Conference paper

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Water scarcity, water reuse, and environmental safety

Abstract: In the arid and semi-arid regions, being the most water-deprived regions of the world, water scarcity is the most pressing challenge. The dry climate and the effects of the global warming are leading to increased pressure on the meager water resources causing a rapid quality degradation of chronically depleted water resources, while the use and disposal of numerous biological and chemical pollutants endangers the water bodies to a degree that part of the resources are not safe to use for human consumption, posing a health risk to the population. The degradation of water resources is magnified by the fast-growing population and the increase in domestic and irrigation water demand, which is impossible to meet from available natural resources. Such adverse development is already apparent in the Near East region (Israel, Palestine, and Jordan) where the shared water resources are already in a deteriorated state unable to satisfy the basic needs. To satisfy current and future needs, a new water resources management strategy is suggested, aiming at the sustainable use of available water resources, supplemented by the development of water reuse and desalination of brackish groundwater and seawater, cautiously considering the associated health and environmental safety, as discussed herewith.

Keywords: desalination; environment; environmental chemistry; IUPAC Congress-44; Middle East; water quality; water reuse; water scarcity.

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Introduction

The Water Security Risk Index [1] indicates that 18 countries around the world are at 'extreme risk' of danger to their water security, of which, 15 are in the Middle East, where water resources are limited and unequally shared in time and space. The water scarcity on one hand and the increased demand on the other hand are complicating the management of water resources [2].

In the US, in the most water scarce states, the population is increasing at 2–3 times the national growth rate, coupled with an increase in irrigated agriculture and increased competition for water among urban, agriculture and the environment. While in other US states, water used for irrigation has decreased because of competition from other sectors and depleting water resources [3]. In Europe, in the intensively irrigated river basins in Southern Europe are experiencing water shortage and strict water demand management and conservation practices are applied in the urban and irrigation sectors including rationing and water trade.

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In India, the population reached proximately 1.21 billion in 2011, while rapid and largely unregulated industrial development is generating massive amounts of untreated toxic waste that end up in estuaries, lakes and landfills, endangering the water quality and health of the population, rendering water unfit for human consumption. In Africa availability of drinking water is of a great concern as the lack of it, deprives improvement of the social status of the population. It is obvious that the race between population increase and drinking supply and sanitation provision coverage will not be met by the deadline of the Millennium Development Goals (MGD), aiming to halve the population lacking these facilities by 2015 [4].

In the Middle East, the Israeli-Palestinian and Jordanian states, the annual volume of renewable water resources is <200 m^3/capita (cap) compared to about 800–1000 m^3/cap in neighbouring countries, 2500 in the UK, 3500 m^3/cap in France and 10 000+ m^3 in the US. In addition, poor conservation and inadequate treatment of point and non- point sources of pollution, including leachate of fertilizers, insecticides and human and industrial wastes into surface and ground water bodies have caused irreversible damage to some of the aquifers [6] and to the pollution of shared water resources due to trans-boundary movement of pollutants, fuelling ongoing political conflicts between the three parties [5].

The chronic stress of water as already observed in the various regions is associated with both the quantity and quality of water, affecting every aspect of life, from ecosystems and the environment, to food security and poverty. Due to very low availability, water has become a rare commodity unable to satisfy the aggregated demand of all sectors.

The worldwide problem is becoming more and more alarming each year due to:

- Population growth
- Urbanization and industrialization
- Increasing per capita demand
- Agricultural sector demand
- Misuse of water and pollution of existing resources, and
- The global warming.

These drivers are likely to continue to grow and to intensify as the non-climatic and climatic factors will progress [6, 7], magnifying the inevitable need for the development of non-conventional water resources to fill the gap between supply and demand. To provide safe and reliable drinking water to the world population, while considering human health and the environment as described in the following for the case study of the Middle East.

Israel, Palestine, and Jordan water balance: 2010–2040 (case study)

In this region, rainfall varies in quantity, intensity and distribution from year to year, while the continuous droughts of the recent years reduced drastically water availability, causing over exploitation of the aquifers and the use of fossil fresh and brackish water sources. In this context, water demand for a total population of 18 million (in 2010) reached 3000 million m^3/yr, of which the urban and agriculture consumption was 40 and 60 %, respectively. For a projected population of 30 million, in 2040, an increment of 3200 million m^3/yr will be required to reach a total amount of 6200 million m^3/yr [8].

