CHAPTER

7

An overview of Kuwait's water resources and a proposed plan to prevent the spread of the Novel Corona Virus (COVID-19) pandemic through Kuwait's water supply facilities and groundwater system

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7.1 Prelude

Since March 2020, Kuwait has been affected by the COVID-19 pandemic that is still raging in the country despite all precautionary measures adopted by the Government of Kuwait. As a forward-looking country that always strives to investigate the underlying scientific reasons of the problems facing the country and to implement the latest technological innovations and discoveries to mitigate those problems, the Kuwait Government, through the different ministries and public institutions, have planned to initiate studies on different ways the virus spreads in a population and preventive actions that can counter it.

This chapter presents an overview of Kuwait's conventional and nonconventional water resources and ties it to the Novel Corona Virus (COVID-19) pandemic and the possibility of the disease to further spread through the water facilities and the groundwater system. At the outset, it must be acknowledged that the nature of the Novel Corona Virus and its spreading behavior in the ecosystem remain somewhat vague. Therefore, developing a comprehensive study necessitates that all possible contamination pathways of the virus be investigated. The chapter discusses the possible migration paths of the virus and proposes a plan to systemically determine its presence and concentrations. The proposed plan primarily focuses on the process of sample collection, sample preservation, and analysis as well as the treatment techniques that could be used to remove the virus from the contaminated mediums.

7.2 Introduction

The State of Kuwait is located in an arid region that is characterized by harsh climatic conditions and scant precipitation (Fig. 7.1). No surface water in the form of rivers or lakes exists within the perimeter of the country. Groundwater is the only natural source of water in the country. It is limited in quantity and is mainly brackish to saline in quality. Very limited amounts of fresh groundwater can be found as lenses floating over the brackish to saline water in the northern part of Kuwait. Groundwater with a salinity of <5000 ppm is extracted in the central and southwestern parts of Kuwait and is used to irrigate nonedible crops and for mixing with the desalinated water to make it potable. Aquifers yielding brackish water are also under great stress, as there is very little natural replenishment for them.

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FIG. 7.1 Location of Kuwait (courtesy of www.worldatlas.com; Mukhopadhyay and Akber, 2018).

The absence of natural sources of freshwater has forced the country to rely almost entirely on desalination plants to secure the bulk of its freshwater needs. Freshwater consumption in Kuwait is considered to be among the highest in the world. The demand for freshwater is increasing at an alarming rate to cope with developmental activities and population growth. If this trend continues unchecked, a large investment will be necessary in the near future to augment the desalination capacity of the country.

Municipal wastewater in Kuwait is generally treated to tertiary level. Recently, membrane (reverse osmosis, RO) treatment has been introduced to renovate the municipal wastewater that produces very high quality water. The treated wastewater is thus a very good additional resource for the country.

7.3 Sources of water

Rainfall is scarce in the country (110 mm on average annually) and most of it evaporates under high ambient temperature (average annual evaporation more than 3000 mm; Omar et al., 1981). Most of the useable groundwater, extracted in the southwestern parts of the country, is brackish (salinity 2500–5000 mg/L; Fig. 7.2). Only in the two large surface depressions of Raudhatain and Umm Al-Aish in the northern part of the country, enough infiltration from the runoff accumulations formed during occasional intense rainstorms occurs to give rise to two near-surface freshwater lenses floating over the brackish to saline groundwater (Fig. 7.2). For its freshwater needs, Kuwait, therefore, mainly depends on the distillation of seawater.

