C and 2.5°C by 2070; and by 3°C to 4°C by 2100 (see Figure 3). Projected increases in mean annual temperature for the region are: 0.5°C to 1°C (2030); 1°C to 1.5°C (2070); and 2.5°C to 3°C (2100). The IPCC also forecasts a decreasing trend in annual precipitation by between 10 and 20 percent for the Mediterranean region and northern Arabian Peninsula. In a best-case scenario, annual average temperatures would rise by between 0.5°C and 1.0°C for most of peninsula region by 2030; by 1°C to 1.5°C by 2070; and by 2.5°C to 3.0°C by 2100. Model results indicate that future increases in daily maximum and minimum temperatures will be similar to changes in average temperature.

Figure 3: Projected effects of climate change in the late 21st century: most of the region will be significantly hotter and drier (*Source: DroteVerner, 2012*)



Climate change threats to water resource systems

The main consequences of climate change related to water resources in the MENA region can be attributed to increases in temperature, lower soil humidity, higher rates of evaporation and transpiration, shifts in precipitation patterns in terms of temporal and geographic distribution, extreme annual and seasonal variability, torrential rains and flash flooding, frequent droughts and desertification, less snow cover at high altitudes (mountain terrains in Lebanon, Syria, and to a much smaller extent in Iraq), and the possibly damaging impacts of future sea level rises to near-shore, fresh groundwater resources. The following sub-sections outline the main impacts of climate change on water resources in the MENA region. ((Laušević et al. 2016).

Reduced availability of surface water

Water is scarce and will become even more so. Climate change, population growth, changes in consumption habits and current development models all exacerbate local water shortages. Experts and international institutions, including the World Bank, have agreed that the situation is critical and will only worsen in the next 20 years, depriving more and more people of water of decent quantity and quality. Water availability is expected to decrease by 30 to 50 percent by 2050 (see Figure 4) and renewable water resources will likely decrease "absolute scarcity" levels of less than 550 m3 per capita per year (*FAO, 2009)*.

The overall picture that emerges from the limited literature on the region and from IPCC (2007a) projections indicates that water availability will be highly sensitive to climate change. Climate change will have significant impacts on freshwater, both affecting its availability and increasing the frequency of floods and droughts in the MENA region. Climate change could also: undermine national development plans; affect human security and livelihoods; significantly impact agriculture, tourism and industry; and act as a push factor in population movements and migration. Water shortage is already the main constraint for most countries in the region, and IPCC model simulations indicate that water scarcity may worsen substantially as the climate continues to change. The change in the value of surface runoff will depend on changes in temperature and precipitation, among other variables. A study conducted by Abdullaand Al-Omari (2008) showed that temperature increases of 2–4°C in Jordan will reduce the flow of Zarqa River by between 12 and 40 percent. Figure 5 shows projected change in the surface runoff in the MENA region due to temperature increase. Runoffs are expected to decrease by 20 to 30 percent by mid-century.

Figure 4: Climate change impacts on water availability by 2050 (*Source: FAO, 2009)*

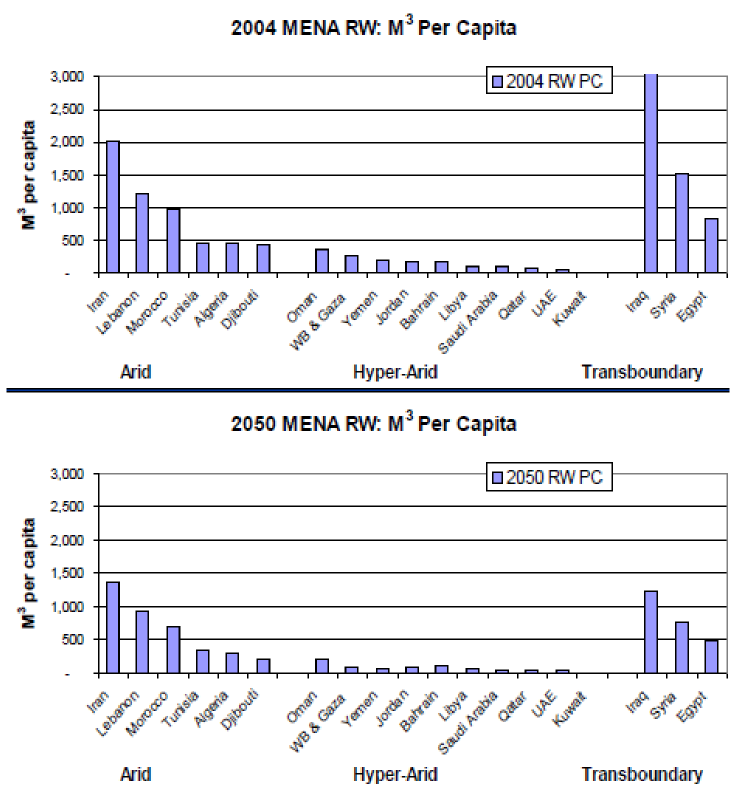
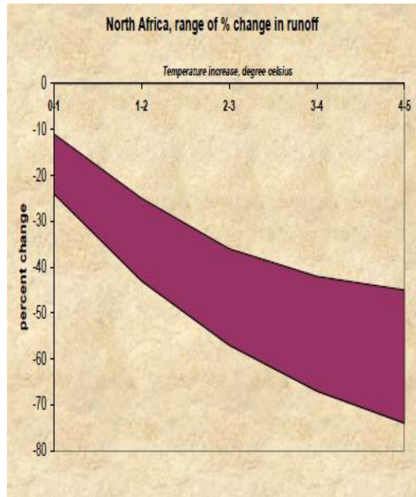


Figure 5: Projected changes in surface runoff as temperatures increase (*Source: World Bank*)



Reduced groundwater recharge

Preliminary climate change and climate variability scenarios for the Arabian Peninsula region indicate that rainfall in the region will become intense and dry spells will become more pronounced. Increased rainfall intensity would likely reduce infiltration and aquifer recharge potential. The potential sensitivity of aquifer recharge to precipitation is summarised in Döll and Flörke (2005), who demonstrate that an increase in surface temperature and reduction in rainfall will result in a 30 to 70 percent reduction in aquifer recharge along the eastern and southern Mediterranean coast. Also, increased temperatures will augment evapotranspiration and further reduce infiltration and aquifer recharge capacity. Climate change will have a negative impact on the quality of groundwater, especially in coastal zones, and sea level rise is expected to threaten many coastal towns. Bahrain risks losing 5 to 10 percent of its total area to rising sea levels. Also, reduced surface water infiltration will exacerbate already unsustainable levels of groundwater depletion.

