VÉDELEM TUDOMÁNY
KATASZTRÓFAVÉDELMI ONLINE TUDOMÁNYOS FOLYÓIRAT

Chidinma Iheanetu, Roman Tandlich

WATER PROVISION UNDER THE COVID19 LOCKDOWN CONDITIONS: SNAPSHOT OF MICROBIAL QUALITY OF ALTERNATIVE SOURCES, THE ASSOCIATED COSTS AND CARBON FOOTPRINTS

Abstract

The situational reality, i.e. everyday functioning of a single human being and the existence of all of *Homo sapiens*, during the COVID19 pandemic requires maintenance of personal hygiene. Here results from the monitoring of microbial water quality of rainwater and treated municipal water from a retail shop in Makana Local Municipality are presented. These are the two main alternative sources of potable water during the current drought rationing of the municipal water supply. Testing of microbial water quality was done using the H_2S test kit. The costs and carbon footprint of retail shop water was estimated using distance travelled to the shop, the related fuel consumption and literature data. Disinfection of the sampled rainwater was done using the One Drop disinfectant. All samples of the harvested rainwater were positive for faecal contamination, while the treated municipal water from the retail shop was always free from faecal contamination. The cost of purchasing 1 litre of the treated drinking water from a water-only shop in the main mall in Makana Local Municipality ranged from 1.64 AR to 2.11 ZAR, depending on the settlement studied. Taking the treated water being the source of water for drinking only, the estimated cost would account for between 9.5 and 36.2 % of the estimated monthly income of a low-income household. The carbon footprint of provision of 1 litre of treated municipal water was equal to 77.5 g CO_2 for the middle-class suburb and to 135.5 g CO_2 for the low-income suburb. Transport burden was the largest portion of the costs and carbon footprints of the drinking water provision from alternative sources in Makana Local Municipality. Installation of the treatment systems as urban furniture in close proximity to the households could provide sufficient of supply of safe drinking water to the Makana population during COVID19 and beyond.

Keywords: H_2S test kit, transport, utility, geographical separation

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VÍZELLÁTÁS A COVID19 OKOZTA LEZÁRÁSOK IDEJE ALATT: PILLANATFELVÉTEL AZ ALTERNATÍV FORRÁSOK MIKROBIÁLIS MINŐSÉGÉRŐL, A KAPCSOLÓDÓ KÖLTSÉGEKRŐL ÉS A KARBONLÁBNYOMRÓL

Absztrakt

Tény, hogy a COVID-19 világjárvány idején a biztonság megköveteli a személyes higiénia betartását. A cikkben a szerzők ismertetik Makana helyi önkormányzat kiskereskedelmi üzletéből származó esővíz és tisztított víz mikrobiális vízminőségének monitorozási eredményeit. Ez a két fő ivóvízforrás az, amely biztosítja a település vízellátását aszály idején. A mikrobiális vízminőség vizsgálat a H2¬S tesztkészlettel készült. A kiskereskedelmi bolti víz költségei és a szénlábnyom nagysága a boltig megtett távolság, a kapcsolódó üzemanyag-fogyasztás és a releváns szakirodalmak alapján kerültek meghatározásra. A mintából vett esővíz fertőtlenítése az ún. One Drop fertőtlenítőszerrel történt. A cikk eredményként megjelenik, hogy amennyiben a víztisztító rendszerek a háztartások közelében lennének elhelyezve, az megfelelő mennyiségű ivóvizet biztosítana Makana lakosságának nem csak a COVID-19 idején hanem azt követően is.

Kulcsszavak: H2-S tesztkészlet, szállítás, közmű, földrajzi elkülönülés

1. INTRODUCTION

In their recent paper Tandlich et al. (2021), the ribovirocell stage of the SARS-CoV-2 virus lifecycle and the continuity of human existence and functioning during the COVID19 pandemic was presented (Tandlich et al., 2021). A brief introduction to this reasoning is provided here and the context is developed further to introduce the current study. A virus has two stages in its lifecycle, namely virion and the virocell (Forterre, 2013). Virion is a non-living stage in which the virus has all the features of a non-living entity that is transported passively in the environment through various physico-chemical mechanisms (Tandlich et al., 2021). On the other hand, once the virion enters the human host cell, it hijacks the cellular and sub-cellular machinery of the host's cell to facilitate its own replication or new virion production, i.e. the virus exists inside the cell as a virocell (Forterre, 2013). Alternatively, the host cell is the ribovirocell stage of existence in the post-infection space-time, where the host cell can maintain the ability to divide and continue to function in a semi-normal fashion in spite of the virus presence inside it (Forterre, 2013). Prior to the onset of the COVID19 pandemic, there were virtually no limits on the movement or access to space on the surface of the Earth for most human beings. After the onset of the pandemic, lockdowns and similar measures limited the physical and spatial dimension of the existence of a single human being (Bagrath et al., 2020). The main aim of such non-pharmaceutical measures was to contain the COVID19 spread and to maintain human existence in a state similar to that of a ribovirocell, i.e. they can function more or less normally. The need for the adherence to non-pharmaceutical interventions is still relevant in 2021, due to the uneven vaccination rates across the globe. At the time of the writing of this article, the developed countries achieved vaccination rates around 59 % in the USA, 77 % in Canada and 80 % in Spain (NY Times, 2021). On the other hand, middle-income and developing countries trailed far behind with full vaccination rates equal to 0.1 % of the population in the Democratic Republic of Congo, 1.7 % in Nigeria and 24 % of the population in South Africa (NY Times, 2021). The non-pharmaceutical interventions were aimed at getting humanity back to some level of normalcy of human beings, to a state of existence which is similar to the ribovirocell state of a cell that had been infected with a virus (Tandlich et al., 2021; Iheanetu et al., 2021).