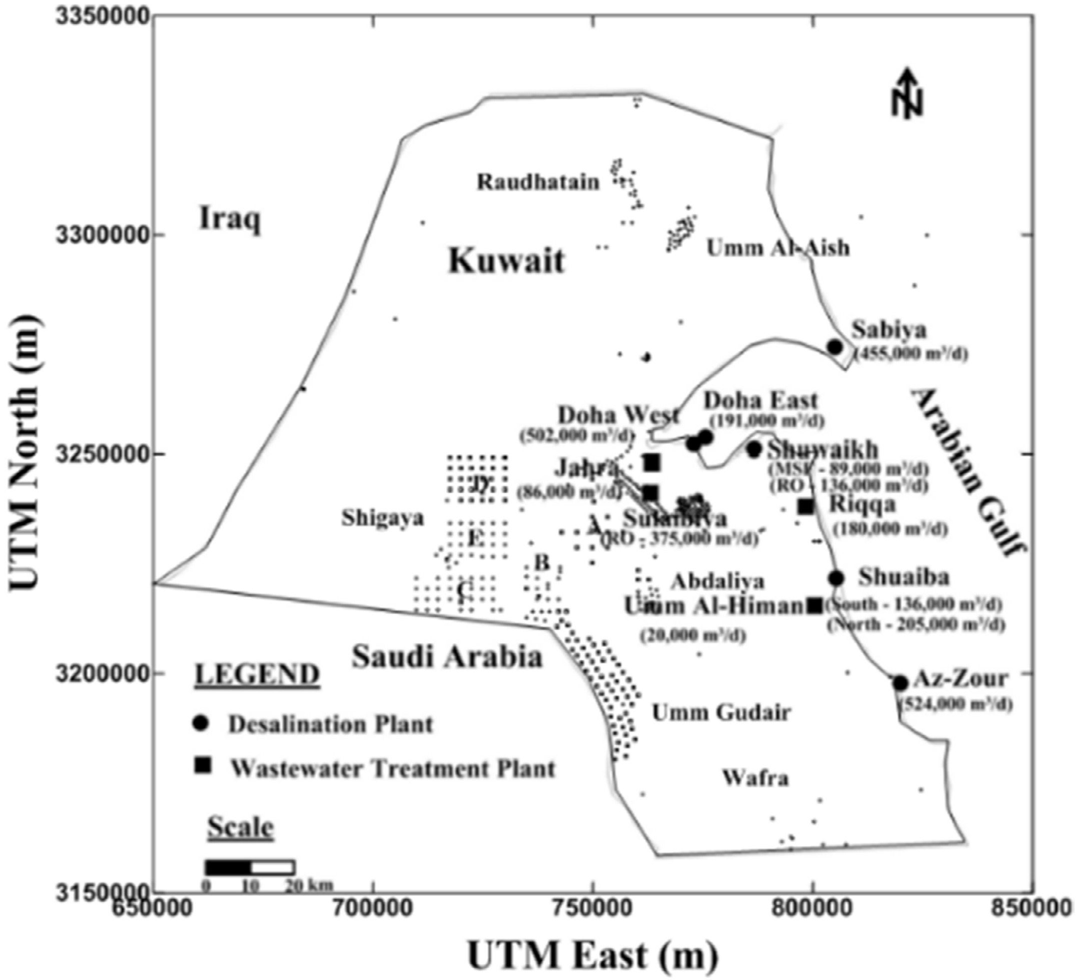

FIG. 7.2 Water fields and desalination and wastewater treatment plants of Kuwait (Mukhopadhyay and Akber, 2018).

7.4 Current status of water availability and consumption

7.4.1 Desalinated water

About 90% of the potable water production in Kuwait is coming from the unconventional resource of seawater desalination. This unusual, and rather fragile situation has grave economic and environmental costs. This is particularly true given the never-ending increase in consumption. The per capita freshwater consumption in Kuwait reached a high of 503 L/d/capita in 2002. This value, which is one of the highest in the world, has since been lowered to the level of 440–445 L/d/capita in the recent years (Fig. 7.3), though it still remains high.

7.4.2 Groundwater

Groundwater is the main naturally occurring water resource in Kuwait. The clastic Kuwait Group (Mio–Pliocene) and the unconformably underlying carbonate Dammam Formation (Middle–Upper Eocene; Fig. 7.4) are the two main aquifers exploited in Kuwait. Except for the localized lenses of freshwater floating over the underlying brackish to saline groundwater under surface depressions in North Kuwait, the exploited groundwater in Kuwait is brackish with total dissolved solid contents (TDS) in the range of 2500–5000 mg/L.