Accordingly, groundwater supplies will be at great risk from rising sea levels in the MENA countries. Higher sea levels would cause seawater intrusion, leading to salinization of MENA groundwater aquifers close to coastlines. Excessive withdrawal from aquifers will only magnify the problem. Furthermore, many General Circulation Models GCMs suggest that greater precipitation variability and downpours will become more intense, and that this would increase runoff and flash flooding while reducing the ability of water to infiltrate the soil to recharge aquifers (e.g. Hurricane Gono in Oman). Seawater intrusion into coastal groundwater resources could also pose threats to Egypt, Lebanon, Syria and the Gulf States.

Severe drought conditions

Higher temperatures and reduced precipitation will increase the occurrence of drought, an effect that is already materialising in many MENA countries, such as Jordan and Syria. Climate change will also require a more severe adjustment in the management of water resources than for any other region, since most of the region's water resources are already being exploited. Drought-affected areas will probably increase, and climate change will accelerate the drought cycle and desertification, especially in North Africa.

Water quality deterioration

Climate change is expected to impair water quality (i.e. via pollution of surface water and seawater intrusion into groundwater aquifers). The expected changes will undoubtedly have impacts on all the socio-economic and environmental goods and services that depend—either directly or indirectly—on these variables. The consequences for the MENA region are far-reaching and likely to be felt the hardest by the most vulnerable groups, such as women, the elderly, children, and the poor and disadvantaged.

Climate change could significantly degrade surface water quality, as torrential rainfall can generate significant surface runoff carrying sediment loads containing pesticides, fertilisers and wastes. This in turn increases siltation in streams, lakes and impoundments. Warmer water temperatures may have further direct impacts on water quality, such as reducing dissolved oxygen concentrations. Cold-water species, such as most salmon and trout, are particularly susceptible to warm water temperatures, and increasingly frequent warm water conditions could bring new challenges to the way managed river systems are controlled.

Climate change may also have a negative impact on the quality of groundwater. In coastal zones, for example, changing recharge patterns, including reduced long-term recharge and/or temporally variably recharge, coupled with rising sea levels, will increase the likelihood of seawater intrusion, thereby degrading the water quality in aquifers. Moreover, sea level rise would also result in the significant dislocation of coastal populations. In Saudi Arabia, it is expected that the sea water level will increase by 50 cm, which would result in the loss of 3,747 hectares of costal area. A similar rise would likely claim between 5 and 10 percent of the total area of Bahrain.

Increased frequency of flood events

A warmer climate and greater climate variability will also increase the risk of floods (Wetherald and Manabe, 2002). Extreme precipitation events, which are likely to increase in frequency and intensity, will augment flood risk. Increased frequency and severity of floods will also have implications for sustainable development (IPCC, 2007a).

Sea level rise

Another major challenge for parts of the MENA region is sea level rise, because most of the region's economic activities, agriculture and population centres are in coastal areas. The effects of sea level rise in this region are likely to be more severe compared to the rest of the world. The high vulnerability of coastal areas to sea level rise results from inundation and increased salinity of the soil, coupled with the reduced availability of freshwater resources, such as aquifers. An overall sea level rise of 1 metre would directly impact 41,500 km^2 of MENA coastal lands. The most serious impacts would occur in low-lying areas in Tunisia, Morocco, Algeria, Kuwait, Qatar, Bahrain and the UAE (Göll, 2017).

Climate change threats to urban wastewater systems

Changes in the intensity and amount of precipitation, increased temperatures, and related evapotranspiration rates; changes in water demands; and changes in the intensity and timing of storm runoff: all these factors will affect water and wastewater treatment systems in cities. Sea level rise in coastal cities will have its effects, too. The uncertainty and unpredictability of climate change present another problem. The uncertainty stems from many factors, such as gaps in regional data, the inability to fully understand natural systems, and the fact that models being used to predict climate change are not linked to all the factors contained within a climate system. These are issues to consider when attempting to deal with and adapt to the effects of climate change on water and wastewater systems.

In the next decades it's considered that climate change is one of the major challenges to the wastewater systems in cities. Temperatures are rising globally due to the increasing concentrations of greenhouse gases in the atmosphere. The mechanisms and processes that occur in a WWTP are affected by climate change; for instance more extreme weather events and more precipitation could lead to more untreated sewer overflow, increased flooding, etc. Wastewater systems have to focus on extreme high water amounts during heavy rain events as well as on no flow or small quantities during dry periods.

A problem arises in that many cities, even in developed countries, use a combined sewer and storm water system, which during heavy rainfall can cause a pollution in surrounding waterways due to sewer overflow. Also, this increase in the amounts of precipitation will increase the amounts of storm water entering treatment plants in addition to the already existing increment in wastewater due to population growth which will form one of the challenges that treatment plants will face as result of climate changes, furthermore, the increased demand for water reuse when droughts become more dominant will affect treatment plants.

According to the US Environmental Protection Agency (EPA), wastewater treatment plants and combined sewer overflow control plans generally have been designed using historical hydrological data records without considering possible changes in flow conditions caused by climate change. It therefore stands to reason that water suppliers will continue to face greater influent-related challenges from sewerage overflows, which in turn can produce high concentrations of Giardia, Cryptosporidium and coliforms (Vo et al, 2014).

Risks of increasing temperature on wastewater systems

Even though wastewater plants generally have a buffer capacity to deal with a moderate fluctuated thermal array, temperature exceeding or below the optimal range will affect biological processes, especially with temperature-sensitive nitrifying bacteria. Also, in some treatment processes (especially biological wastewater treatment processes, such as in anaerobic reactors and stabilisation ponds) temperature plays a crucial role. Temperature is in negative relationship with land requirements, and in positive relationship with removal efficiencies, which makes the usage of some treatment processes feasible. Anaerobic reactors, for example, can be used for diluted wastewater in warm climate areas. Also, stabilisation ponds, when applied in warm-temperature regions, will occupy less area and perform more effectively. On the other hand, mechanical and high-tech process (such as activated sludge) are less dependent on temperature.

When air temperatures increase at activated sludge facilities that use fine bubble-aeration, there may be a need to increase the required size of blowers to provide sufficient air. Something to keep in mind is that an elevation in water temperatures might be good or bad, depending on which treatment process is being used and if there is a need to nitrify, as temperatures increases will accelerate nitrification. So, the expected increase in wastewater temperature might be sometimes beneficial.