One of the main non-pharmaceutical interventions was the access to safe drinking water for the maintenance of personal hygiene by countries population around the globe. At the same time, sufficient hydration of the human body is necessary for the maintenance of health, i.e. "8 to 10 glasses a day was reported to help with nutrient transport and regulation of body temperature" (Aman and Masood, 2020). At the onset of COVID19, around 785 million people around the world had no access to safe drinking water and up to 3 billion humans did not have access to hygiene facilities (Atkinson, 2020). Lack of access to drinking water, especially in sub-Saharan Africa and South America, has led to the call for creative solutions for hygiene provision during the COVID19 pandemic. Examples can include the use of the mobile sinks, which can be manufactured out of recycled wood and could be distributed in urban areas, along the lines becoming urban furniture which are "all objects, elements, and small constructions that integrate the urban landscape, utilitarian nature or not, implanted upon the government's authorization, in public and private spaces" (Mendes et al., 2020). Another proposed solution was the tippy tap, which is a device consisting of a bottle filled with clean drinking water that can be tipped over and used for hand-washing, along with soap (Mbakaya et al., 2020). It has been used in the Makana Local Municipality of the Eastern Cape (RUCE, 2020) and in multi-stakeholder health promotions campaigns across South Africa (UNICEF, 2021).

Maintenance of hygiene and access to drinking water is necessary to prevent secondary infections and the increased pressures on the healthcare system during the COVID19 pandemic. In addition, COVID19 has caused multi-dimensional health and social impacts, e.g. neglecting of healthcare treatment, loss of income and wages to name but a few (Haleem et al., 2020). Thus further health deterioration of populations under the COVID19 lockdown must be prevented at all costs. Water quality plays an important role here, namely in the prevention of the cascading effects in the context of the coronavirus pandemic as a disaster. Several authors to date have reported on the water quality which was observed during the lockdown and the duration of the COVID19 pandemic. Duttagupta et al. (2021) examined the data for the water quality in the Ganges river, which had suffered from arsenic pollution prior to the onset of the COVID19 pandemic. Results of the authors' analysis indicated that the COVID19 lockdowns led to decreases in agricultural activity and lowered effluent production/discharge into the environment. That in turn contributed to the lowered concentrations of chemical and biochemical oxygen demand in the sampled catchment, which are measured of the organic matter concentration, compared to the pre-COVID19 concentrations (Duttagupta et al., 2021). Khadse et al. (2020) presented a review of methods for the examination of microbial water quality. The same authors reported finite concentrations of coliform and faecal coliform bacteria in water samples from India during the COVID19 pandemic (Khadse et al., 2020).

Kumar (2021) stated that there is an urgent need for a holistic assessment of the water cycle in the urban environments. This is caused by the need to achieve the Sustainable Development Goal 6 and to assess the ongoing changes to the urban water cycle due to increasing urbanisation (Kumar, 2021). These variables are linked to the notion of water security. Water security has been a shifting notion, or a dynamic process which reflects the continuous evolution of the term, as indicated by the recent paper of Mishra et al. (2021). Those authors engaged with the definition of a water crisis (directly or indirectly a result of compromised water security or related the water security), state that “the water crisis is generally considered as technology related problems but under emerging paradigms focus is shifted towards recycle and reuse of water, considering waste and stormwater as resources, managing demand effectively, promoting green infrastructure, increasing community and stakeholder participation, effective governance, and multidisciplinary approach to achieve water security” (Mishra et al., 2021) (Muyambo et. al., 2017). “Another set of sustainable solutions include interlinked water, energy, and food components, with a balance between natural resource use and society’s demand on such resources” (Mishra et al., 2021). This indicates that a multitude of considerations that must be kept in mind and implemented in terms of water security, as well as for the practical implementation of the necessary interventions. The water security dimensions, that are most relevant in the context of COVID19, include the “household dimension, urban dimension, the safe or desirable quality, and the economic dimension” (Mishra et al., 2021).

In South Africa, a recent paper dealt with the results on the concentrations of heavy metals in the surface water in the Limpopo province, which is used for potable purposes (Molekoa et al., 2021). Between 2016 and 2020, Molekoa et al. (2020) reported that the surface water from sampling sites was not suitable for drinking in spite of being used by the community around the river. However, there were some improvements in water quality due to the suspension of mining and other industrial activities during the COVID19 pandemic (Molekoa et al., 2020). Tandlich (2020) reported that the microbial water quality was not up to standard during the hardest phase of the COVID19 lockdown in South Africa. The sampled area has a long history of drinking water challenges. Alternative resources to municipal drinking water supply, such as rainwater harvesting, are available and practised by many households (Malema et al., 2019). At the same time, small operators started providing drinking water through sales in retail outlets since about 2015. This water is accessible at a price of about 1.00 to 1.40 ZAR per litres (local data from Makhanda, Eastern Cape, South Africa; 1 USD = 15.00-16.20 ZAR at the time of the writing of the current article). The harvested rainwater is often consumed after no or limited treatment. The small water retailers generally take municipal water, sometimes store on their shop premises, and subject it to the treatment with sand filtration, ultrafiltration, the reverse osmosis, and ozonisation/disinfection. Rainwater is then available for domestic use at the household, where it was harvested. On the other hand, the water retailers sell the treated municipal water through self-service dispensers in grocery stores or through assisted dispensing in serviced and specialised water-only shops. Dispensing takes place into any containers that customers bring or into pre-cleaned PET bottles/containers. Containers from hardier plastic materials with taps are also available, but at a premium price.

During the COVID19 lockdowns, the access to drinking water and safe potable water sources has played a critical role in the containment of the pandemic (see above). Water retailers have generally been allowed to operate without restrictions in the Makana Local Municipality during all stages of the COVID19 lockdowns in South Africa. Travelling to the water-only shops is possible by car, on a bicycle, by walking or a taxi. The first two options are exercised in the middle- and upper-income neighbourhoods from the Makana Local Municipality. The taxi option for transport is exercised by mostly by household residents from the low-income neighbourhoods, which are located on the outskirts of the Makana Local Municipality, South Africa. Walking can be a mobility method of both the Makana residents from low-income settlement and middle/upper-income parts of the urban part of the municipality. The trigger for this form of transport can be the purchase of drinking water during personal exercise, or as a matter of no-other-choice due to transport interruptions. The last statement is based on the fact that there have been challenges in travelling between low-income urban settlements and the centres of towns/cities, to shopping centres where the water shops are located during South African lockdown stages. The water-only shops became available intermittently due taxi strikes and dissatisfaction with the COVID19 restrictions on passenger capacity in the taxis. For the analysis in the current study, only the transport with the passenger car or a taxi are considered to provide a realistic estimate of the provision of substantial drinking water volume from an alternate source on a single occasion.