Of this amount only 2600 million m^3/yr will derive from natural resources, the remaining 3600 million m^3/yr will be supplied from non-conventional sources, namely water reuse-1900 million m^3/yr and desalination of brackish and sea water-1700 million m^3/yr [8]. Irrigated agriculture is still the predominant consumer of water and will continue to grow to keep pace with the growing demand for food and poverty alleviation in the rural areas. Water allocated for irrigation will increase by about 1.4 billion m^3 to about 3.2 billion m^3, mostly from reuse of effluents.

Water scarcity and impact on water quality

The supply of 2.2 billion m^3 of natural water, in 2010, reflected a withdrawal in excess of the renewable resources by 0.5 billion m^3/yr. Monitoring of water resources and drinking water quality, checking for biological, physical, chemical and radiological contaminants indicates that the non-compliance rate with the drinking standards is due to excessive concentrations of nitrates (50 %), salinity (20 %) and organic pollutants (30 %) [9].

The Sea of Galilee (Lake Kineret) which extends on a surface area of 167 sq km, the operational volume is normally regulated between 209 and 213 m b.m.s.l., but due to the continuous drought of the recent years, the lake's water level has drastically dropped to its lowest levels below the permissible (red) lines, to 214.5 m b.m.s.l., 2 m in 2008, 2 m below the permissible (red) line, severely threatening the lake's ecosystems and water quality. In other water basins, the rivers that once supported rich aquatic and wetland ecosystems are now seriously depleted and polluted. The rivers which flow to the Mediterranean Sea and the Jordan River that once supported rich aquatic and wetland ecosystems have become seriously depleted and polluted.

The very low water level in water bodies and the higher concentrations of biodegradable organic material, in terms of Biological Oxygen Demand (BOD) and Chemical Oxygen demand (COD) may lead to eutrophication. Eutrophication is a worldwide problem and a large number of lakes are exposed to eutrophication, hindering many of their functions including the supply of drinking water, recreation, cultural and bird sanctuary.

Eutrophication is caused by the degradation of the organic material and excess discharge of nutrients, such as N and P, producing dense algal bloom that causes high turbidity, decreased Dissolve Oxygen (DO) and increased hypoxia in the deeper layers of the water body. Excessive production of planktonic algae, leads to oxygen deficiency, fish death, reduced biodiversity and the formation of the nitrogen fixing bacteria- cyanobacteria. The harmful algal blooms (Cyano-HABs) – blue green algae – emit foul odour and produce toxins which harm the ecological balance, indicating that the lake's natural "buffering capacity" may be in danger [10].

Anthropogenic sources also contribute to the presence of metals, but the degree of metal toxicity and bioavailability is related to water chemistry composition, including Dissolved Organic Carbon (DOC) pH, hardness, DO and also to other chemical and biological processes such as the redox state, chelation, complexation, digestion, prey and grazing by zooplankton, protozoan and algae grazing. Due to these processes, quantifiable differences in metal bioavailability elements are to be expected, although, assimilated elements are likely to be retained in surface water exerting a biological response, as was demonstrated for Fe by Sivan et al. [11] showing that photo-induced redox cycle of Fe is largely controlled by biological activity, while chemical photoreduction of Fe accounts for only a small fraction of the observed Fe(II) in the upper layers of the lake.

The diversion of the surface water flow although it was a necessity to meet essential water requirements, it has had an adverse impact on the aquatic systems, altered the hydrological cycle, eliminated the wetlands and reduced the biodiversity and the natural functioning of the aquatic ecological systems. It has also drastically affected the Dead Sea which has lost much of its surface area from 950 sq. km in the beginning of the twentieth century to the current 392 sq km, causing a rapid change in the ecological balance of this fragile eco-system and the surrounding oases and wetlands [12].