A warmer climate would accelerate reaction kinetics (Metcalf and Eddy, 2003) and thus reduce energy requirements. However, warmer temperature have also reportedly created favourable conditions for the corrosion of raw wastewater pipelines with the formation of hydrogen sulphide (Vo et al, 2014). In addition, the increased fermentation of solids in sludge thickeners will produce malodourous effects (Vo et al, 2014).

Threats of increased rainfall and sea level rise to wastewater systems

The increase in rainfall intensity and its recurrence can cause erosion in some water sources, such as lakes or river catchment areas, and the turbidity levels of water will rise as a result. The way this increase effects water quality is that in the production of drinking water it interferes with the disinfectant process through added costs for de-coagulants and the handling of solids: it can also overload the functional process. This issue is a concern for cities that mainly do not filter the drinking water supply, such as New York City (Loftus 2011), as it may force a city into installing an expensive filtration system.

Flooding caused by increased precipitation, or coastal flooding caused by sea level rise, will damage collection lines and wastewater treatment infrastructure, including pipelines and tanks, making them unsafe.

For cities that use a combined sewer system, heavy rains will overload wastewater treatment plant capacity. Also, for treatment plants close to coast, coastal flooding can increase the salinity of inflow, which will upset the biological process and can affect the reuse capacity of treated wastewater.

When these facilities and infrastructure get damaged they will likely release untreated waste into the environment and ecosystem, which in turn will cause considerable damage to the environment and population. The high costs to be borne can be both tangible and intangible. The damaging effects of floods and sea level rise are the primary concern of WWTPs that are built in flood zones, valleys or coastal areas.

One of the direct effects of global warming is the incrementally increased intensity and frequency of rainfall, which is proven by a stream of flow records from the past several decades. What humankind now faces, and will continue to face, is the prospect of storms in greater number and magnitude, which in turn will produce more violent flooding. This is certain to cause more water pollution from a broader range of sources—mainly from wastewater treatment, storage and conveyance systems.

The way that heavy rain affects the performance of wastewater treatment processes is that it increases the volume of pollutant concentrations, floatable materials and sediments in grit tanks or primary settling tanks at the beginning of the storm event. This happens as the result of the "first flush effect"—i.e. where storm water washes off roadway rubbish and sediments and into the combined sewerage system. Thus, as more heavy rain events occur more frequently as result of climate change, bar screens and grit chambers will need to be cleaned more frequently.

Also, wastewater characteristics will undergo extreme change when wastewater is diluted with rain water contaminated by toxic chemicals in roadway sediments. As a result, some biological processes, such as activated sludge, nitrification/denitrification or formation of sludge flocs, will need to be changed (Vo et al. 2014).

Drought threats to wastewater treatment systems

Higher air temperatures will increase water evaporation, thus increasing drought frequency and severity. The intensity and recurrence of high temperature events and droughts are expected to increase from climate change, which will in turn decrease water storage capacity while likely increasing water demand. As the droughts continue and the demand for fresh water keeps growing, additional water supplies and storage facilities will be required. Furthermore, the increased demand for water reuse when droughts become more dominant will affect treatment plants. Droughts can also concentrate inflows, which is another challenge for wastewater treatment plants to consider.

Another problem arises from the fact that climate change will shrink the base flow of rivers and streams in areas vulnerable to drought events, which in turn will restrict and reduce the effluent requirements of wastewater treatment plants because base flow is used to establish a WWTP's required effluent parameters. Thus, there may be a need for more treatment facilities to satisfy these requirements.

When rainfall suddenly occurs after long dry period, it immediately reduces the concentration of activated sludge in aeration tanks, while on the other hand leading to a surge in sludge loading. Also, the high organic loading rate with high nitrate concentrations will cause denitrification in the secondary clarifier, which creates a gel-like foam on the surface. Up to two weeks are needed to remove this foam layer, and up to five weeks are needed for recovery of the sludge volume index to the specified value (Vo et al. 2014).

Climate change adaptation and mitigation for water and wastewater systems in the MENA region

Climate change adaptation consists of "initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects" (IPCC 2007b). Because urban centres (cities) are dynamic systems that face unique climate impacts, their adaptation must be location specific and tailored to local circumstances. The starting point in managing risks and building long-term resilience is for a city to understand its exposure and sensitivity to a given set of impacts, and to develop responsive policies and investments that address these vulnerabilities.

Many human and natural systems are strongly influenced by climate. Industries and urban and rural communities are also affected by climate factors. Climate can influence productivity and reliability of supply. Cities and infrastructure are expected to cope safely and efficiently with severe weather events. Improved technical knowledge and modern communications are helping to increase understanding of the relationship between climate exposure and national welfare.

Although climate change is projected to have serious impacts on water resources in the MENA region, only modest efforts and steps are being taken in scientific research related to mitigation and adaptation. The scientific community in most MENA countries is still suspicious regarding climate change phenomena, and remains hesitant to acknowledge the risks. (Laušević et al. 2016). In addition, MENA countries, like other developing countries, have low adaptive capacity to withstand the adverse impacts of climate change due to the high dependence of a majority of the population on climate-sensitive sectors, such as agriculture and water resources sectors, coupled with poor infrastructure facilities, weak institutional mechanisms and lack of financial resources. In most MENA countries, comprehensive national policies to address climate changes have not been adopted to date. Over the past two decades, a range of acts, regulations, measures, policies and strategies directly related to water scarcity and indirectly related to climate change have been developed and even adopted. However, effective implementation of these climate change measures may require the development of response measures that are primarily designed to achieve other development objectives. Therefore, the development of mitigation and adaptation strategies to protect water resources on MENA region is required if national socioeconomic goals are to be attained. MENA countries are therefore seriously concerned with the possible impacts of climate change, including:

- water stress and reduced availability of fresh water due to a potential decline in rainfall;
- threats to agriculture and food security, since most of the agricultural activities are either rain-fed (as in Jordan, where about 71 percent of cultivated land is rain fed) or irrigated agriculture (as in Egypt, where more than 90 percent cultivated land is irrigated);
- threats to biodiversity, with adverse implications for forest-dependent communities;
- adverse impacts on natural ecosystems, such as wadi systems, coral reefs in MENA cities located by the Red Sea, grasslands and mountain ecosystems; and
- impacts on human health due to the increase in vector-borne and water-borne diseases. (Laušević et al. 2016).

