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Desalinated drinking water in the GCC countries – The need to address consumer perceptions

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ABSTRACT

The Gulf Cooperation Council (GCC) countries consist of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates. These countries depend mainly on seawater desalination to meet their water needs. Although great emphasis is given to characterize desalinated water for its physicochemical and microbial properties, e.g. presence of metals, other organic contaminants and for bacteria, sensorial characteristics including smell, taste and color have not received the same attention. This is possibly attributed to the fact that inhabitants of GCC States do not use desalinated tap water for drinking consumption, rather they depend on locally produced or imported bottled water where color, taste and odor are not problematic. To address the consumer needs and perceptions of drinking desalinated water in GCC countries, water quality standards and guidelines, should respond to the public concern about other sensorial characteristics (organoleptic properties) including taste, odor, and trigeminal sensations. Often the root causes of color and smell in water are attributed to the presence of organic and inorganic contaminants and to bacterial growth which is frequently accompanied by the production of metabolites and byproducts that are obnoxious. The unpleasant sensorial problems associated with desalinated drinking tap water may constitute the driving force for most people in GCC countries to depend on bottled water. To encourage people in the GCC countries to consume desalinated tap water, it is essential that water testing include measurements of physicochemical properties, biofilm presence and organoleptic parameters to improve overall water quality. This review highlights the contribution of organoleptics for consumers of desalinated tap water. It extends water quality research to be addressed by standards for organoleptic parameters in desalinated drinking water. Accordingly, consumer awareness and outreach campaigns should be implemented to encourage people to drink tap water in the GCC countries.

1. Water situation in the GCC countries

According to prior studies and reports, the GCC countries have more than 55% of the world desalination plants, followed by North America (17%), Asia (10%), Europe (10%), Africa (6%), Central America (1%) and the rest of the world of (1%) (Elimelech and Phillip, 2011; Mezher et al., 2011; Saif, 2012). As freshwater resources become scarcer, the GCC countries, like other regions in the world, are increasingly "manufacturing" drinking water from seawater desalination or demineralization (Shomar, 2013). In the last decade, worldwide production of desalinated water has increased dramatically, from about 32 million m^3/day in 2001 to nearly 75 million m^3/day in 2013, and the production capacity is expected to reach 120 million m^3/day by 2020 (Shomar, 2013). Fig. 1 shows distribution of desalination plants in the eastern part of the GCC region (Lattemann and Höpner, 2008).

The severe water shortage in the region is also associated with climate change. According to Pal and Eltahir (2015), future temperatures in the GCC region are projected to exceed a threshold for human adaptability. In the past, these countries adopted national strategies to provide their citizens with clean water for the period 2000–2010 via a massive seawater desalination program. Today desalinated water accounts for more than 60% of the potable water supply in the GCC region (Darwish et al., 2013).

A recent study by Rowell et al. (2015) demonstrated that bottled water consumption is prevalent in most of the GCC countries. For example, the bottled water market in Qatar includes both domestically produced desalinated brands as well as imported natural and mineral water varieties. Consumption of bottled water, or other non-tap alternatives, is problematic because such a resource is costly, generates waste, and neither sustainable nor healthy.

Minerals can give water its natural flavor and can add salty and a sweet or a bitter taste to water that are responsible for much of a

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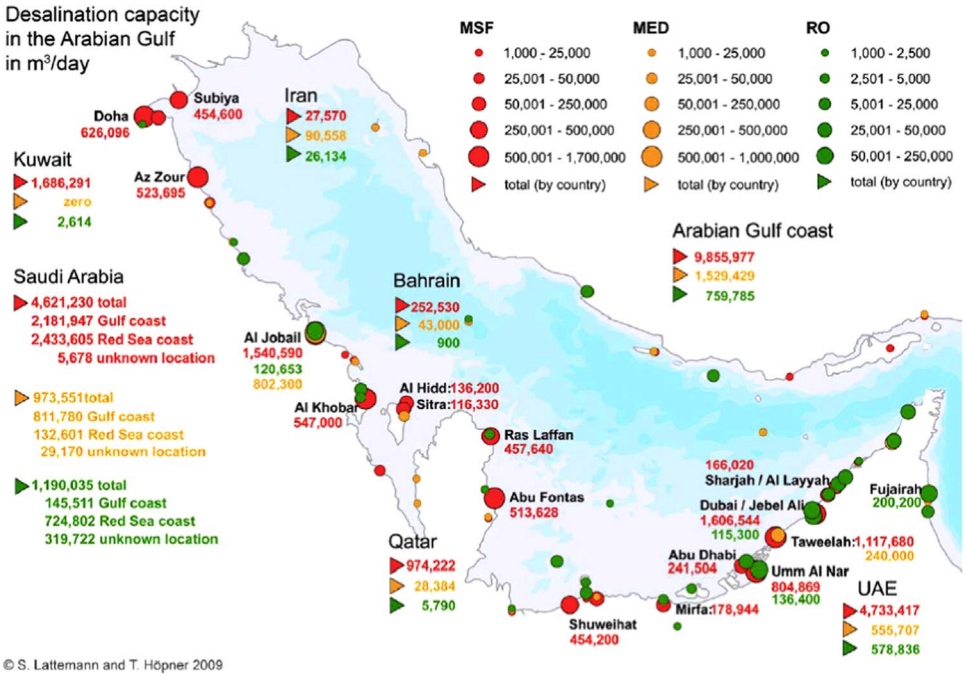

Fig. 1. Distribution of desalination plants in the eastern part of the GCC region.