Based on the context above, the current study had two main aims. The first one was to assess the microbial water quality of rainwater from a household in Makana Local Municipality, and from one of the water-only retail shops. The collected samples were tested for potential microbial contamination using the H_2S test kit (Malema et al., 2019; Tandlich, 2020). At the single household level, the rainwater disinfection was tested using the One Drop preparation, to eliminate the microbial contamination of the harvested rainwater. The second aim of the study was to calculate the potential costs and carbon footprint of provision of the treated municipal water from a local water-only shop. The data for this part of the study was collected as a combination of a literature review of the carbon production unit values for the individual steps in the water provision from the shop. In addition, some data was collected during various phases of the COVID19 lockdown in South Africa. The overall goal of the study was to provide some assessment of the various dimensions of water security, namely the household one, the urban one, the economic one, and the microbial safety one.

The current study is part of an ongoing project to study the water quality in Makana Local Municipality in South Africa. In the context of the COVID19 pandemic, the description of microbial water quality is important to document the situational reality in the study area (based on the definitions from Iheanetu et al., 2021). The current study is aimed at providing a snapshot towards ascertaining the needs to maintain a ribovirocell state of one’s human existence due to drinking water provision during the COVID19 pandemic conditions (Tandlich et al., 2021). In other words, what are the conditions of water security on the ground in Makana Local Municipality that are related to maintenance of the semi-normal functioning of Makana residents in the COVID19 space-time or reality, under the coronavirus pandemic conditions. What are the factors, related to the water provision are in play and must be considered in terms of drinking water provision, that can influence the maintenance of the ribovirocell state of human existence under the COVID19 pandemic conditions? In other words, what are the factors related to drinking water provision to maintain some sort of normalcy of existence in Makana Local Municipality during the COIVD19 pandemic, i.e. what is the local nature of the ribovirocell in Makana Local Municipality in relation to the drinking water provision and the maintenance of personal hygiene during the coronavirus pandemic?

2. MATERIALS AND METHODS

2.1. Microbial water quality testing and disinfection experiments

The study was conducted between June 2020 and October 2021. Not all project activities were executed at once, but rather the study was conducted in a semi-opportunistic fashion due to the fluid nature of the COVID19 pandemic restrictions. The microbial water quality was measured over on four occasions during the study. The H_2S test kits were prepared and all consumables for the test kits were procured as previously reported by Malema et al. (2019) and Tandlich (2020). Rainwater samples were procured from a single donor household in the Makana Local Municipality in a similar fashion as reported previously by Malema et al. (2019). The difference was that sampling for microbial water quality assessment performed directly from the rainwater harvesting tank into 5 H_2S test kits at the sampling site. On a given sampling occasion, the tap of the 1500 litre rainwater tank was sterilised with 70 % ethanol and the tap was opened. The rainwater was allowed to run for 10 seconds, and 5 H_2S test kits were filled with the sampled rainwater. The H_2S test kits were then incubated for 72 hours, as described by Malema et al. (2019). Results were read as the number of the H_2S test kits that were positive for faecal contamination on a given sampling occasion. That number was converted into values 0 (all five H_2S kits negative for faecal contamination), 1 (1-4 H_2S kits positive for faecal contamination and thus the faecal contamination of rainwater is suspected) or 2 (5 H_2S kits positive for faecal contamination and thus the faecal contamination of rainwater is confirmed) after 72 hours of incubation (Tandlich, 2020). The faucet of the rainwater tank was swabbed on three occasions for the presence of faecal contamination, with the procedure being the same as reported previously for municipal water inside a single household by Tandlich (2020). All faucet samples were free of faecal contamination and did not have any influence on the results of faecal contamination assessment in the harvested rainwater.

For the disinfection procedure with One Drop (One Drop South Africa, Johannesburg, South Africa), 5 litres of the rainwater were collected into a Polyethylene Terephthalate (PET) bottle. The sample was then transported into the laboratory at Rhodes University, without violating the COVID19 pandemic lockdown procedures, and the disinfection experiments were performed there. The transport was done with the samples on ice and the experiments were initiated within 1 hour of collection. For the experiments, conditions under which a disinfection could be conducted in the donor household were simulated in the following way, after the samples were brought to ambient temperature. A two-litre plastic milk bottle was washed, as reported by Malema et al. (2019) and filled with to 98 % of capacity with the sampled rainwater. Then a kitchen dropper (similar to the following product: https://www.amazon.com/Droppers-Silicone-Medicine-Dropper-Kitchen/dp/B0922HKRT4; website accessed on 22nd November 2021) was used to remove 0.26 cm^3 of One Drop disinfectant from its storage container. That volume was equal to the volume of the full tip of the dropper, as calculated using the https://www.omnicalculator.com/math/cone-volume based on the measurements with a Vernier Calliper (purchased from Makita Industrial Power Tools, Makhanda, South Africa).

Next, 0.15 cm^3 (a total of four drops) was added to the treated rainwater in the two-litre milk bottles, and those bottles were incubated for 4 and 8 hours at 25 ± 1 °C, respectively. The dosage was estimated based on preliminary experiments (data not shown). After the respective incubation period, five H_2S test kits were filled with the treated rainwater and incubated as stated above. All results were converted into 0-2 score based on the number of positive test kits (see above), after the experiment was run in triplicate. After data collection and measurements completion, all results were shared with the inhabitants of the donor household, with no personal information being collected about them. Thus no ethical clearance was required for the current study and the rainwater-harvesting part of it. Sampling of the treated municipal water from the water-only retail shop was done by filling a 10 litre PET bottles and transporting the water into the laboratory at Rhodes University. There 5 H_2S test kits were filled with the sampled water and incubated, as the rainwater samples. Results were read in the same fashion as the rainwater results.