Similarly, the erratic rainfall and consequently the recharge of the aquifers and abstraction pattern have greatly altered the natural state of groundwater, leading to serious depletion of underground aquifers, with consequences for both short and long-term water quality. In addition, hazardous substances found in drainage and wastewater are discharged into natural water bodies, harming aquatic life exposed to excess nutrients, suspended particles, biodegradable organic material as well as emerging pollutants [13].

Discharge of inadequately treated effluent from municipal and industrial treatment plants, runoff from urban drainage and agricultural wastes, fertilizer and pesticide residues, leachate from landfills and sea water intrusion has rendered 15 % of the Coastal aquifer water unfit for drinking, because of high concentrations of nitrates and chlorides exceeding standard limits for drinking water. In Gaza Strip, nitrates and chlorides levels have exceeded the recommended WHO drinking water standards 45 mg/L NO_3 and 250 mg/L chlorides [14], while improper sanitation causes water borne diseases including cholera typhoid, dysentery diarrhoea, salmonellosis and hepatitis [15].

East of the Rift Valley, some groundwater aquifers, like Jafr Dhulia, were depleted in the 1970s and 1980s and others like Azraq and Agib basins are showing signs of fast depletion and increasing groundwater salinity [16]. The northeast aquifers: Sirhan, Hamad, and Azraq basins are classified as brackish water. Salts accumulation have also occurred in the Jordan Valley, the Dhuleil area east of Amman, and elsewhere. Whereas, high concentrations of nitrates, phosphates and salinity were observed in Khirbet es Samra (Amman-Zarka area), Mafraq, Agaba and Ramtha areas, up to 3–4 times of the natural level. In the springs around Amman, the nitrates content has increased to 60–72 mg/L compared to a natural concentration of 15–20 mg/L. In places such as Zarka Municipality, the water well is safe to use only after mixing with better quality water to reduce the salt and nitrates content.

To comply with stringent drinking water quality standards, water treatment plants are being built to reduce the turbidity level to <1 Nephelometric Turbidity Unit (NTU) (the National Water Carrier Central Treatment Plant). Also, many point-of-use (at the tap) and point-of-entry (at the house) treatment systems, including reverse osmosis, ion exchange, and distillation systems are used throughout the region to reduce organic and inorganic contaminants [17].

Environmental impact of non-conventional water resources

Meeting water supply needs of the expanding world population cannot be met by further construction of new dams and canals and other infrastructure, a situation that is further complicated by the changes of the hydrological cycle, the reduced quantities and timing of precipitation and increasing rate of evapotranspiration [18]. Additional water supply can only be met through a mix of improved demand management, innovation, conservation and regulation of available resources coupled with the development of non-conventional resources supplemented by water transfer and import.

Of the various options, the use of brackish water, recycling of wastewater and desalination emerge as the major solutions to fill in the widening gap between demand and supply, providing a realistic outlet to the severe regional water scarcity, as follows.

Water reuse

Reuse of municipal effluents is necessary to create new water supplies and maintain in-stream flows and to evolve non-potable potable applications, classified as indirect or direct use [19]. In regions with stressed water resources, in particular, indirect and direct potable reuse are already playing an increasing role in water supply. Sewage comprises 70 % of the consumed water and reuse of effluents has already reached 70 %, in Israel, 12 % in Spain, 9 % in Australia and Italy and 5 % in Greece.

Water reuse is becoming commonplace, either due to water scarcity or due to the high cost involved in pumping and treating water, while the paradigm of collecting, treating and disposal of wastewater is scrutinized. The majority of the urban water consumption (75–85 %) is returned to environment. Therefore, the aim is to capture, restore to potable quality and reuse the industrial and municipal wastewater, providing:

- A reliable treatment to meet water quality requirements for the intended reuse,
- Protecting public health, and
- Gaining public acceptance

Wastewater constituents

Wastewater contains a wide variety of contaminants and pathogens and has a very high loading of organic matter and inorganic micro-pollutants loads. The occurrence, fate and effects, regarding human health and ecological impacts of these contaminants have to be better understood.