The Dammam Formation is only locally exposed near the Greater Burgan oilfield along the Ahmadi Ridge trending parallel to the Arabian Gulf coastline. Otherwise, the surface of Kuwait is covered by the sandy and gravelly unconsolidated to semiconsolidated sediments of the Kuwait Group and the Holocene aeolian deposits. Calcareous and gypsiferous hard layers of low permeability, a product of diagenesis of the near-surface Kuwait Group sediments,

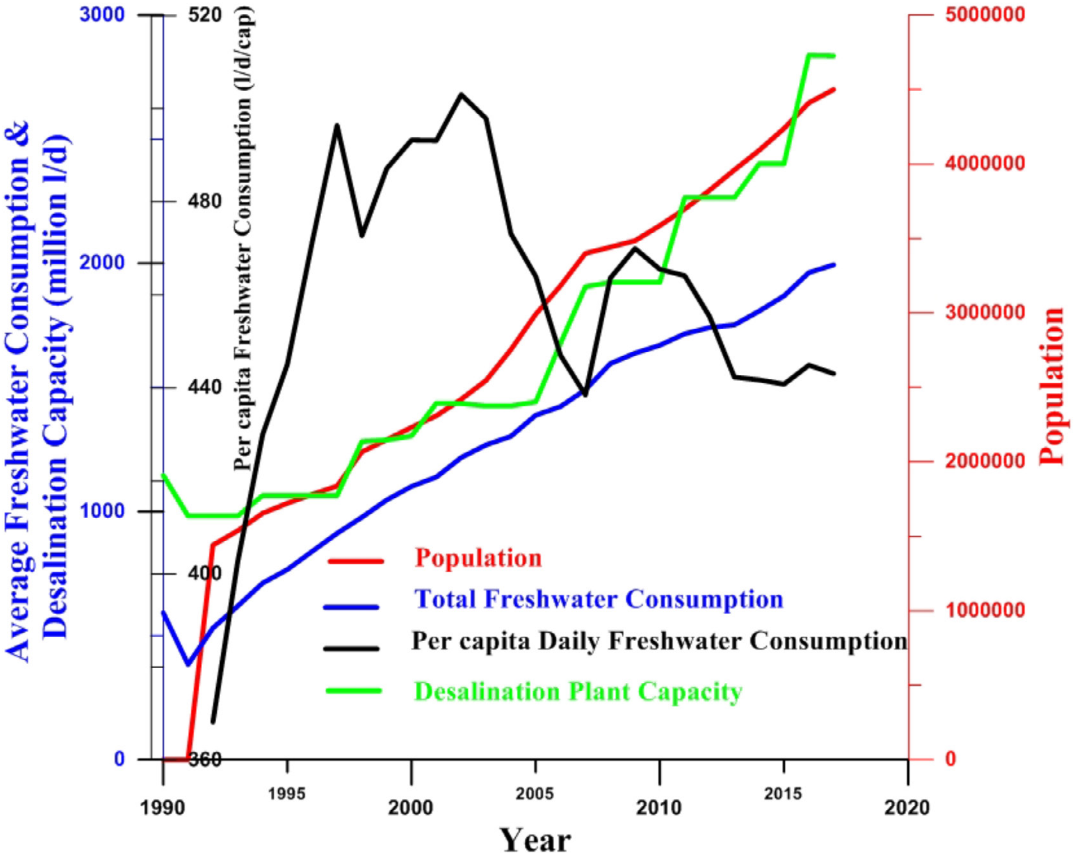

FIG. 7.3 Development of installed desalination capacity, population, and water consumption in Kuwait during the period 1990–2018. *Data Source: MEW, 2019.*

are irregularly distributed at varying depths from the ground surface all over Kuwait (Al-Sulaimi and Mukhopadhyay, 2000) that often hinders downward infiltration of surface runoff and return water from irrigation.