The impacts of climate change are inevitable and raise issues related to adaptation. Although climate change will affect virtually every sector and region, this part of the study looks at the water resources sector in MENA countries to illustrate the nature of adaptation problems and policy research needs. (Verner, 2013)

The primary aim of exploring mitigation and adaptation strategies is to develop a climate change policy that is specifically geared towards more vulnerable sectors in the country, as well as to establish a public policy that encourages and supports adaptation at local or community level and in the private sector. Another goal is the development of sustainable economic growth, which in return allows for a greater allocation of resources for the development of adaptive technologies and innovations. Listed below are a few expected outcomes from these proposed policy actions:

- reduced vulnerability;
- adaptation to expected climate changes;
- promotion of sustainable development;
- poverty reduction;
- protection of the environment;
- institutional strengthening;
- capacity building on climate change;
- establishment of a legal framework to address climate change; and
- public awareness of climate change. (Laušević et al. 2016).

The availability of water is essential for many industries and other natural resources. Every major city faces water stress already, and climate change will exacerbate water stress and shortages in some parts of the MENA region, while increasing the occurrence of flooding in other parts. Dams could be susceptible to extreme rainfall events if they deviate from historical design standards. Dam overtopping and failure can have catastrophic short-term and medium-term effects in terms of human and economic loss.

Measures have already been adopted to counter growing water scarcity in MENA countries, such as water conservation, finding additional water sources (desalination and wastewater reuse), and water demand management, all of which can serve as future climate change adaptation strategies. In their efforts to adapt to climate change and water scarcity problems, water ministries in MENA countries have introduced water strategies and several policies to conserve water and seek alternative supplies. In addition to optimising the use of rainfall-fed recharge in some basins to augment storage in the main basins, water harvesting systems, wastewater reuse, virtual water, and desalination have been identified as potential adaptive measures to water scarcity. These measures, however, need to be further developed and implemented. Such strategies may range from changes in land use and cropping patterns to water conservation and flood warning systems. Water vulnerability and adaptation to climate change should therefore be part of any sustainable water resources regime, along with integrated development policies designed to (REC, 2016a):

- build on existing policies to protect water resources, the environment and economic development against current climate conditions (the adaptation baseline); and
- make incremental changes to the adaptation baseline to mitigate direct and indirect effects of climate change (climate change adaptation).

Taking into account the scarcity of water resources and their anticipated decrease in many MENA countries resulting from climate change, the following adaptation measures may be taken (REC, 2016a):

Surface water development

- Surface water optimisation through supply-enhancing measures, including: surface and subsurface storage, minimising losses to surface evaporation and seepage, soil and water programmes, and protecting surface water supplies from pollution
- Developing sustainable management plans for surface water in wadi systems, converting open canal systems to pressurised pipe systems, giving priority to modernising and upgrading systems, and giving precedence to water projects that make significant contributions towards meeting rising municipal and industrial demands
- Expanded rainwater harvesting
- Water storage, conservation and reuse
- Desalination.

Groundwater protection

Most groundwater aquifers are exploited at more than double their safe yield capacity. The sustainability of irrigation in the MENA region highlands and desert areas will be greatly endangered unless strict measures are taken to address this issue. As such, the development and implementation of an action plan is needed to ensure that plans for groundwater protection, management, monitoring and restoration are defined, integrated and managed in a cost-effective manner (JSNC, 2009).

Priority actions needed for groundwater resources protection are (Al-Jeneid et al. 2008):

- formulation of an integrated water resource management plans to rationalise water use and protect aquifers from being excessively salinized; and
- legalise and institutionalise the reuse of treated sewerage water.

Enhanced use and development of non-conventional water resources

Non-conventional water resources may be defined as “water resources that are not readily available and suitable for direct beneficial use, including wastewater reuse, water desalination, and weather modification.” Alternative water resources, such as reused municipal wastewater and desalinized seawater/brackish are see enhanced use, and submarine springs with significant flows have been located along the Lebanese and Syrian coastal areas. The most common source of non-conventional water is treated domestic and industrial wastewater. Wastewater reuse is becoming more popular throughout the world, particularly in arid and semiarid regions, because it can reduce environmental and health-related hazards if planned properly, while also increasing crop yields through supplemental irrigation and wastewater nutrients.

Jordan is a good example for using this source of water to alleviate the water scarcity problem. Roughly 25 municipal wastewater treatment plants have operated in Jordan in the past three decades. Effluent from these plants we be used either for irrigation around the plants or discharged to wadis or reservoirs where it is diluted and utilised for agriculture.

Brackish water is another of non-conventional source of water that can be utilised after treatment. To further pursue the brackish water option, the ministries of water in MENA region should assess the potential of brackish water resources in terms of sound technical, economic and environmental feasibility in all groundwater basins, and then conduct research and studies on desalination and on optimisation of brackish water use in agriculture and industry.

Water quality and environment

MENA countries have witnessed some deterioration in water quality in the last two decades due to industrial pollution, overuse of agrochemicals, drainage water, overloading of wastewater treatment plants, over-pumping of aquifers, seepage from landfills and septic tanks, and the improper disposal of dangerous chemicals by certain industries. The overloading of existing wastewater treatment plants due to high population growth and socioeconomic development have further degraded the effluent from most wastewater treatment plants. The performance of many of plants is inadequate, resulting in effluent of low quality. This effluent may have adverse effects on public health due to the presence of pathogens or the accumulation of toxins in effluent-irrigated soils. Furthermore, pollution of surface and groundwater due to seepage will result in the deterioration of quality of some water resources and will limit their use for different purposes. Enforcing standards for wastewater discharges to sewers, treated effluent and water for other uses is essential. Thus, any standards adopted should consider national priorities, economic conditions and the availability of water supplies, as well as health and other environmental implications. The implementation of standards and their enforcement require facilities and expertise, which involves significant costs: enforcement in particular requires commitment and coordination between many agencies and at many levels. The adopting and implementation of guidelines for water used in irrigation by water ministries in MENA region countries, in cooperation with their related ministries, will increase the availability of water that can be used for irrigation.

Strengthening water resources monitoring systems

Enhance monitoring efforts to improve data for weather, climate, and hydrologic modelling to aid understanding of water-related impacts and management strategies. In addition, databases that support water resources and environmental management should be integrated.

Measures to improve system efficiency

The overall efficiency of water resources system is low, due to losses in the system, system constraints and inefficient farm practices, but also due to the constraints of funds and inflow patterns. In the precipitation increase scenario, adaptation measures to increase efficiency may include the adoption of better farm management and irrigation practices. Special care should be taken to control the high waters in the root zone, which considerably reduce crop acreage. Precision land levelling and proper field sizing may also be required.