- Wastewater constituents include:
- Physical: thermal and solid properties
- Biological: pathogens, microbial and antibiotics
- Chemicals: pH, alkalinity, ions, metals, fats, oils and grease (FOG), organics and nutrients and micro nutrients.

In addition to the diversity of chemicals found in domestic, commercial, industrial and agricultural waste, there are other biologically active chemicals that are inadvertently produced during the disinfection of drinking water. The reaction of free chlorine, ultraviolet light and ozone with natural organic matter produces by products such as Trihalomethanes (THM) and halo-acetic acids. While, biologically active endocrine disruption, such as human and veterinary medicinal and personal care products termed Endocrine Compounds (ECs) or Pharmaceuticals and Personal Care Products (PPCPs) are new pollutants of a great concern.

The EC degradation produces transformation products in the environment having potential impact on aquatic and terrestrial ecosystems and human health [20]. These compounds originating from municipal Wastewater Treatment Plants, manufacturing facilities, hospitals and healthcare facilities are in the focus of environment research in various parts of the world, extending beyond the investigation of polychlorinated biphenyl (PBC), dioxins and pesticides [21, 22]. Classes of biological inorganic chemical and ECs associated with wastewater reclamation and reuse and which are thought to be important to human and ecosystems health were listed by National Research Council [18]. All of which, must be removed or transformed to harmless compounds to reach the permissible levels of total suspended solids, BOD, faecal coliforms, and residual chloride.

Wastewater treatment systems and quality standards

Environmental safety and health impacts of wastewater have long been a matter of concern regarding the potential threat to landscape, agricultural workers and to crops and soils irrigated with wastewater effluents [23]. Accordingly, extensive investments are made in the construction of domestic and industrial wastewater treatment plants able to produce treated effluents meeting stringent quality standards and public health regulation for reuse and disposal of effluents to land and or water bodies.

Nowadays, a secondary treatment stage of wastewater has become a vital component of wastewater treatment. A standard treatment process for municipal wastewater includes a primary treatment followed by a biological activated sludge system, combining an aeration stage for the degradation of the organic load, using suspended microbes to degrade organic nutrients, and a sedimentation stage designed to separate the solids and the liquid fractions. Recently, membrane biological reactors (MBR) which combine suspended biomass with immersed microfiltration or ultrafiltration membranes are used to increase the process efficiency. With less chemicals and energy consumption, an MBR produce high quality effluent, suitable for unrestricted irrigation and other industrial applications.

The biological (secondary) treatment is complemented with additional physical and chemical treatment processes (tertiary treatment), such as the Soil-Aquifer Treatment (SAT) process which is applied in Israel to treat the Dan Region wastewater. The wastewater treatment plant which serves the Tel Aviv Metropolitan area (130 million m^3/yr or about 25 % of the countrywide wastewater (2012) incorporate the SAT to infiltrate the secondary effluents through sand layers into a confined aquifer where they are subjected to further physical, biological and chemical processes [24]. In a different wastewater treatment system, serving the Haifa Region (30 million m^3/yr) and other wastewater treatment plants serving small and medium towns, the secondary effluents are detained in about 300 reservoirs, ranging between 8 and 0.5 million m^3 and a total volume of about 175 million m^3 [25].

The upper and the underground storage of the secondary effluents for several months greatly improves the physical and chemical characteristics of the effluents to a level that complies with the quality standards in force for unrestricted irrigation [26], as shown in Table 1.

Table 1 Quality of effluents, before and after underground or surface storage compared to quality standards for reuse in irrigation and disposal (in mg/L).

Parameter	Haifa – Kishon surface reservoir water quality		Dan Region WW recharge system water quality		Effluents quality standards Inbar 2005	
	Inlet	Outlet	Inlet	Outlet	Unrestricted Irrig. Use	Discharge to water bodies
pH	7.4	7.5	7.9	7.2	6.5–8.5	7–8.5
BOD	29	4	18	8	10	10
COD		40	80	59	100	70
TSS		11	21	9	10	10
Nkeld	30.7	9.5		9	25	10
TP		2.1	3.8	1.9	5	1
Chlorides	364	301		250	250	400
EC	1.97	1675		2425	1.4	–
MBAS		0.1	1.3	0.3		
DO		4.9	1	5		
f. Coliorms		0	2200	25		
Boron	0.25	0.24	0.2	0.16	0.4	–
Hg					0.002	0.0005
Cd		0.0002	<0.005	<0.002	0.01	0.005
Cu		0.012		0.004	0.2	0.02
Pb		0.002	<0.008	<0.002	0.1	0.008
Cr		0.003		0.004	0.1	0.05
Fecal Coliform counts					10	200
Residual Chlorine					1	