Groundwater produced by Kuwait's Ministry of Electricity and Water (MEW) and Kuwait Oil Company (KOC) currently provides 9% of Kuwait's annual water supply that mainly provides the make-up water that is added as a 5% blend to desalinated seawater for its chemical stabilization and to make it potable. The rest is used by the oil industry and other domestic, industrial and commercial activities. Agricultural farms also produce groundwater for irrigation purposes; but no records are kept for the volume of water produced (Al-Sulaimi et al., 1994). In recent years, a conscious effort has been made by the water administrators of the country to reduce the brackish groundwater production to ensure the protection of the quantity and quality of this valuable resource. As a result, since 2005, the extraction has been lowered from more than 150 million m^3/yr to about 70 million m^3/yr (Fig. 7.5). In the freshwater fields of Raudhatain in north Kuwait, the initial production at a rate slightly above 2 MIGPD (9090 m^3/d) over the period 1963–1967 was reduced to about 1 MIGPD (4545 m^3/d) to control the rising total dissolved solids (TDS) in the produced water. By 1989, the total withdrawal from the two freshwater fields during the year declined to 24 MIG (109,105 m^3), approximately 66,000 IG/d (300 m^3/d). During the Iraqi occupation of 1990–1991, the field facilities were destroyed. Subsequently, hydrocarbon pollution of the freshwater lens at the Umm Al-Aish field, caused by the damaged oil wells, was detected. As a result, the Umm Al-Aish field has been abandoned. The Rawdatain Bottling Company is currently producing water at a maximum rate of up to 0.5 MIGPD (2275 m^3/d) from the Raudhatain field with no production by MEW (MEW 2019).

7.4.3 Renovated wastewater

The total average treated effluent of municipal wastewater at the two major conventional treatment plants in operation (Riqqa and Jahra, Fig. 7.2) was about 226,000 m^3/d in 2005 (Shahalam et al.). About half of it was discharged to the sea and the rest was used for agriculture and landscaping.