Implementation of integrated watershed management practices

The implementation of integrated watershed management practices can play an important role in the rationalisation of resource use and the allocation and protection of sources (both surface and groundwater), while the proactive use of pricing and market mechanisms can boost water use efficiency. An effective and economically beneficial adaptation option lies in the construction of dams over all potential wadis. The finite nature of renewable fresh water makes it a critical natural resource to be examined in the context of population growth and climatic changes. Fresh water availability is dictated to a large extent by climate, and particularly by the timing and location of precipitation, as well as evaporation rates, which can vary tremendously from season to season. Watershed protection would also have benefits for groundwater storage and flood alleviation.

Urban water use

There is an urgent need to devise policies, both economic and structural, to practice water conservation in urban areas to ease the rising pressure on drainage and supply systems, as well as to reduce the pressure on sewerage treatment facilities, both of which are essential for the preservation of water quality. (Verner, 2013)

Flood control

Flash floods have a varied impact on different areas (e.g. desert wadis or rural areas). Proper risk and vulnerability analyses for each flood-prone area will need to be carried out in a changed climate. Up-to-date topographic maps are needed for the vulnerable areas, and flood control authorities should keep up-to-date records of settlements and infrastructure development. Official clearance from the flood protection agency may be required for the establishment of settlements and created infrastructure in new areas.

Research programmes

In MENA countries, few and limited studies have been published in the field of climate change, and there are many gaps that need to be filled in the future, especially pertaining to vulnerability and adaptation of the water resources, agriculture, and health sectors. Climate change studies are based in most cases on modelling, remote sensing and projection techniques, but, due to the lack of facilities and insufficient funding for Arab research institutions, empirical and experimental techniques are still being applied.

Any assessment of climate change impacts, vulnerability and adaptation to climate change requires a wide range of physical, biological and socioeconomic models, methods, tools and data. The methods for conducting such assessments are improving gradually, but are still inadequate to help policy makers formulate appropriate adaptation measures. This is due to uncertainties in regional climate projections, the unpredictable response of natural and socioeconomic systems, and the inability to foresee future technological developments.

Continuing research will lead to better and more precise information about the impacts of climate change on water resources across the MENA region. The use of statistical and dynamic downscaling with regional models can open doors for generating high-resolution climate change scenarios and investigating their impacts on a regional scale.

Public awareness and stakeholder capacity programmes

Public awareness of the issue of climate change in MENA countries is still in the early stages of development, and most of the countries have highlighted the difficulties involved in improving the situation. By and large, Arab society is not sufficiently aware of the consequences of global climate change, and better efforts to raise awareness are needed. Public debates, increased media interest in the problem, and intensified activities by non-governmental organisations are some ways of accelerating the process. Public interest and support are also crucial for the development and implementation of long-term governmental strategies and climate change policies.

There is also a need for capacity building to enable the environmental authorities to play a major role in planning, coordinating and implementing adaptation programmes. Their capacities need to be strengthened in terms of human, financial, technical and technological resources. Means of awareness raising can include workshops, radio and television programmes, newspapers, films, pamphlets and websites.

Barriers to increased adaptive capacity

Each country has its own specific barriers to the implementation of adaptation and mitigation measures, such as limited financial and technical resources, lack of human and institutional capacity, an inadequate legislative framework, and insufficient public support. The vulnerability and adaptation assessments included in the first and second national communications carried out by various MENA countries identify the following barriers to adaptive capacity (REC, 2017a):

- Inadequate infrastructure for water conveyance, collection and treatment;
- poor or lack of industrial pre-treatment capacity;
- poor or inadequate facility operation and maintenance programmes;
- inadequate access to technology;
- insufficient capital to fund a domestic wastewater pollution management programme;
- limited human resources, equipment and facilities at water ministries;
- lack of coordination and poor exchange of knowledge and experience among agencies associated with wastewater reuse, as well as with national or municipal-level planning programmes;

- weak capacity for conducting surveys, assessments, investigations and applied scientific studies to evaluate and predict health impacts caused by wastewater reuse;
- limited number of educational and awareness-raising programmes on safe wastewater reuse;
- lack of enforcement of existing regulations;
- inadequate inventory of communities' use of treated wastewater;
- insufficient monitoring and assessment of environmental progress;
- limited studies on diseases associated with wastewater discharge and reuse;
- lack of financial resources to implement climate change adaptation measures;
- lack of clear and specific legal and policy frameworks for climate change issues;
- lack of incorporation of climate change impacts into development policies, plans and programmes in some of the most climate-sensitive sectors—e.g. water management, agriculture, disaster management etc. (while it is true that the need for such integration is being slowly realised, actual integration needs to be greatly accelerated).

Conclusions

This study recognises that there is an alarming deficiency in scientific and technological capabilities, in addition to a lack of political will, to confront and address problems posed by climate change in the MENA region. There are not enough scientific facilities to study this phenomenon, insufficient funds are allocated to such research, and the studies that have been undertaken leave gaps that should be filled. Climate change mitigation and adaptation need to be integrated into development strategies; and issues related to planning, scientific capacity, stakeholder involvement and public awareness need to be urgently addressed.

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3. Water quality management: focusing on pollution reduction coming from urban and rural areas

MENA Water World Cafe 2017 Background Paper, Working Group 3

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Introduction

The Middle East and North Africa Region (MENA) is the most water scarce region in the world. Worldwide, the average water availability per person is close to 7,000 m^3/person/year, whereas in the MENA region, only around 1,200 m^3/person/year is available (Yamouri, 2010). Related with freshwater, in MENA region there is less than one percent of the world's renewable freshwater resources. The region is defined largely by drought and desert and suffers from a scarcity of fresh water, uneven availability, a growing gap between supply and demand, deteriorating water quality, and predominant agricultural water use. The region is vulnerable to the impacts of climate change on its water resources. The frequency and intensity of droughts are expected to intensify and severely affect the ability of MENA countries to manage their freshwater resources and coastal zones.

Besides the overarching water scarcity problem in the region, the water quality issues are also becoming increasingly apparent for both surface and groundwater (Wingqvist 2010). In fact, the quantity and quality issues are connected, for instance as lesser dilution of pollution and increasing levels of salinity and alkalinity due to overexploitation.

The World Water Week 2017 focuses on the topic "Water and waste: reduce and reuse", which addresses the wastewater management as critical component of the water-waste cycle, from the source through distribution, collection and treatment to disposal and reuse, including water, nutrients and energy recovery.