Source: Ministry of the environment web Site, 2011 and Inbar, 2005

The data indicate that the resulting effluent quality is suitable for discharge to aquatic systems and or for non-restricted irrigation and other industrial applications.

Environmental impact of wastewater reuse

Stringent regulations govern the quality of effluent discharged to water bodies, while public policies promote water reuse rather than the costly development of additional water resources with considerable environmental toll and capital expenditure. In this context, the use of the effluents for agricultural irrigation diverts the freshwater from irrigation for use by the other sectors, yielding tangible benefits to the municipalities, the farmers and the environment. The substitution reduces the pressure on scarce water resources, while contributing to the preservation of the green space and elimination of effluents discharge into water courses, avoiding the pollution of streams, aquifers and the sea.

However, using effluents for irrigation may be associated with increased salinity of the irrigated soils [27] and possible accumulation of persistent endocrine substances in the ecosystem [28]. Such substances were detected in fish exposed to wastewater effluents dominated streams [29, 30] and in drinking water distribution systems [31, 32]. However, the presence of endocrine substances in aquatic systems and their adverse impacts on health and living organisms is inconclusive and needs further investigation, taking into consideration that the numerous compounds potentially present in the effluent impacted water, the extent of in stream dilution, hydraulic residence time and in-situ attenuation processes. Under such circumstances, evaluating the impact of endocrine substances seems to be an impossible task because of lack of data [33] and conclusive evidence about their accumulation in soils and the likely effect on the environment and human health [34].

Desalination

Desalination is universally recognized as an attractive and realistic option to produce fresh water for drinking purposes, to satisfy domestic water demand, especially where other alternatives to augment water supplies have grown more expensive, making desalination an ideal solution able to compete with other "conventional" water resources. As such, in many countries, in arid regions and elsewhere, thousands of desalination plants were installed to supply drinking water for the rapidly growing population. In the context of Israel, Palestine, and Jordan, brackish groundwater and sea water desalination is already playing a significant portion of the supplied water. Reverse Osmosis (RO) process is used to build flexible and modular plants to desalinate brackish and seawater to produce more than 450 million m^3/yr in large plants and in medium and small domestic desalination units, producing 100–200 L/day [17]. More plants are under construction or planned to gradually increasing sea water desalination to a total of 1.6 billion m^3/yr by 2040 [8].

Desalination process

A typical desalination plant is a large factory and extended infrastructure sited on or close to a sea shore and includes a sizable surface or deep sea inlet intake, pumping feed water with total dissolved solids of up to 50 000 mg/L and at a varying temperature of 10–32 °C. The RO process includes a pre-treatment stage consisting of multimedia and cartridge filters before feeding the raw water into the RO vessels. The vessels contain high flux and low and high salt rejection membranes in stages to produce a permeate (45 % of the inlet water) containing 20–100 mg/L of chlorides. Energy recovery devices are incorporated to recover 80–85 % of the waste energy released during the depressurization of the residual brine before discharge back to the sea. The brine (55 % of the inlet water) is returned back to the sea while the anti-scale, fouling prevention chemicals and anti-corrosion products are treated before disposal.

Environmental impact of desalination

Desalination plants may affect the environment in many different ways, including coastal land use and the marine environment due to the installation of deep sea intake and outfall. The use of cleaning chemicals, the excessive energy consumption and the associated greenhouse gas emissions and the disposal of the concentrated saline waste are all a threat to the environment. Other locally impacts are associated with the siting of the plant and seawater intake which can affect the biodiversity if situated in ecologically sensitive coastal areas. The possible entrapment of aquatic creatures in the seawater intake and the build-up of the chemicals can damage the fragile marine ecosystem and threatens marine life.