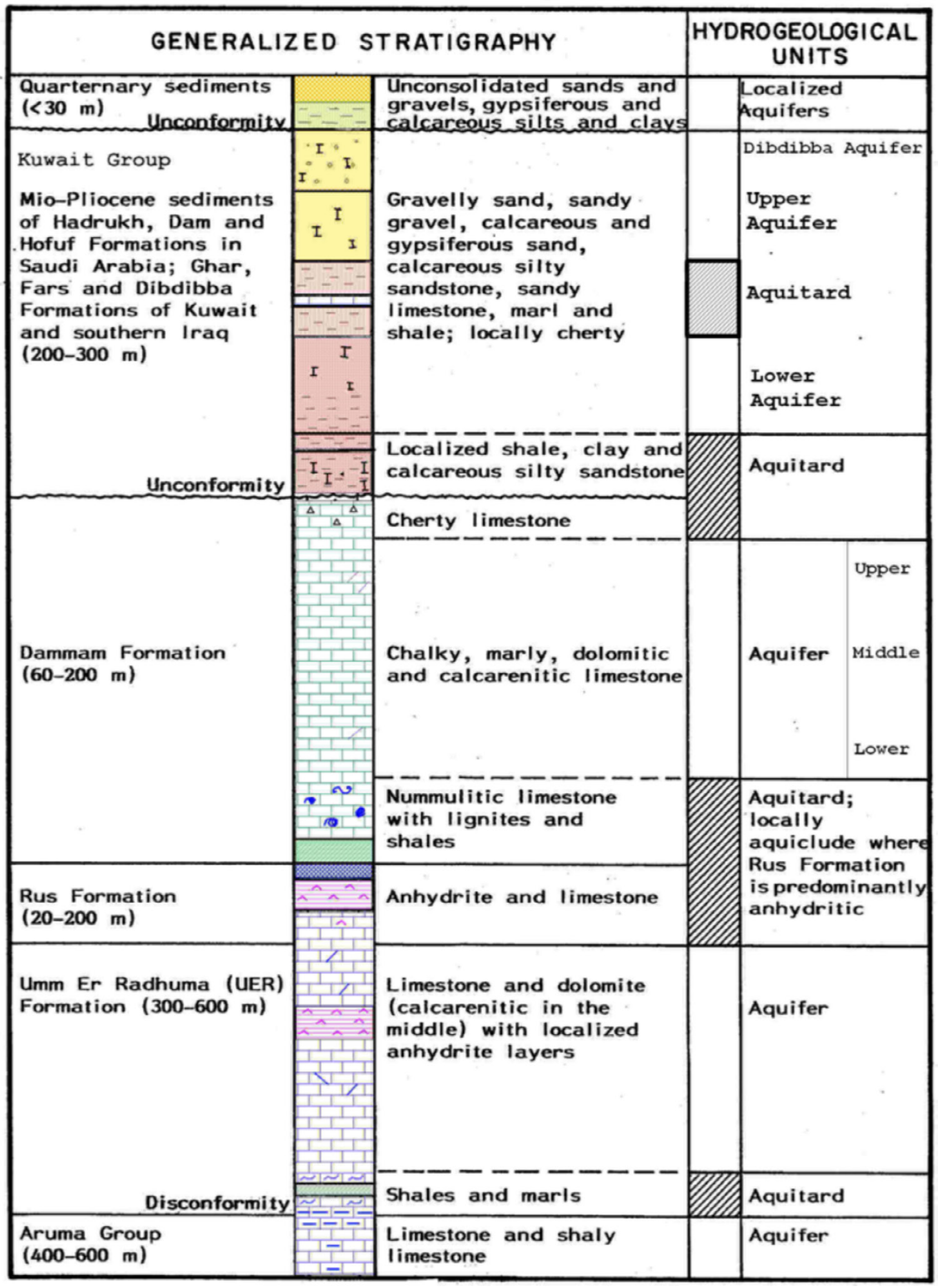

FIG. 7.4 Hydrostratigraphy of Kuwait (after Mukhopadhyay et al., 1996).

Based on the study by Abdel-Jawad et al. (Abdel-Jawad et al., 1997), a municipal wastewater treatment plant using the reverse osmosis (RO) process and constructed by a private consortium on Build–Operate–Transfer (BOT) formula, has come into operation in Sulaibiya in 2004. The plant has a design capacity of 375,000 m^3/d. It accepted an inflow of 355,102 m^3/d and produced 306,218 m^3/d of treated effluent during 2006 (Shahalam et al.). The volume of wastewater generated will be increased in the future with increase in population and consequent consumption (the population has risen from 4.1 million in 2014 to 4.6 million in 2018; approximately 100,000 persons/yr (MEW, 2019)), leading to a steady increase in water consumption, as revealed in Fig. 7.3. The treatment capacity will also be increased to keep pace (Burney et al., 2001). The treated water is planned to be used for irrigation, artificial recharge of the aquifers, and recreational purposes.