2.2. Costs and the carbon footprint of the drinking water provision from the retail shop

The one water-only shop with the most comprehensive treatment system in place in Makana Local Municipality was chosen as the study source of the treated municipal water. That choice was based on the preliminary observations about the use of the shop by a large variety of residents of Makana Local Municipality. Multitude of Makana residents, from all socio-economic strata and all parts of Makana Local Municipality, used the shop as a source of drinking water during the study. That was indicated by the observation of citizens on the mall grounds, i.e. in a public place where no one can have an expectation of privacy. No interactions took place between the study team and any of the observed customers of the water-only shop. No personal data was collected about the customers at the main mall, i.e. no ethical clearance was required for this part of the current study. At the same time, the shop was used by members of the study team as a source of their drinking water. The following visual observations were made during the study: there were taxis dropping off passengers in the vicinity of the water-only shop and the passenger proceeded to purchase water at the water-only shop shortly after disembarking from the taxi. Taxis are the main means of transport for the people from the low-income areas of Makana Local Municipality to the main mall in the local municipality. In addition, the water-only shop customers were observed to be individual passenger vehicle owners, employees of various retail outlets from the main mall (based on the observation of the uniforms with various retail-outlet insignia), workers from the game farms or safaris within the Makana Local Municipality. Thus the choice of the water-only shop is deemed justified as the most-likely source of treated municipal water, for domestic uses such as drinking, to be used by the Makana residents.

To simulate the possible practices for drinking water provision from relevant alternative sources as possible, plastic containers are used to collect the drinking water from the water-only shop, namely the 10 litre PET bottles. The use of these containers poses an ethical challenge, as the use of the plastic bottles increases the environmental footprint of the current study. Thus the footprint must be minimised, while also providing useful data about the costs and the carbon footprint of the drinking water provision from the water-only shop in the main mall in Makana Local Municipality. Therefore the following research paradigm was adopted. Distance of two types of settlements was considered for commuting of residents to the main Makana mall. Firstly, a middle-class suburb within an average driving distance to the main shopping mall in Makana Local Municipality was chosen. The distance to the water-only shop and back was measured using a speedometer of a 1.5 litre-engine passenger vehicle over the course of a five-week period. The measurements were compared with a distance from Google Maps and the average of the two distances was used in the costs and the carbon footprint calculations, for water provision from the water-only shop. Secondly, a low-income suburb on the outskirts of Makhanda were chosen as the model areas and the distance to the water-only shop was determined using Google Maps for the Makana Local Municipality. The total volume of with the treated municipal drinking water, which was purchased per one occasion of approximately 30 litres, was determined by filling all three 10 litre PET bottles to the brim. Then the bottles were transported to the laboratory and were weighed on a commercial platform scale (see https://borderscales.co.za/product/industrial-platform-scale-adam-cnp/ for details). The average weight of a single 10 litre PET bottle was equal to 10.181 kg, while the average volume of one bottle was equal to 10.7 litres. As a result, 32.1 litres was purchased per one sampling refill of approximately 30 litres, and the total weight of the PET used in the study was equal to 543.36 g.

Overall, various types of containers were observed during the shopping for drinking water, e.g. the five-litre PET bottles which were reused, the ten-litre PET bottles which were reused, and various containers from household products. The average price of 10 and 25 litres containers for water with dispensing taps is about 155 to 250 ZAR. The ten-litre PET bottles can be bought for an initial price of 39 ZAR per bottle, which includes the initial 10 litres of treated municipal drinking water. During the COVID19 pandemic, a large number of businesses in South Africa experienced decreases in revenue and economic activity. Many employees were placed on furloughs or became unemployed. The South African government provided social safety net for those citizens of the country. This has been done through a government payroll support scheme (the so-called TERS scheme; Department of Employment and Labour, 2021), and the Social relief of distress grant of 350 ZAR for South African citizens with no other income (Government of South Africa, 2021a). Based on the decrease in disposable income, a significant restructuring of spending patterns by individual South Africans was required. Under those circumstances, the provision of drinking water would be based on the financial resources available in a household. At the same time, there would be a need to commute from a location outside of the Makana city centre to the water-only shop and the need to maximise the volume of drinking water procured in one trip. Therefore the transport of drinking water was examined for the 10 litre plastic bottles, as the most affordable, as well as most practical, container available to the Makana Local Municipality residents. The three 10 litre PET bottles were filled to the brim at the water-only shop and transported in an upright position, though unsecured, between the middle-class neighbourhood, the water-only shop, and the Rhodes University campus. The bottles could fall sideways or topple over in the trunk, with the aim of the experiment was to determine the time it would take for the 10 litre PET bottles to start leaking or to become unfit for purpose.

3. RESULTS AND DISCUSSION

3.1. Microbial water quality and One Drop disinfection efficiency

Results of the microbial water quality testing are shown in Table 1. It can be seen that all the samples from the water-only shop, which sold treated municipal water, were negative for faecal contamination on all sampling occasions with a score of zero. On the other hand, the rainwater harvested from the household in Makana Local Municipality was always positive for faecal contamination with a score of 2. On a single occasion during the study, the 1500 litre rainwater harvesting tank was dosed with One Drop disinfectant based on the instruction from the manufacturer, i.e. at a dosage rate of 1 mL of One Drop per 25 litres of treated rainwater. Resampling of the rainwater in the tank took place 7 and 10 days after the dosing of One Drop. The samples were still positive for the presence of faecal contamination, as indicated the score of 2 from the H_2S test kit. Thus sterilisation of the harvested rainwater was redone in the laboratory at a rate of 0.15 cm^3 per 2 litres, i.e. 1 mL of One Drop per 13.3 litres of treated rainwater. Disinfection, i.e. a score of 0 from the H_2S test kit, was achieved after 8 hours of disinfection (see Table 1 for details). A finite concentration of organic matter in the treated rainwater could have decreased the efficiency of the disinfectant, as particulate matter was observed visually in the harvested and sampled rainwater. The other reason for the insufficient efficiency of the One Drop disinfectant could be the fact that the rainwater tank did not contain a first-slush system in its design, only a rough sieve-filter was present on the inflow into the tank.