Quantity wise, a desalination plant producing 100 MCM/yr of desalinated water discharges up to 535 tons/yr of Fe and 40 tons/yr of P and 55 MCM/year of concentrated brine containing 73.5 g/L of salts, double the background level. The brine increases the background salinity level by 4.9 % within 350 m from the outfall, gradually decreasing to 1 % at a distance of 3500 m from the outlet. The RO process specific energy consumption (SEC) is 2.91 kWh/m^3, out of a total plant average energy consumption of 3.5 kWh/m^3 and the Emission of CO_2 amounts to 286 g/m^3 [35].

The RO technology is well established and clearly the least energy intensive [36]. However, the energy consumption, the associated greenhouse gas emissions and other environmental impacts are still significant, fuelling the general water industry's perception that seawater desalination industry is inadequately viable [37].

To alleviate some of adverse impacts, off-shore seawater intake are built as a submerged structure with slow intake velocity to avoid interference with the aquatic life. The pre-treatment of the raw water is carried out with low level of chlorination or substituted with mild biocides. The filter backwash waste stream is treated to remove the suspended solids that are disposed at a landfill. Also, the use of alternative energy to reduce gas emission is also considered.

At the desalination stage, improved membranes, having a longer life expectancy, higher flux and higher surface area per unit volume are being introduced. Further advances are expected in the RO process including the use of nano-membranes, carbon nanotubes, membrane distillation, forward osmosis and ion concentrate polarization, while hydraulic turbo charger and positive displacement pistons will increase further the waste energy recovery to 90–95 % [38, 39].

Outfalls for the discharge of the brine are designed where possible in close location to a power plant outfall, allowing to blend the brine with cooling water discharged from power plant or built with diffusers designed to achieve a rapid mixing with the entire water column, thus avoiding the sinking of the dense brine, resulting in lower salinity and lower temperature. The issue of concentrate management is more crucial for inland desalination plants with limited area to build evaporation ponds and in which techniques to reduce the volume of the concentrates are required if costly zero liquid discharge (ZLD) is to be avoided [40].

Conclusions

The excessive exploitation of water leading to severe depletion of the world water resources, coupled with the continuous increase in water demand and competition among users are all the cause of concern regarding the state of current and future world water resources, as well as the impact of the global warming and the anthropogenic pollution of resources on water availability. Under such conditions it is quite certain that the natural water resources would not be able to fill the gap between water demand and water supply.

Non-conventional water sources would be required in large quantities to satisfy the growing need for the urban consumption and water Of the water consumers, irrigated agriculture is the major consumer and will continue to be the predominant water user to keep pace with the growing demand for food and poverty alleviation in the rural areas, adding to the instrumental value of irrigation in maintaining environmental services and ecosystem resilience. However, farmers have to adapt to the water scarcity situation, to recognize the competitive needs of the other sectors and the growing cost of obtaining additional water. While economic incentives and improved infrastructure will be required to encourage farmers to switch from potable water to alternative water sources, as well as to use improved irrigation techniques and adjusted cropping systems.

In accordance, it is essential to adapt to the future potential changes and evolve a new water management strategy which will consider the rise in temperature, the change in precipitation pattern and alteration of the amount and distribution of rain and their impact on the availability of water resources, to feed the world. A sustainable use and preservation of natural resources employing innovative water resources management tools such as IWRM [41] will be required to define viable and appropriate solutions for allocation of water resources between the various users and in parallel to accelerate the development and use of non-conventional water resources-water reuse and seawater desalination.

Wastewater is a source that is continuously increasing with the increase in urban water demand and therefore the need for it integration as an important part of the water cycle. Driven by water scarcity and climate change, water reuse will be increasingly practiced worldwide to augment river flows, restoration of wetlands and dried streams, as well as a viable and preferable resource of water for irrigation of agricultural crops. Advanced wastewater treatment systems will generate effluents highly suitable for unrestricted irrigation and other non- potable uses. However any safety impacts associated with water reuse on human and environment have to be fully clarified including perception and attitude towards water reuse by some societies in order to put in place the necessary mitigation measures [18].