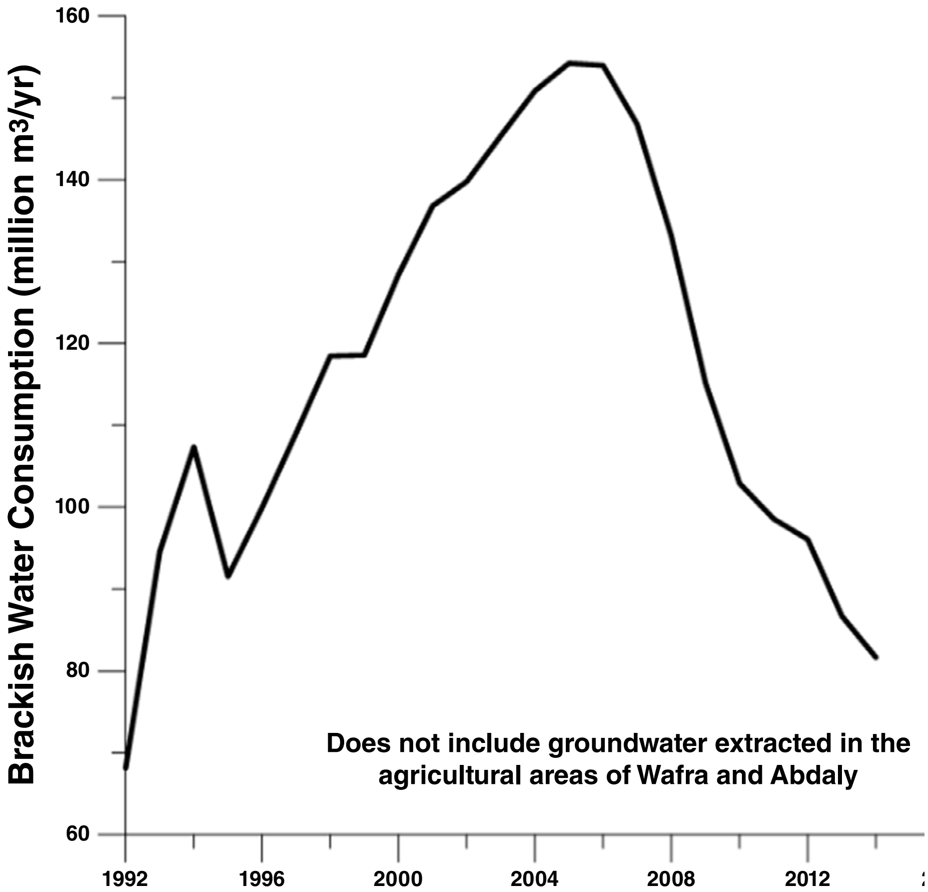

FIG. 7.5 Brackish groundwater consumption in Kuwait during 1992–2018. *Data Source: MEW, 2019*.

7.5 Possible spread of the Novel Corona Virus through water facilities

Novel Corona Virus (NCV-19) refers to a strain of viruses that are endemic in humans with normally mild infections such as the common cold. Cross-species transmission of this Virus has recently produced unusually virulent strains which can cause viral pneumonia and in serious cases even acute respiratory distress syndrome leading to death. In light of the outbreak of the Corona Virus Disease (COVID-19) in the past few months with serious health and economic repercussions that brought the whole globe to a virtual standstill, it is important to develop a better understanding of the occurrence and evolution of this strain of viruses in the ecosystem. In an arid country such as Kuwait, water could potentially act as a conduit through which the COVID-19 can be transmitted. It should be noted that proposing a comprehensive plan that addresses the migration paths of the Novel Corona Virus and the means and methods to prevent it from spreading further through the water supply facilities and the groundwater system would have been more of a "wishful thinking" given the chaotic situation that the Kuwaiti government had to deal with when the pandemic was at its peak. At that stage, the priority was to contain the spread of the disease among Kuwait's population and to treat the patients whose numbers were increasing at alarming rates. Now that the situation has almost been brought under control as dealing with the pandemic became a routine daily practice, suggesting such a plan is a plausible proposition. Serious attempts should be made to address this issue and to prescribe preventive and remedial measures to reduce the chances of the disease to spread through this "conduit". These efforts should be closely coordinated with Kuwait's Ministry of Health that is handling the treatment of the COVID-19 patients and analysis of samples of their body fluids. Microbiology laboratories specialized in Corona Virus strains and well-trained teams in sampling and analysis of the samples collected should be assembled for this purpose. All precautionary measures that will be required to be implemented during sampling and handling of the samples in these laboratories should be put in place before the actual sampling and the laboratory analysis of the samples are taken in hand. The needed polymerase chain reaction (PCR) machines, essential for the identification of the virus in a medium, should be procured and tested. The laboratory staff should be trained on the PCR technique and the use of the PCR machines. The services of staff with expertise in handling this deadly virus should be solicited to ensure the safety of the team during the implementation of the plan. The sampling and the laboratory teams should be trained on handling the samples with all necessary precautionary steps so that the contamination of the laboratory space, equipment and their personal infection by this highly contagious virus are avoided.