Tandlich (2020) reported that municipal water in Makana Local Municipality was confirmed for faecal contamination, with the H_2S kit score of 2, only on 1 out of 12 samples taken during the hardest COVID19 lockdown in South Africa. However, up to 67 % of the samples were suspected of being contaminated with faecal microorganisms/bacteria, as the H_2S test kit mode score was equal to 1 (Tandlich, 2020). Molekoa et al. (2021) measured only heavy metal concentrations and no microbial analysis was conducted.

Table 1 Results of the H_2S test kit analysis of rainwater and the treated municipal water from Makana Local Municipality.

Sampling occasion	Rainwater H_2S kit result	Treated Municipal water result
1	2	0
2	2	0
3	2	0
4	2	0
One Drop disinfection 4 hours	1 ± 0[a]	NA[b]
One Drop disinfection 8 hours	0 ± 0[a]	NA[b]

[a] This is the average score of three replicate treatments with five kits per treatment run.

[b] Not applicable.

Results from the current study do indicate that the treatment facility in the water-only shop, in the main mall of Makana Local Municipality, is effective in preventing the faecal contamination of the drinking water sold there. It can thus be considered a reliable and alternative source of drinking water for the Makana population. Finally, the microbial water quality results provide an encouraging snapshot about the reliability of the additional treatment in removing microbial contamination from the Makana drinking water, in the water-only shops. Disinfection of the rainwater at a rate of 1 mL per 13.3 litres of treated rainwater. This piece of information provides a first local calibration for the treatment efficiency of the One Drop disinfectant in the Makana Local Municipality. It also indicates that the disinfection should be done outside of the rainwater harvesting tank, and in the household where the rainwater will be used for domestic uses. The best option would be to start the disinfection of the water the night before the intended use of the treated rainwater, given the need for an 8-hour incubation during disinfection (see Table 1 for details).

3.2. The cost calculations for alternative provision of drinking water using a 10-litre PET bottle

The cost of the drinking water from the water-only shop will determine the availability of that resource to the population of Makana Local Municipality. To study this, the three tested 10 litre PET bottles were transported in the passenger vehicle until they cracked or became unfit for use. The total duration of the experiment was 12 months. The first bottle cracked near the neck and started leaking after 6 months. With the second bottle, a crack appeared in the bottle screw cap after 8 months. The final third bottle started leaking and became unfit for the purpose of drinking water collection after 12 months of refills and transporting in the passenger vehicle. Thus average time to breakage of the 10 litre PET bottle was 8.7 ± 2.5 months. During the study, there was an average of 8 refills of a 10 litre PET bottle per month and the average price of one refill was 13.50 ZAR. The return distance travelled from the household in the middle-income suburb was measured by Google Maps as 4.0 km. At the same time, the return distance with the water-only shop was measured using the speedometer from the passenger vehicle over a five-week period between September and October 2021. The average distance per single refill trip of three 10 litre PET bottles was equal to 5.4 ± 0.8 km. Thus the average distance of water refill is equal to 4.7 km. The cost of one such trip can be estimated at based on the cost of gas refill of the passenger vehicle used and the price of gasoline during the duration of the study, i.e. 0.96 ZAR per km and so the average cost of a return trip to the water-only shop from the upper/middle class suburb was equal to 9 ZAR. The distance from the low-income area of Makana Local Municipality to the water-only shop was equal to 5.3 km one way or 10.6 km for a return trip. The cost of a single trip will be estimated as follows. Data from Makana Local Municipality indicate that the cost of a single taxi trip to the water-only shop from the low-income area was equal to 12 ZAR, i.e. a return trip will cost 24 ZAR. The taxi fare is based on the study team taking the trip by taxi from the city centre to the low-income suburb of Makana Local Municipality and back during the study.

Given the information from the previous paragraph, the cost of water provision from the water-only shop is calculated per litre of purchased water. The calculations are shown below for the travel from the middle-income suburb of Makana Local Municipality and the low-income settlement. The total cost of provision of 1 litre of drinking water from alternative resource for the water-only shop (*TWC*) can be calculated using Equation (1).

$$TWC = TC + CC + CR \tag{1}$$

In Equation (1), *TC* is the transport cost per litre, *CC* is the container cost per litre over the average lifetime of a 10 litre PET bottle and the *CR* is the refill cost per litre. The *TWC* value for the middle-income suburb in Makana Local Municipality can be calculated, as shown in Equation (2).

$$TWC = \frac{9}{32.1} + \frac{39-13.5}{8.7\times 8\times 32.1} + 1.35 = 0.28\,ZAR + 0.01\,ZAR + 1.35\,ZAR = 1.64\,ZAR \tag{2}$$

In Equation (2), the first term on the right-hand side represents the average price per 1 litre refilled when travelling from the middle-income suburb to the water-only shop and back. The second term on the right-hand side of Equation (2) is the cost of the 10 litre PET as a water storage container during the lifetime of that single bottle, i.e. 8.7 ± 2.5 months. The numerator in the second term on the right-hand side represents the price of the PET bottle, while the denominator provides and expression of the number of litres that can be placed in a single 10 litre PET bottle over the lifetime of that bottle. The final term on the right-hand side of Equation (2) is the average cost of a refill for a single litre of the treated municipal water at the water-only shop. Results of the calculations indicate that the average price of the provision of 1 litres from the water-only shop, by residents from a middle-class suburb in Makana Local Municipality, was equal to 1.64 ZAR.