Water quality concerns in MENA Region

The population growth, urbanization, industry development and intensifying agriculture are the main driving forces for pollution and deterioration of water quality worldwide. In MENA region, the water quality issues are highly related also to the specific climate and hydrological conditions, overexploitation of the water resources, geopolitical, social and economic context.

The **urban wastewater** is the main source of nutrient loads and decline of hygiene conditions of natural waters. The primary targets of this pollution are usually surface waters and the main affected quality parameters are the total nitrogen (N), total phosphates (P), microbiological parameters (Coliforms) and parameters sensitive to nutrient loads (BOD, COD). Deteriorating water quality is one consequence which involves insufficient sanitation infrastructure that consequently has contaminated surface and groundwater, with negative impacts on the environment and public health.

This problem is addressed mainly by investments in sewage networks and construction of urban wastewater treatment plants. Sewage treatment and recycling waters creates benefits both in relation to water quality and quantity. According to published data of 2010, about 43% of wastewater generated in the MENA region is treated; a relatively high percentage compared to other developing-country dominated regions. This is because of the perceived importance of wastewater as a water resource (Qadir M., 2010) and the reuse of this element is considered crucial in the new approach of integration water management. Nowadays, the share of treated wastewater could be estimated to about 50%.

However, in rural areas, the population live scattered on large areas, which make investments in a sewerage network economically unfeasible. As a consequence, there are no sufficient investments in networks apart from the large cities and cesspits are the dominant method for collection of wastewater. Most houses have their own cesspit, or share a cesspit among a cluster of houses. The wastewater percolates into the groundwater, often overflows into the streets and too often when the cesspits are full, the waste is dumped into a nearby wadi.

The **industrial water pollution** is relatively rare in MENA, compared to other regions (Lipchin C. et al 2006) however there are cases, related mainly to inadequate prevention and control. Although the pollution prevention policies in different countries are different, most of the larger industries are obliged to have their own WWTPs. Industries generally reuse a lot of water internally due to unavailable or expensive water resources. Industrial effluents may vary broadly in terms of pollution agents, depending on the technological process and the wastewater treatment.

The **agriculture sector** is traditionally important for the countries' economies and the livelihood of rural communities, but it is also driver for various environmental impacts. Water pollution from agriculture is related mainly with excessive use of fertilizers and pesticides, and unsustainable land use practices. The pollution from agriculture has both point source and diffuse origin and affects both surface and ground waters.

Water quality is dependant also on other human activities, including **solid waste collection, treatment and management**, which directly impact ground waters. Some landfills are located on sensitive locations, such as on top of aquifers used for abstracting drinking water. Considering the high dependence of drinking water supply on ground waters, the transfer of pollutants from surface to ground waters is very important aspect in MENA region.

The **environmental, social and economic costs of water pollution** are high. According to AFED (2008), the average annual cost of environmental degradation in the Arab region is 5% of GDP. Unsafe water, lack of sanitation facilities and poor hygiene are the leading causes of mortality and morbidity in developing countries. It is estimated that up to half of all hospital beds in the world are occupied by victims of water contamination.

Water quality is also important for various industries that require high-quality water to operate. Lower quality water could impact and limit the choices of technology available to developing countries. Reductions in water quality have the dual effect of not only increasing the water stress to industrial companies in these areas but also increase the pressure to improve the quality of the industrial wastewater. This in turn increases the costs spent on environmental rehabilitation and remediation (Dakak, A., 2016).

Sustainable Development Goal on Water and Sanitation

The Sustainable Development Goals (SDGs), adopted at the United Nations Sustainable Development Summit on 25 September 2015, include Goal 6 "Ensure access to water and sanitation for all". The following targets are defined under SDG 6:

- By 2030, achieve universal and equitable **access to safe and affordable drinking water for all**
- By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations
- By 2030, **improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally**
- By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity
- By 2030, **implement integrated water resources management at all levels**, including through transboundary cooperation as appropriate
- By 2020, **protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes**
- By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies
- Support and strengthen the participation of local communities in improving water and sanitation management

SDG 6 not only addresses the issues relating to drinking water, sanitation and hygiene, but also the quality and sustainability of water resources worldwide. It is particularly important for arid and semi-arid regions, representing the major part of MENA region, where the water stress affects significantly the quality of life and economy.

The limited availability of natural waters resources determines their high social and economic values, and subsequently the high importance of their protection. Therefore, the target of improving water quality by reducing pollution, increasing the wastewater treatment and water recycling is highly relevant to MENA countries.

Water quality management in national policies

As a consequence of the limited resources, the water management policies in MENA region focus primarily on the supply of water for the population and agriculture. Although the legal and institutional frameworks vary from country to country, it is common approach each part of the water cycle to be under responsibility of separate institution. Because the management approach is linear, the coordination and communication among the institutions appears to be limited to the transfer of management responsibilities from one institution to the other as the water is transferred. For example, a process of decentralization of water supply service delivery by helping create independent public companies responsible for service for small cities and towns is taken place. The water quality and quantity monitoring systems are spread among various institutions with insufficient contact and coordination among them in the majority of the countries (Water SUM Feasibility Study, 2016)

Many of the countries in the region have introduced the Integrated Water Resource Management (IWRM) in their policies but still the water quality and environmental aspects are not fully integrated. Monitoring activities and data bases are scattered in and data exchange between institutions and countries is limited.

Some country-specific examples of the water quality aspects, tackled by the national water policies are provided in the descriptions below, based on the experience of Water SUM Project, implemented by REC since year 2015.

In **Jordan**, the National Water Strategy 2016 – 2025 focuses mainly on the supply of water for the population, agriculture, tourism and industry. The country is affected by severe water scarcity, resulting by climate and geographic features but aggravated by population growth, refugee’s crisis and climate change. The strategy build on previous strategic documents, reinforcing and strengthening the integrated water resources planning and management that is aligned with the SDGs.

The water quality issues and pollution prevention are addressed rather horizontally than by dedicated specific objectives. The policy puts emphasis on the wastewater collection, treatment and reuse, addressing simultaneously the water quality and quantity issues. The national water strategy and the national substitution policy consider treated wastewater effluent as a water resource that has been added to the water budget for reuse, with priority given to agriculture for unrestricted irrigation. Significant investments in waste water treatment plants (WWTP) are planned.

The strategy states that severe deterioration of water resources quality due to agricultural activities has been witnessed in many areas recently. In order to safeguard water quantities, improved agricultural practices should be applied and the government should establish a reduction of agricultural activities in areas where they may negatively impact supply drinking water.

In terms of monitoring systems, the strategy provides consolidation of the monitoring networks and finalization of the National Water Information Systems (NWIS).