7.6 Monitoring of water quality and collection of water samples

The water quality in the hospitals where the corona virus patients are treated and in the quarantine facilities where the suspected carriers of the disease are detained should be routinely checked. For this purpose, the water samples should be collected from water coolers, bottled water and taps in the kitchens and bathrooms of these facilities. This is important as the nature and the spreading behavior of the Corona virus are still ambiguous since this is a new strain of viruses that has recently started circulating in the human habitat. Therefore, all possible contamination pathways should be investigated. Sampling of bottled water in the above-mentioned facilities will serve two main purposes: (1) in an ideal case, it should represent an uncontaminated sample of water that can act as a reference; (2) in case the virus survives longer on a plastic or a metal surface, as reported in some research studies (Susana et al., 2013), the outside surface of a water bottle in a quarantine center or a hospital treating COVID-19 patients may get contaminated and, in turn, contaminate the water inside when the bottle is opened and water is used for drinking. Also, individuals who are detained in quarantine centers, COVID-19 patients who are treated in designated hospitals, medical and nursing personnel, handling and cleaning workers and others who provide services in these facilities could come in contact with the taps and water coolers in the bathrooms and kitchens of these facilities, thereby increasing the likelihood of further spreading the contamination. Similarly, the potable water distributed through a pipeline network in such facilities may be contaminated if the potable and the wastewater networks near such facilities are located close to each other and leakages occur in both of them. Also, wastewater samples should be collected from discharge pipes of such facilities. Additionally, seawater samples should be collected from wastewater discharge points that discharge wastewater originating at these hospitals and quarantine centers. Furthermore, wastewater samples should be collected from input and output points at the wastewater treatment plants that use both conventional and membrane treatment processes. Samples from the sludge and the rejects of these plants should also be collected. Collection and analysis of these samples will help in developing a better understanding of the nature of this deadly virus and its transfer paths through different mediums.

To investigate the possible presence of the virus in the freshwater network, water samples should be collected from input seawater to the desalination plants as well as plant outputs and rejects. Water samples should also be collected from surface and elevated freshwater reservoirs, freshwater distribution centers for water bowsers, freshwater distribution points for residential areas and booster pumping stations along the network.

To check the possible presence of the virus in the freshwater network at residential areas, tap water samples should be collected from randomly selected houses and residential units representing the different Governorates of Kuwait. This will shed some light on the somewhat unknown behavior of the NCV-19 virus since quite a significant number of people living in these areas could become asymptomatic carriers of the virus. During their day-to-day activities, those carriers of the virus could transmit it while handling water facilities such as pumps and storage tanks at their residences. They could also contaminate the wastewater. Any leakage in the wastewater and the freshwater networks in those areas could potentially spread the virus.

To examine the contamination of groundwater by water polluted with Corona virus from the freshwater network and/or from water leaked from the wastewater network, boreholes should be drilled near quarantine facilities of suspected carriers of the virus and hospitals where corona virus patients are treated (as long as the groundwater levels at these locations are within 10 m from the surface as the virus is not expected to survive after passing through a thick column of soil) down to about 5–10 m below the groundwater levels. The importance of this step stems from the fact that numerous studies carried out over the past few years have shown that leakage occurs in the freshwater distribution system in Kuwait at rates ranging from 7% to 15%. Therefore, drilling wells to collect groundwater samples is essential for the determination of the relationship between water leaked from the freshwater system and wastewater distribution systems and groundwater. Groundwater samples should be periodically collected from the boreholes drilled near these sites. Since brackish groundwater is used for different purposes, including irrigation and landscaping, livestock rearing, construction work, nonpotable use in households, and for mixing with desalinated water to make the mixture potable, samples should also be collected from the groundwater fields in the country. The groundwater samples should be collected at the extraction point to be used as a reference, at different points along the brackish groundwater network and before and after mixing with desalinated water. Samples should be collected from the aforementioned sources in two cycles at a 6-month interval to check the status of the infection by the virus and its survival in the environment over an extended time period.