The *TWC* value for the low-income settlement in Makana Local Municipality can be calculated, as shown in Equation (3).

$$TWC = \frac{24}{32.1} + \frac{39-13.5}{8.7\times 8\times 32.1} + 1.35 = 0.75\,ZAR + 0.01\,ZAR + 1.35\,ZAR = 2.11\,ZAR \tag{3}$$

Results of the calculations indicate that the average price of the provision of 1 litre from the water-only shop, by residents from the low-income suburb in Makana Local Municipality, was equal to 2.11 ZAR. The *TC* value was 2.68 times higher for the low-income settlement than in the middle-income suburb of Makana Local Municipality. The question must be asked if these values provide the whole picture about the cost of access to the treated drinking water in Makana Local Municipality. The costs must be reflected as the percentage of the income in a given Makan household, which is illustrated in the calculations below.

The lowest income level of a household would be observed if a person is unemployed and during the COVID19 pandemic they were awarded the 350 ZAR social distress grant. It is assumed in the calculations below that the low-income settlement values are representative of the low-income settlements' water provision costs across the Makana Local Municipality and that we are dealing with a single-person household. Let's assume that the treated municipal water from the water-only shop is used as a source of drinking water only during entire month of one grant payment. To complete the assumptions, let's further assume that the daily drinking water consumption is 2 litres in the single-person household on the 350 ZAR social distress grant. Under these assumptions, the single person living on the 350 ZAR grant with spend 126.60 ZAR on provision of 60 litres of treated municipal drinking water per month. This will account for 36.2 % of the monthly income of such a single-person household. Makana Local Municipality is located in the Eastern Cape Province, where the official unemployment rate was reported to be equal to 47.1 % (ECSECC, 2021). There is therefore a large probability that a substantial portion of the Makana population would have receive the 350 ZAR grant during the COVID19 pandemic. Results of the calculations in this context also indicate that the provision of the drinking water from the water-only shop would place substantial financial burden on the low-income households in Makana Local Municipality. This is especially the case, as the average size of the Eastern Cape household has been reported to be 5.48 persons (Global Data Lab, 2013-2021). If the social distress grant was the only income in an average Makana household, the cost of procuring the drinking water from the water-only shop would exceed a single monthly payment of 350 ZAR. If two social distress grant were paid out into a single Makana household of average size, then access to drinking would pose similar challenges as the cost of the drinking water would cost 693.77 ZAR or 99.1 % of the total amount of the two social distress grants.

Let's consider another scenario. The minimum wage is set by legislation, and it ranges from 11.46 ZAR per hour to 20.76 ZAR per hour in South Africa (Government of South Africa, 2021b). If a person works 8 hours a day and 22 days per month, then the single-breadwinner household would have a monthly income between 2016.96 and 3653.76 ZAR per month. A substantial portion of the Makana population would be exposed to minimum wage income conditions. If 5.48 persons in a household procure the treated municipal drinking water from the water-only shop at a rate of 60 litres per person per month, the total drinking water cost amounts to 328.8 litres per household per month or 693.79 ZAR. This was account for between 19.0 and 34.3 % of income in a low-income household, where one breadwinner is earning a minimum wage. If there were 2 breadwinner in an average Eastern Cape size household, then the provision of treated municipal water from the water-only shop would account for 9.5-17.2 % of the total household income. Therefore if a Makana household had an income of at least 2 minimum-wage equivalents, then the drinking water cost could be absorbed into that family's budget. However, not all domestic water uses would be met and this is a problem as there are currently water supply cuts across Makana Local Municipality every 48 hours. The domestic water uses are derived from the per capita water volume which is normally stated to be equal to at least 25 litres/person/day (CER, 2017, page 21). This amounts to 750 litres per person per month and to 4110 litres per average-sized household in the Makana Local Municipality. In the middle-income suburb, the cost of provision of this volume from the water-only shop would amount to 6740 ZAR. In the low-income suburb, the cost of provision of this volume from the water-only shop would amount to 8672 ZAR. In low-income and middle-income suburbs, these costs of drinking water provision from the water-only shop would be prohibitive for the full supply of the minimum domestic water needs of households in Makana Local Municipality. These calculations and conjectures demonstrate the case for the need to have a treated drinking water at the household level or as close to it as possible.

3.3. Calculations of The carbon footprint for alternative provision of drinking water using a 10-litre PET bottle

The carbon footprint of the treated drinking water provision can be calculated using Equation (4). The total carbon footprint of provision of 1 litre of drinking water from alternative resource for the water-only shop (*TCF*) can be calculated using Equation (4).

$$TCF = \frac{TCCF+CCF+CRCF}{32.1} \tag{4}$$

In Equation (4), *TCCF* is the transport carbon footprint per trip to purchase 1 litre of treated municipal drinking water, *CCF* is the container carbon footprint per trip to purchase 1 litre of treated municipal drinking water. The *CRCF* is the refill cost per trip to purchase 1 litre of treated municipal drinking water. The *TCF* value for the middle-income suburb in Makana Local Municipality can be calculated, as shown in Equation (5).

$$TCF = \frac{613.2g\ CO_2}{32.1} + \frac{3300g\ CO_2 \times 0.54336}{32.1} + 2.5g\ CO_2 = 19.1\ g\ CO_2 + 55.9\ CO_2 + 2.5g\ CO_2 = 77.5g\ CO_2 \qquad (5)$$

In Equation (5), the *TCCF* was calculated based on the values from the United States Environmental Protection Agency (US EPA, 2021). Here it is stated that the "8,887 grams of CO_2/gallon of gasoline = 8.887 × 10^{-3} metric tons CO_2/gallon of gasoline" are emitted (US EPA, 2021). Based on the collected data from the passenger vehicle used in this study, the fuel consumption of the 1.5 litre engine vehicle was 17.8 km per 1 litre of gasoline, i.e. 67.64 km per gallon. The average distance for travelled during one refill run of 32.1 litres was equal to 4.7 km (see above), i.e. 0.069 gallon of petrol was used to collect 32.1 litres of treated municipal drinking water from the water-only shop. Therefore the *TCCF* in Equation (5) is equal to the value stated. The *CCF* value was estimated based on the work by Ncube and Borodin (2012), who stated that the transport of the PET bottles has a negligible carbon footprint, but that recycling of 1 kg of PET has a carbon footprint of 3300 g CO_2 equivalent. Reuse of the 10 litre PET bottles in this study is deemed as a form of recycling in this study. Given this fact and the total weight of the PET used in the study, the second term on the right-hand side of Equation (5) is 3300g and 543.36 g. Finally, the carbon footprint of the treatment of the municipal water, which has been shown to be contain faecal contamination during the COVID19 lockdown (Tandlich, 2020). Therefore the value of carbon footprint of 1 m^3 of the treated municipal water will be approximated by the carbon footprint of the respective value for the reused water and set at 2.5 kg CO_2 per 1 m^3 or 2.5 g CO_2 per 1 litre (Cornejo et al., 2014).