Besides the National Water Strategy, the water quality topic is tackled by the following policies and legal instruments in Jordan:

- Public Health Law No.47 - Year 2008.
- Environmental Protection Law No. 52 – Year 2006 and its amendments and related regulations
- The Environmental Impact Assessment Regulation No. (37) - Year 2005
- Regulation for the Licensing and Permitting of Excavation and Infrastructure Network Projects (No. 112/2007).
- Regulation of Harmful and Hazardous Waste Management, Transfer and Handling No. 24 – Year 2005
- Instructions on the Protection of Water Resources - Year 2011.
- Instructions for the Management and Handling of Hazardous Waste - Year 2003.
- Instructions for Disposal of Industrial and Commercial Wastewater into the Sewage Network – Year 1994

- Standards for Drinking Water (JS 286/2015).
- Standards for Reclaimed Domestic Wastewater (JS 893/2006).
- Standard for the Requirements for Discharges of Industrial Effluents (JS 202/1991).
- Standards for Industrial Reclaimed Domestic Wastewater (JS 202/2007) (JS893).
- Standard for Storage – General Precautionary Requirements for Storage of Hazardous Materials (JS 431/1985).
- Drinking Water Resources Protection Guideline, July 2006.

In **Tunisia**, the water management policies consist of several policy documents, covering different aspects and time horizons. In 2003, the Ministry of Agriculture published the Water Master Plan for the water sector. Two main strategic options were identified and implemented: the 10 years strategy of water resources mobilization (2001–2011) initiated for the 1st time in 1990, and the long-term strategy (2030).

In 2013 a policy on Sustainable Management of Water Resources was developed by the Ministry of Environment. The document recognizes that the urbanization, industry, tourism and agriculture are the main sources of water pollution and pays special attention to the human activities in proximity to the reservoirs. The Strategic objective 1 is dedicated to the preservation of available water resources, including pollution prevention and control. The policy proposes technical, legal and institutional measures to improve the water quality control system in the country. It defines the need of improved sanitation and wastewater treatment, adapted to the urban and rural context, incentives for clean technologies and updating of quality standards.

However, the most important legal instrument, setting the provisions on water quality and protection of water resources in Tunisia, remains the Water Code (Le Code des Eaux), developed in 1975 and revised in 2013. It includes several articles and gives rise to related laws, decrees, and standards regarding water quality monitoring. (Water SUM Feasibility Study, 2016).

The water quality is covered also by the following legal documents:

- Law 82-66 of August 6, 1982 on standardization and quality.
- Law 75-16 of March 31, 1975 (Water Code, as amended and supplemented by Law 87-35 of July 6, 1987 and Law 88-94 of August 2, 1988).
- Decree 85-56 of January 2, 1985 on the terms of discharges into the receiving environment.
- Decree 2005-1991 of July 11, 2005 defining the study of environmental impact (ANPE).

In **Egypt**, the National Water Resource Plan – 2017 is based on the IWRM approach and covers various aspects of water management, including the quality of surface and ground waters, identification of pollution sources and setting policy objectives for water quality, and protection of public health and environment. The plan identifies that the water quality of Nile River and the other main water bodies is affected by agriculture drainage water, containing salt, nutrients, pesticides, and industrial and municipal effluents, draining either directly or indirectly.

The Specific objective on protection of health and environment include targets on compliance with water quality standards, limiting the use of non-renewable groundwater and ecological conditions in coastal lakes and Ramsar sites.

The solutions for improvement of the water quality include at first place pollution prevention and control, providing alternatives for less harmful technologies and practices, minimizing the pollution from agriculture and industries, as well as increased share of wastewater treatment.
The policy objectives for the strategy on water quality are:

1. Improvement of water related public health conditions
2. Sustainable use of groundwater resources (both shallow and deep)
3. Meet the water quality requirements of the various functions of the waterways.

Besides the National Water Resource Plan, the legal instruments in Egypt related with water quality are:

- Law 48 (1982) concerning the protection of the River Nile and Waterways from pollution implement by Decree 8/1982. Law 48/1982 provides the basis for the protection of surface and groundwater against pollution and water quality standards.
- Law 4 (1994) Law for the Environment.

Morocco has introduced the river basin management approach and established nine river basin agencies, responsible for authorizing water abstractions and wastewater discharges for all users, based on a basin master plans (Plan directeur d'aménagement intégré des ressources en eau, PDAIRE). These authorities also collect charges effluent discharges and provide financial and technical assistance to service providers for the prevention of water pollution and the efficient use of water resources. They also monitor the quality and quantity of both surface and groundwater and are in charge of managing water-related emergencies.

Wastewater treatment in Morocco has expanded significantly in the last decade. According to published data from 2015, there are 62 wastewater treatment plants in the country (Kurtze J. et al, 2015). The country's goal is 100% wastewater recycling and treatment by the year 2030 (Salama, 2014).

There is a general Water Law (Loi 10-95) since 1995 in the country. This regulation aimed at changing the emphasis of water resources management from supply expansion to demand management. The law also provided the legal basis for the establishment of river basin agencies for integrated water resources management.

Lebanon officially adopted its National Water Sector Strategy (NWSS) in 2012. The strategy outlines the main shortcomings in water sector in the country and defines the strategic solutions and implementation priorities. The 3rd priority of the NWSS is dedicated to putting wastewater on a sustainable footing and protecting the environment. Series of investments and measures are defined in this regard: (i) developing wastewater infrastructure to increase coverage of collection networks and treatment capacities, optimizing treatment processes and sludge disposal, and ensuring reuse where possible; (ii) improving wastewater management by implementing an institutional and business model for wastewater collection, treatment and reuse; and (iii) environmental protection by promoting and improving water quality management, and protection of recharge zones.

Laws and regulations for water quality and water resources protection date back to 1925, though complementary application decrees have not always been written. The Water Organization Law No. 221 of May 2000 establishes its legal framework which led to the adoption of Law 221 in 2000 along with a number of by-laws which were adopted in 2005.

The principal action taken by the government under the Law 221 was put for the separation between policy-making and service provision. There are also few laws covering wastewater disposal, solid waste discharge, industrial wastewater discharge, and other water pollutants.

Water quality monitoring and data exchange

Monitoring the quality of surface water will help protect our waterways from pollution. At local, state and national governments level, the use monitoring information may help to control pollution levels. This information is used to understand exactly how it is impact in the water supply and to help understand the important role all human activity plays in water conservation.

