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Water reuse integration in the holistic water cycle

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Abstract

Wastewater reclamation and reuse (WRR) is an emerging water generation tool for combating water stress. The objective of this paper is to develop a conceptual approach which will pave the way to WRR sustainable integration in a multi-resources regional or local system. For that purpose, a holistic Water Cycle Concept has been developed. The water cycle is divided into two partly overlapping circles: (a) Potable production circle, consisting of natural surface and ground water, desalinated water and rainwater, and (b) Recycled water circle, mainly for irrigation, industrial uses and streams rehabilitation. Greywater and direct potable use are developing options. The resulting water quality encounters are being analyzed, e.g. excess boron and magnesium deficiency in effluents originated from domestic desalinated water use are both detrimental to crops, lack of magnesium also endangers soil stability and food nutrition value. Innovative technologies for complementing the holistic approach have been developed, e.g. minerals recovery from seawater and brine, electrochemical and natural processes hybridization for nutrients and hormones removal and biofilms prevention by nanoparticles injection. In conclusion, holistic water cycle approach enables management of water quality challenges and directs innovative solutions that protect food resources and eliminate long term threats to public health.

Keywords: Water reuse; water cycle; water treatment; desalination; innovation

1. Introduction

The natural water resources cannot support the growing demand for both urban and rural areas around the world (Global Water Partnership (2012); some of them suffer from recent draught events and years of groundwater over-pumping. The most practical solution to that is non-conventional water resources development for different domestic, agricultural and industrial uses. Agriculture is commonly considered as the best and largest consumer of reused water, where impediments such as large capital investments, negative public perceptions and lack of regulatory frameworks prevent WRR from reaching its full potential (Sheikh et al., 2018).

Wastewater reclamation and reuse is an emerging water generation tool for combating water stress. That is in addition to seawater and brackish water desalination, rain water harvesting and water conservation. Since seawater and wastewater quantities are basically endless, and since the cost of desalinated water have considerably dropped to affordable levels, inadequate water quality and water transport energy are mostly the limiting factors. The objective of this paper is to develop a conceptual approach which will pave the way to WRR sustainable integration in a multi-resources regional or local system.

2. Holistic Water Cycle Concept

Looking at the big picture of the water market in the 21st Century, it can be concluded that quite a revolution is taking place - revolution of the water cycle. The classic natural cycle becomes more complex, an integration of natural and artificial water. This can be illustrated schematically as presented in Figure 1. Two circles may be observed here:

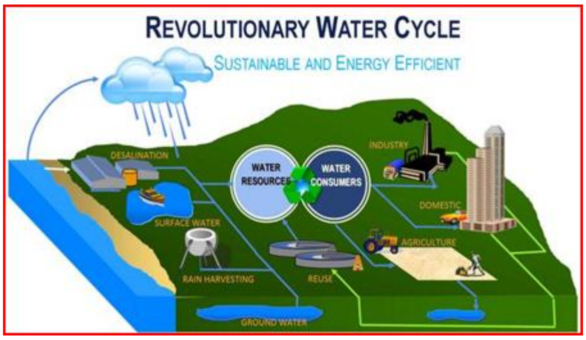

Figure 1. Israel‘s holistic water cycle

(1) The left circle describes the production of freshwater, consisting of natural sources accumulated in surface and sub-soil water reservoirs, desalinated water and harvested rainwater collection and treatment systems. This circle supplies quality drinking water primarily to the city and some to agriculture and industry.

(2) The right circle is a circle of recycled water: the wastewaters are collected and treated. The treated effluents are supplied for agricultural irrigation, city parks, industrial uses and streams rehabilitation. There could be smaller scale circuits, implemented in some industrial parks and plants which recycle their own pre-treated wastes, thus saving on paying for incoming water on one hand and sewer discharge fees on the other. Greywater reuse is a potential additional water circuit, not widely developed yet. Direct potable use is a developing option.

3. Effluent Quality Challenges and Solutions

Figure 2 depicts a variety of water quality challenges characterizing the water cycle described above. The drinking water quality, plus additional components resulting from its use, eventually dictates the quality of the wastewater generated by the water consumer. That

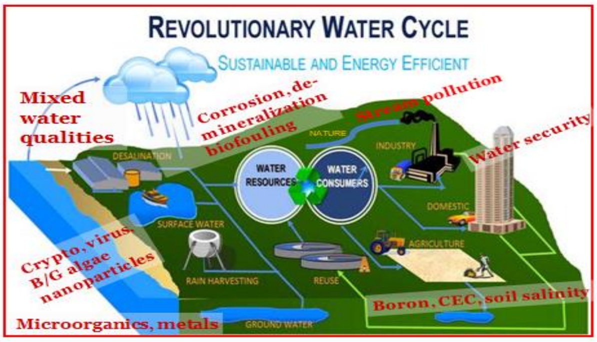

Figure 2. Water quality challenges and Drivers

quality impacts down the road on the treatment plant, the effluent quality it produces and surrounding environmental components. e.g. the boron and magnesium existing in seawater: while desalination helps significantly by reducing effluent salinity, boron passes through RO membranes and magnesium is completely removed by them. Effluents originated in desalinated water use stay desalinated all the way to the irrigation field. Access Boron concentration is detrimental to crops and lack of magnesium is detrimental to both crops and soil stability (SAR) (Lahav et al, 2010), as well as affecting food nutrition value. Other contaminants in the effluents which are not affected by treatment or transport processes may reach natural water sources and penetrate to the water classic cycle. Water quality challenges are numerous; some important ones can be assembled in few categories as follows: (a) Tertiary effluents - Boron, salinity, pharmaceuticals ((Paltiel et al., 2016), NPs (Ma et al., 2016); (b) Direct potable reuse - biofouling, corrosion, boron, minerals deficiency in product water, and (c) Sludge and brine management. Innovative technologies for complementing the holistic managerial approach have been developed, including remineralization of desalinated water by minerals recovery from seawater and brine (Penn et al., 2009), electrocoagulation-flocculation for particle separation and membrane pretreatment, hybrid of electrochemical and natural processes for nutrients (Adin, 2018) and hormones removal, biofilms formation prevention applying nanoparticles (Dror-Ehre et al., 2012) and implementation of reversible flow membranes.

4. Conclusions

Holistic water cycle approach enables management of water quality challenges and directs innovative solutions that protect food resources and eliminate long term threats to public health. Holistic interpretation of the water cycle is necessary to define the water reuse integration, challenges and solutions in the multiple-resources systems of this century. Planning should be assisted by managerial decisions supported by research and development of sustainable technologies.

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