The carbon footprint was calculated The *TCF* value for the low-income settlement in Makana Local Municipality can be calculated, as shown in Equation (6).

$$TCF = \frac{2473.74g\ CO_2}{32.1} + \frac{3300g\ CO_2 \times 0.54336}{32.1} + 2.5g\ CO_2 = 77.1g\ CO_2 + 55.9g\ CO_2 + 2.5g\ CO_2 = 135.5g\ CO_2 \quad (6)$$

In Equation (6), the *TCCF* was calculated based on the values from the United States Environmental Protection Agency (US EPA, 2021). The most common taxi, which provides transport between the low-income settlements in Makan Local Municipality and the main mall, is the Toyota Quantum which is a 2.8 litre diesel engine and a fuel consumption of 8.7 litre per 100 km (Toyota South Africa, 2021). Here it is stated that the “10,180 grams of CO_2/gallon of diesel = 10.180 × 10^{-3} metric tons CO_2/gallon of diesel” are emitted (US EPA, 2021). Based on the data from Google Maps, the distance that a taxi travels on a return trip to the main mall in Makana from the low-incomes settlement is 10.6 km. The fuel diesel consumption can be estimated to be at 0.9222 litres of diesel or 0.243 gallon of diesel. Therefore the *TCCF* in Equation (6) is equal to the value stated. The *CCF* value was estimated based on the work by Ncube and Borodin (2012), who stated that the transport of the PET bottles has a negligible carbon footprint, but that recycling of 1 kg of PET has a carbon footprint of 3300g CO_2 equivalent. The reuse of the 10 litre PET bottles in this study is deemed as a form of recycling during the study. Given this fact and the total weight of the PET used in the study, the second term on the right-hand side of Equation (5) is 3300g and 543.36 g. Finally, the carbon footprint of the treatment of the municipal water, which has been shown to be contain faecal contamination during the COVID19 lockdown (Tandlich, 2020). Therefore the value of carbon footprint of 1 m^3 of the treated municipal water will be approximated by the carbon footprint of the respective value for the reused water and set at 2.5kg CO_2 per 1 m^3 or 2.5g CO_2 per 1 litre (Cornejo et al., 2014). The life-cycle assessments, which are often used to calculate carbon footprints of human activities, are incorporated into the values used in the calculations in this study. The carbon footprints of provision of the 1 litre of treated municipal water from this study are lowered than or comparable to the value of Botto (2009, Table 4).

3.4. Integrating remarks and overall implications of the results

Results of this study provide a template for the provision of safe drinking water, which is free of faecal contamination, in the Makana Local Municipality. Rainwater can be disinfected at the place of harvesting using the One Drop disinfectant at the rate of 1 mL per 13.3 litres of treated water. A first-flush device should be installed at the rainwater harvesting tank to eliminate the particulate or organic matter, which can decrease the treatment efficiency of the disinfectant. Treatment of the drinking water at the water-only shop can lead to the elimination of microbial/faecal contamination from municipal drinking water in Makana Local Municipality. As provision of safe drinking water has been a challenge in the study area before and during the COVID19 pandemic, it is important to collect the data related to the provision of the drinking water which is safe for domestic uses and human consumption. Water is an essential part of human existence and challenges in its provision can impede an existence during the COVID19 pandemic, which is a semi-normal and which allows a human being having to navigate the situational reality during the coronavirus pandemic (Iheanetu et al., 2021). For this, minimum 25 litres of drinking water per person per day must be available to the Makana Local population. The cost calculations from this study indicate that there is a disparity of the total price of the treated drinking water provision in Makana Local Municipality, depending on the geographical location of the particular household. To maintain personal hygiene and the normal functioning of the human society, as well as to maintain some level of acceptable normalcy of the individual residents in Makana, the water space must be redefined and access to drinking water must be made mode even, more equitable. Installation of the treatment systems as urban furniture in close proximity to the households across Makana Local Municipality might provide a solution to maintain sufficient and microbially-safe drinking water supply to the municipal population. The relevant technologies could be installed and used as urban furniture in the vicinity of all households across Makana Local Municipality. In this way, the drinking water provision could be ensured for microbiologically safe potable water and the urban furniture in questions must resemble the system used in the water-only shop.

Results of the *TCF/TWC* calculations provide a snapshot of the challenges that residents of Makana Local Municipality during the COVID19 pandemic. The water provision is an essential component to maintain the state of positive forward fluidity of one's existence (Iheanetu et al., 2021; Tandlich et al., 2021), i.e. the state of ribovirocell on a single human inhabitant of Makana Local Municipality. Methodology from this study provides for a simple template for data collection on the challenges in the environmental impacts of drinking water provision, which can be carried out with everyday items and equipment. Internet resources and data derived from everyday activities can be used, as the source of real-world data that can assist in the disaster risks management of the challenges to maintain adherence with non-pharmaceutical interventions and measures to contain the spread of the COVID19 pandemic. This methodology provides a way to collect data on the impacts of the COVID19 pandemic, when increased complexity of the disaster risk management environment is fluid and the involvement of simple tools might speed the ability to collect that data about the impact of everyday human activities on surrounding environment. Citizen scientists could and should be involved in similar data collection on a much larger scale, i.e. to collect data for a larger scale and to ensure that the data from the current study are not automatically extrapolated to the entire Makana population and that the fallacy of composition, in terms of water provision and the related environmental impacts, is avoided.