The decision-making in regards to the protection of water resources requires reliable and frequently updated information about the quality and quantity status of the surface and ground waters. This information is provided by the water monitoring systems and is usually analyzed, stored and processed at national level.

The information collected depends on the management question, but the water quality monitoring may include:

- physical characteristics – e.g. temperature, colour, light, sediment suspended in the water
- chemical characteristics – e.g. dissolved oxygen, acidity (pH), salinity, nutrients and other contaminants
- biological characteristics – e.g. bacteria and algae composition

Traditionally, the water monitoring in MENA region is focused with priority to the quantity due to the long-lasting water scarcity problems and the primary needs of drinking water supply and irrigation systems. However, all countries have also established monitoring networks for water quality.

The MENA region is characterized with distinct hydrological variability of surface waters and presence of temporary streams, which result in specific pollution dynamics. These result in region-specific challenges in surface waters monitoring that need to be addressed by careful adaptation of the monitoring and data analysis methods.

From the other hand, groundwater is an essential resource as well for the region, especially for the countries with most arid climate and those, sharing large aquifers. Monitoring of the risks relating to overexploitation, salinity increase and transfer of persistent pollutants with groundwater recharge is crucial.

In spite of the diverse water management and monitoring setup in the broad MENA region, some common features of the water quality monitoring could be outlined:

- Quality and quantity monitoring networks are often separated in terms of sampling points locations and institutional responsibilities. In some cases this result in difficulties to establish relations between the hydrology and pollution dynamics.
- The monitoring of drinking water is often performed by specific institution (water supply operator, Ministry of Health or equivalent).

- Basic physico-chemical parameters are usually broadly present but the sampling and analysis of more sophisticated parameters (e.g. pesticides and heavy metals) vary significantly, depending rather on the available technical capacity than on the decision-making needs.
- The monitoring programs are highly heterogeneous across the region, and sometimes across the territory of one country, both in terms of types and number of parameters monitored and monitoring frequencies.
- Monitoring based on biological indicators for water quality is not present. The biological parameters are limited to hygienic microbiological measurements.
- The integrity between the different monitoring networks in one country is often low and data exchange for decision-making purposes is not sufficient.
- Many of MENA countries has started the development of national information systems for waters, intended to store and facilitate the analysis of monitoring. However most of these systems have not reached full functionality, particularly in respect to the water quality.

Data Management in the Middle East and North Africa is much like every other region of the world. Frequently, at the core of water issues is a disagreement over data sources, data methodologies for collection and analysis, and the data themselves, whether it is raw or analyzed. Beyond the fundamental issues related to data are equally intransigent issues related to the open sharing of data, be it among entities in a single country or across national borders. Something that has to be improved in the following years is the foundation of a common network to build upon, leading to development of inventories of water resources data, and eventually to harmonized data collection and analysis for country-level, or even regional-level water planning and management.

The design of this future network should make clear that private sector participation is invited at each stage of the process, including the sharing of scientific research by university and professional communities with the private sector; funding for scientific collaboration, education, and investment; and project development and implementation. There is a range of private sector entities that needs to be engaged: non-government, non-profit groups, as well as private interests, for-profit companies, and trade associations. However, traditional means of employing these resources, especially for-profit entities might have to be modified to fulfill the Network's goal of deploying more efficient and increased water services in the region.

Regional cooperation on the protection of water resources

Considering the large proportion of shared river basins and aquifers between the countries in Northern Africa and Middle East, the coordination at transboundary and regional level is essential for the protection and sustainable use of these resources. The water dependence of Egypt, Syria, Kuwait, Jordan, Iraq and other countries in the region is very high, because they are reliant on water that has its source outside of their own territory.

In the aspect of water quality, the transboundary impacts are related mainly to the deterioration of quality due to overexploitation and transboundary pollution transport. Often the information on the water quality issues is not shared between the countries and regular data exchange is missing.

Regardless of the different policy frameworks, most of the countries in the region have approved national water resources plans or developed frameworks which contain elements of policy, in the form of strategy or master plans. Regional harmonization between such national water policies is needed in order to achieve full deployment of the IWRM approach.

Summary and conclusions

The water scarcity in MENA region, combined with increasing water demand for the population, agriculture and industries require enormous efforts to protect the available water resources, both in quantity and quality aspects. Deterioration of water quality has high social, economic and environmental costs.

The target of improving water quality by creating and integrated management approach including reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse by 2030 is highly relevant in MENA countries and need to be high remarked in the political agenda.

The investments in wastewater treatment and reuse address both the issues of water quality and closing the gap between demand and supply and increases the available resource. The already broad application of reuse of treated wastewater for irrigation proves the efficiency of this approach and helps to overcome the controversial public opinions. Adequate quality standards and control mechanisms have to be introduced in this regard, to safeguard the quality of agriculture production.

The agriculture and livestock sector continues to cause and form the major part of nutrient loads and pollution with pesticides. In the same time the arable lands are expected to further expand in order to meet the increasing food demand. Therefore, the reinforcement of sustainable land-use practices and adequate regulations on agrochemicals use are highly important of saving water and keeping the good quality of the resource.

Effective water quality monitoring programmes are required to have the adequate information of the status of water quality and to perform informed decision-making. The following needs are identified in relation to the water quality monitoring:

- Develop efficient monitoring networks, with smart selection of sites, based on river basin principle for surface waters and on contemporary hydrogeological data, for groundwaters.
- Capacity building, related to monitoring strategies and methods, data analysis and processing.
- Development of common approaches/frameworks in terms of data processing at national and regional levels.
- Improvement of the existing monitoring network by introducing new measurement, transmission and data processing technologies. Restore and maintain the existing water monitoring network before creating new monitoring points
- Establish relation with climate change
- Include data form the private sector

The feasibility studies, developed in the framework of Water SUM Project outline the needs of reinforcing legislation in the environmental aspects of water and wastewater and updating the water quality standards, based on the opinions, expressed by many interviewed experts.

As many of the main rivers, streams and aquifers in the region are shared between two or more countries, the need of improved transboundary cooperation in water resource protection is obvious. This include at first place a good communication between the countries that will ensure the exchange of data for implement coordinated efforts to prevent transboundary pollution.

There is a need of continuous efforts in raising public awareness on the values of clear natural waters and stimulating the behaviour change, to prevent waste dumping and pollution from households and farms, affecting the surface and ground waters.

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The present background document comprises three articles prepared by experts to address the topics of three MENA Water World Café 2017 working groups: Rethink before use (Group 1); Climate change and the water-waste cycle (Group 2); and Water quality management (Group 3).

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