Possible soil salinity and built up of salts in the irrigated soils [26] and the impact of new chemicals that are being introduced into the society at an ever increasing rate shall be addressed. The health impact of exposure to chronic low doses of complex mixtures of endocrine and advanced nano-compounds that can act, in an additive manner and impact the environment shall be investigated, as well as to prioritize pollution control efforts to process domestic, industrial and agricultural waste before use [34].

As for desalination, water extraction from brackish groundwater and desalinated sea water will increasingly become a significant reliable and efficient water source, providing unlimited manufactured water for domestic use and at the same time, adopting mitigation measures to protect environmentally sensitive coastal areas and the marine environment.

Such development is a "game changer" for water managers to opt for water production as well as on the decision on the location, quantity and staging of development, to satisfy the needs. Much has been achieved in the recent years but further significant improvements in the design and operation of non-conventional sources are anticipated as the result of dedicated research and optimization systems that are being conducted [37, 38], aiming for accessible and practical solution for the water scarcity in the world arid regions facing water shortage.

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References

[1] Maplecroft (2011). Climate change and environmental risk, http: (//maplecrof.com).
[2] World Health Organization. Global water supply and sanitation assessment 2000 Report. WHO/UNICEF Joint Monitoring Program for Water Supply and Sanitation. Geneva (2008).
[3] J. Kenny, N. Barber, S. Hutson. *US Geological Survey Circular 1344*, Reston, VA. (2009).
[4] S. Ahuja. In *Comprehensive Water Quality and Purification*, S. Ahuja (Ed.), Volume 1, pp. 1–10, Elsevier, Amsterdam (2014).
[5] M. C. Larsen. In *Comprehensive Water Quality and Purification*, S. Ahuja (Ed.), Volume 1, pp. 11–20, Elsevier, Amsterdam (2014).
[6] J. El Kharraz, A. El-Sadek, N. Ghaffour, E. Mino. *Proc. Eng.* **33**, 14 (2012).
[7] M. Zeitoun, C. Messerschmid, A. Shaddad. *Groundwater*, **47/1**, 146–160 (2009).
[8] Y. Shevah. In *Comprehensive Water Quality and Purification*, S. Ahuja (Ed.), Volume 1, pp. 40–70, Elsevier, Amsterdam (2014).
[9] Israel Hydrological Service. Israel Water Authority, Ministry of infrastructure Report, Tel-Aviv, Israel (2008), (In Hebrew).
[10] D. Merkel, T. Zohari, S. Sukenik, A. Sea of Galilee management under low water level conditions and impact on water quality report. Israel Water authority, Ministry of Infrastructure, Tel-Aviv (2008). (In Hebrew).
[11] O. Sivan, Y. Erel, D. Mandler, A. Nishri. *Geochimica et Cosmochimica Acta* **62**, 565 (1998).
[12] A. Malkawi, I. Husein. *Proceedings of the Frontiers of Chemical Sciences V: Research and Education in the Middle East: Malta Conferences Foundation*. Paris, France (2011).
[13] A. Abramson, A. Tal, N. Becker, N. El-Khateeb, L. Asaf, L. Assi, E. Adar. *Int. J. River Basin Management*, **8** (1), 39 (2010).
[14] Y. Abu Maila, I. El-Nahal, M. Al-Agha. *Environ. Geol*. **47**, 84 (2004).
[15] EWASH-*Emergency water, sanitation and hygiene group*. EWASH Report (2012).
[16] E. Salameh, H. Bannayan. *Water Resources of Jordan: Present Status and Future Potentials*, Amman, Jordan: Friedrich Ebert Stiftung and Royal Society for the Conservation of Nature (1993).
[17] A. R. Tamimi, N. Abu Shbak. *Qualitative use of home reverse osmosis filters of some areas in Gaza Strip. Jerusalem: Palestinian Hydrology Group for Water and Environmental Resources Development*. Report. (2011).
[18] National Research Council (NRC) Issues in potable reuse – The viability of augmenting drinking water supplies with reclaimed water. Washington, DC: The National Academy Press (2008).
[19] National Research Council (NRC). *Water reuse: Expanding the Nation's water supply through reuse of municipal wastewater*. The National Academy Press, Washington, DC. (2012).
[20] L. B. Barber. In, *Comprehensive Water Quality and Purification*. S. Ahuja (Ed.), Volume 1, pp. 245–266, Elsevier, Amsterdam (2014).
[21] T. A. Ternes, H. Joss. *Siegrist Environ. Sci. Technol.* **38**, 393A (2004).
[22] G. G. Ying, R. S. Kookana, A. Kumar, M. Mortimer. *Sci. Total Environ.* **407**, 5147 (2009).
[23] H. I. Shuval, Y. Lampert, B. Fattal. *Water Sci. Technol.* **25**, 15 (1997).
[24] N. Izeckson. *Dan Region Wastewater Treatment and Reclamation-Plant Operation Report*- 2011. Mekorot, Tel-Aviv (2012).
[25] Israel Ministry of the Environment. (www.sviva.gov.il/environment. (2011), (in Hebrew).
[26] M. Inbar. *Ministry of the Environment Report*, Tel-Aviv, Israel (2005), (in Hebrew).
[27] G. Levi, P. Fine, D. Goldstein, A. Eizencot, A. Zilberman, A. Hazan, Z. Grinhouse. *Water Eng.* **86**, 38 (2013) (in Hebrew).
[28] A. M. Vajda, L. B. Barber, J. L. Gray, E. M. Lopez, A. M. Bolden, H. L. Schoenfuss, D. O. Norrisl. *Aquatic Toxicol.* **103,** 213 (2011).
[29] L. B Barber, A. M Vajda, C. Douville, D. O. Norris, J. H. Writer. *Environ. Sci. Technol.* **46**, 2121 (2012).