To further assess the vulnerability of groundwater to contamination by the virus, column tests should be conducted using a combination of different types of soils (gravelly sand, medium and fine grained sand, silty sand, clayey sand, silt, etc.) and Corona Virus contaminated water. For this purpose, 125–150 cm long columns, filled up to 1 m by the above soil types should be set up in the laboratory with sampling points at 10 cm intervals. One to two liters of virus contaminated water should be allowed to pass through the columns and soil samples should be collected at different depths for the determination of the virus content. The time taken to reach different sampling points should also be recorded. The water and soil samples collected from the soil columns should be microbially analyzed for the presence and concentrations of the virus.

7.7 Preservation, analysis, and treatment of water samples

Microbial analysis of the samples collected should be carried out at laboratories designated for such analysis by Kuwait's Ministry of Health or in laboratories specially set up for this purpose to identify and quantify the presence of Novel Corona Virus. A few selected samples should be sent to outside laboratories, specialized in viral culture, for result verification purposes and to identify any genetic mutation of the virus.

To study the effects of temperature and time on the survival of the Corona Virus in water, the collected samples should be preserved at different temperatures (in the range of 0–60°C at the increment of 10^{0} C) for different durations (e.g., 1 h, 2 h, 4 h, 6 h, 9 h, 12 h, 18 h, 1 day, 2 days, 3 days, 4 days, 5 days, 10 days, 15 days, 20 days, 25 days, 30 days) and analyzed for the presence and concentration of the virus. The sampling and analysis may be discontinued once two consecutive samples from a particular setup (constant temperature with variable treatment durations) produce negative results for the virus. If found to be polluted by the Corona Virus, the collected water samples could be treated in designated laboratories using UV light, ozonation and chlorination techniques and a similar analysis should be carried out after treatment to investigate the efficiency of these methods for disinfection of water contaminated with the virus.

7.8 Concluding remarks

Since March 2020, the COVID-19 pandemic has had enormous impacts on Kuwait, claiming the lives of hundreds of people and leaving thousands hospitalized, which by all accounts are huge numbers given the small population of the country. The pandemic is still raging despite all precautionary measures adopted by the Government of Kuwait with scars that are expected to last for years to come. In a country that is located in an arid region with harsh climatic conditions and scant precipitation, the water resources are vital for the prosperity and wellbeing of Kuwait. The absence of surface water in the form of lakes and rivers and the fragility of groundwater, which is the only natural source of water, coupled with freshwater consumption patterns that are considered to be among the highest in the world necessitate that every effort be exerted to protect and preserve this essential commodity for this generation and the generations to come. Water could potentially act as a "conduit" through which the COVID-19 pandemic could be transmitted. Given the uncertainty of the pandemic in terms of evolution and spreading behavior, a comprehensive plan should be developed and carefully executed to identify all possible contamination pathways of the virus and to arrive at effective mitigation measures to eliminate or, at least, reduce its potential negative impacts. For proper execution of the plan, all resources, facilities and manpower, should be dedicated and efforts should be coordinated among the concerned entities to confront the threats of this serious pandemic and to render Kuwait a COVID-19 free country.

Acknowledgments

Figs. 7.1 and 7.2 and a few excerpts of this article were obtained from a previous article that was prepared by the same authors under the title "*Sustainable Water Management in Kuwait: Current Situation and Possible Correctional Measures*" and was published in Volume 13, No. 3 of the "*International Journal of Sustainable Development and Planning*."

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