The calculation results of the carbon footprint of the treated municipal water provision indicate the size of the potential effects of increased traffic to the water-only shop as a source of the CO_2 emissions in Makana Local Municipality. There is again a geographical disparity among the populations in various suburbs of Makana, in terms of their carbon footprint. However, the data indicate another dimension of the provision of safe drinking water in Makana. More precisely, the emission equivalents of CO_2 per 1 litre of treated drinking water indicate the size of emissions which could be avoided if the sustainable supply of safe municipal drinking water was available to all Makana residents at the household level. This, in combination with the urban furniture treatment proposition just above, could improve the chances of adherence to personal hygiene by Makana residents during the COVID19 pandemic. Such an interpretation provides for ensuring the water security in terms of microbial safety, urban landscape, and economic considerations. In other words, the principle of utility is ensured in terms of drinking water provision in Makana Local Municipality. Principle of utility (as summarised by

McLaughlin, 20174, page 288) can be applied here, in as much as ensuring that the drinking water provision, which follows principles of water security, should be optimised geographically in Makana Local Municipality. In this way, the location of a suburb or a settlement will not pre-determine the challenges and results in varying costs of water provision for domestic uses during the coronavirus pandemic.

The COVID19 pandemic has imposed restrictions on movement, the coronavirus disease and the secondary infections or compromised access to healthcare. In other words, the pandemic led to suffering by humanity and the population of Makana Local Municipality is no exception. Sustainable provision of drinking water is necessary to maintain some sort of normalcy, i.e. the ribovirocell state of human existence or positive forward functioning and adaptation of humanity to the “new normal” of the post-COVID19 space-time (Tandlich et al., 2021; Iheanetu et al., 2021). Existence of life is fundamentally linked to water and if it is available the humanity experiences less pain and more pleasure, i.e. higher level of utility is achieved in the COVID19 space-time and in terms of water security. On the other hand, the lack of access to safe and economically affordable water in urban areas such as Makana Local Municipality will lead to more pain and less pleasure in the existence on one residents or the entire population (as summarised by McLaughlin, 20174, page 288). The COVID19 pandemic has caused suffering, e.g. to many employees and businesses or residents due to limited access to drinking water. However, there has also been pleasure experienced by humanity, e.g. the enjoyment of life by the survivors of the coronavirus, the fastest development of the coronavirus vaccines, but limited distribution of those vaccines globally. Even in a case of Makana Local Municipality and in terms of water security, it is clear that disparities continue to exist. It could be said that humanity exists, during the COVID19 pandemic, in a state of *utilitarian qubit*.

The *utilitarian qubit* is defined in this context, as a state of human existence where pain and pleasure are with each member of *Homo sapiens* at all times and it is uncertain to what extent pain, to what extent pleasure has a more pronounced influence on our status as individuals and as humanity. The *utilitarian qubit* could be seen as a starting point of the human existence in the COVID19 pandemic space-time. It can be interpreted here as a condition of the human geography that triggered or brought back into the spotlight the need to ensure that basic public services, e.g. drinking water provision, must be maintained and ensured at all times for all people impacted by the coronavirus. To maintain the ribovirocell state of a human’s existence, to facilitate semi-normal functioning on an everyday basis of humans round the world, but also under local conditions…it is necessary to understand the landscape of the local provision of basic needs of human population. The provision of safe and economically accessible drinking water will fall into this category. The results from the study presented here, provide estimates about the disparities in the access and costs associated with the provision of drinking water free of faecal contamination. The carbon footprint can provide an indication about how the provision of drinking water from municipal sources can be managed to decrease the CO_2 emissions. This in turn could facilitate decreasing the long-term impacts of drinking water provision on the environment of Makana Local Municipality. In this way, the state of *utilitarian qubit* which parts of Makana population might find themselves in, could be altered into the ribovirocell state of positive forward fluidity of Makana residents in the COVID19 space-time.

4. CONCLUSIONS

Transport burden was the largest portion of the costs and carbon footprints of the drinking water provision from alternative sources in Makana Local Municipality. Installation of the treatment systems as urban furniture in close proximity to the households could provide sufficient of supply of safe drinking water to the Makana population during COVID19 and beyond. To maintain the ribovirocell state of a human’s existence, to facilitate semi-normal functioning on an everyday basis of humans round the world, but also under local conditions…it is necessary to understand the landscape of the local provision of basic needs of human population. The provision of safe and economically accessible drinking water will fall into this category. The results from the study presented here, provide estimates about the disparities in the access and costs associated with the provision of drinking water free of faecal contamination. The carbon footprint can provide an indication about how the provision of drinking water from municipal sources can be managed to decrease the CO_2 emissions. This in turn could facilitate decreasing the long-term impacts of drinking water provision on the environment of Makana Local Municipality. In this way, the state of *utilitarian cubit* which parts of Makana population might find themselves in, could be altered into the ribovirocell state of positive forward fluidity of Makana residents in the COVID19 space-time.

ACKNOWLEDGEMENTS

The authors acknowledge the Rhodes University Sandisa Imbewu Fund for partial supporting of the study consumables and equipment. The Faculty of Health Sciences of the Technical University in Liberec is acknowledged for providing resources for the access to literature sources to complete the calculations part of the study. No review of this article has been done by either of the two institutions, so no formal endorsement should be implied by the readers from either university of the study findings.

Conflict of interest

The authors declare no conflict of interest.

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Chidinma Iheanetu

Faculty of Pharmacy and Biotechnology Innovation Centre, Rhodes University, Grahamstown, South Africa

E-mail:

ORCID: 0000-0002-4415-3813

Roman Tandlich

Faculty of Pharmacy and Biotechnology Innovation Centre, Rhodes University, Grahamstown, South Africa

E-mail: r.tandlich@ru.ac.za.

ORCID: 0000-0002-9696-0473