[30] M. J. Focazio, D. W. Kolpin, K. J. K. Barnes, K. K. E. T. Furlong, M. Y. Meyers, S. D. Zaugg, L. B. Barber, M. E. Thurman. *Sci. Total Environ*. **402,** 201 (2008).
[31] M. J. Benotti, R. A. Trenholm, B. J. Vanderford, J. C. Holady, B. D. Stanford, S. A. Snyder. *Environ. Sci. Technol.* **43** (3), 597 (2009).
[32] L. B. Barber, S. H. Keefe, G. K. Brown, E. T. Furlong, J. L. Gray, D. W. Kolpin, M. Y. Meyers, M. W. Sandstrom, S. D. Zaugg. *Environ. Sci. Technol.* **47**, 2177 (2013).
[33] A. B. A. Boxall, M. A. Rudd, B. W. Brooks, D. J. Caldwell, K. Choi, S. Hickman, E. Innes, K. *Environ. Health Perspect.* **120** (9), 1221 (2012).
[34] D. J. Lapworth, N. Baran, M. Stuart, R. S. Ward. *Environ. Pollut.* **163**, 287 (2012).
[35] Desalination and Marine Environment in Israel, Marine Monitoring Programme, Marine and Coastal Environmental Div., Ministry of the Environment.
[36] A. Yechiel, Y. Shevah. *Desalination and Water Treat.* **46**, 304 (2012).
[37] J. C. Schrotter, S. Rapenne, J. Leparc, P. J. Remize, S. Casas. *Comprehensive Membrane Sci. Eng.* **2**, 35 (2010).
[38] M. Elimelech, W. A.Phillip. *Science* **333** (6043), 712 (2011).
[39] Y. Oren, E. Korngold, N. Daltrophe, R. Messalem, Y. Volkman, L. Aronov, M. Weismann, N. Bouriakov, P. Glueckstern, J. Gilron. *Desalination* **261** (3), 321 (2010).
[40] V. Namboodiri, N. Rajagopalan. In *Comprehensive Water Quality and Purification*, S. Ahuja (Ed.), Volume 2, pp. 98–119, Elsevier, Amsterdam, (2014).
[41] H. Hötzl. *Proceedings of the 7th International Conference*, Limasol, Cyprus (2009).