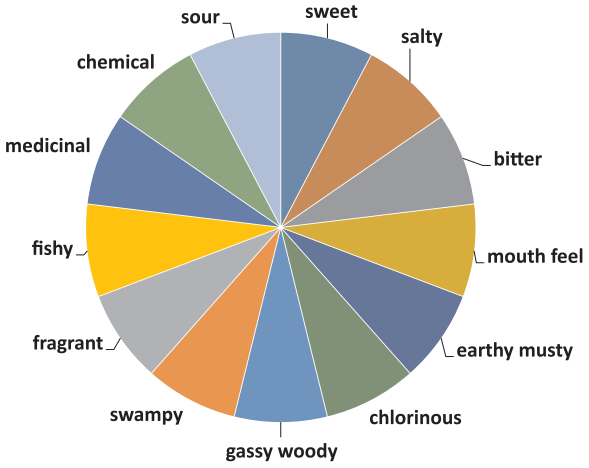

Fig. 2. Drinking water flavour wheel (adapted from Mallevialle and Suffet, 1987).

waters' "mouth feel". Surface waters are usually saturated with dissolved oxygen (DO), have higher microbial, organic matter (OM) and particulate contents (turbidity), and experience temperature variations from warm to near freezing (Marcussen et al., 2013). Groundwater typically maintains a constant cool temperature but contains a relatively high mineral content, with fewer microorganisms and turbidity (Whelton et al., 2007). As a consequence, waters come in many "natural" flavors to which individuals become habituated. For example, Mallevialle and Suffet (1987) reported and documented more than 13 different flavors for drinking water (Fig. 2). In addition, some flavors can be reduced or increased by the use of disinfectants (Kitazawa, 2006). By contrast, desalination processes remove most of the compounds that give water its natural flavor. Although minerals are often put back into treated water to minimize the corrosion of the distribution system infrastructure, questions such as how to re-balance the mineral content in order to restore taste and health benefits remain to be answered.

While minerals are known to be vital for good nutrition, the optimal levels necessary to maintain "good" taste or improve health in desalinated water are still unclear. The public interest and concern questions whether the composition of the "manufactured" water has positive or negative health effects. Although desalinated (or demineralized) water is locally marketed as a very pure product, there are potential negative effects to human health (WHO, 2011a).

From regulatory and public health perspectives, desalination is a relatively new source for potable water supply in most countries, meaning that health and environmental policies, regulations, and guidelines are evolving. Rapid growth in desalinated water production worldwide is necessary, indispensable and provides a safe, reliable, alternative water source which is increasingly affordable (Dawoud, 2005; Dolnicar and Schafer, 2009). However, public perceptions of desalinated water are becoming increasingly skeptical about existing programs, policies and legislation, as well as water quality and management programs. Public awareness and skepticism on the safe use of desalinated water can be improved by ensuring that existing monitoring and management programs are supported by credible scientific evidence (Nriagu et al., 2017). The present critical review will thus analyze water desalination technologies and issues associated with water consumption in the GCC countries including Qatar to ensure that water quality is covered by national standards in line with WHO Guidelines. We will identify research gaps needed to further our understanding of possible health outcomes related to consumption of desalinated water how to improve consumer perception using experimental and scientific evidences.

2. Desalination technologies in the GCC countries and public perception of quality of desalinated tap water

Currently, 27.7 Million m^3/d (Mm^3/d) of potable water is produced by thermal desalination (Fig. 1), which accounts for 31% of all installed desalination capacity in the world. Approximately 75% of all thermal desalination plants are located in the Arabian Peninsula, where Saudi Arabia produces 12.9 Mm^3/d followed by the UAE of 7.8 Mm^3/d. The most common thermal desalination plants in the GCC region are the Multistage Flash (MSF), the Multi-Effect Distillation (MED) and Vapor Compression (VC) installations (Darwish et al., 2013). Thermal desalination methods are implemented mostly within the GCC region due to the availability of oil and gas (the backbone of the economy). Most of Qatar's power plants are hybrid electricity-water plants, where heat from combustion is used for thermal desalination. The MSF desalination technology, in which water is removed from seawater by distillation in