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Citizen science based monitoring of microbial water quality at a single household in a South African local municipality during the COVID19 lockdown

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Abstract

Personal hygiene and access to potable/drinking water, which is safe for human consumption, are critical to containing the COVID19 pandemic. The principle of citizen science, with limited use of laboratory resources, was applied to monitoring of microbial quality of the municipal water supply in Makana Local Municipality in the Eastern Cape Province, South Africa. Samples were taken just before and during 30 days of the strictest phase of the COVID19 nation-wide lockdown in South Africa. The H_2S test kit was used as the basis for the microbial testing, while a cell phone app was used for the temperature monitoring at the author's house. During the study, the ambient temperature ranged from 17 to 29 °C, with decreases below 18 °C occurring on three out of 12 sampling occasions. Thus the results of the H_2S test kit might have been slightly influenced by the fluctuations of the ambient temperature. On 8 sampling occasions between 1 and 4 H_2S test kits were positive for faecal contamination. Three samples or 25 % were free of faecal contamination. One sample had all five H_2S test kits were positive for faecal contamination. Results of statistical testing indicated that potable/drinking water from the municipal supply in Makana Local Municipality was probably faecally contaminated at the author's household on an intermittent basis. Ongoing monitoring of microbial drinking water quality is necessary and continuing at the sampled location.

Introduction

The 2017 United Kingdom Risk Register of Civil Emergencies indicated that there was a very high chance of a pandemic influenza occurring in the next few years (UK Government 2017). Those predictions came true when the COVID19 disease outbreak started in late December 2019 (Tandlich *et al.* 2020). Results of a recent genetic study indicate that the SARS-CoV-2 virus (the causative agent of COVID19) originated most likely in bats in parts of Asia and was subsequently transferred into pangolins where it mutated (Andersen *et al.* 2020). The mutated virus then got transferred humans and mutated again; and started causing mild to severe (respiratory) disease in humans (Andersen *et al.* 2020). The SARS-CoV-2 virus has been shown possess phylogenetic similarities to the causative agent of the severe acute respiratory syndrome (SARS), i.e. the SARS-

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CoV virus (Wang *et al.* 2020). The previous SARS outbreak(s) did not reach the same global proportions as the SARS-CoV-2 virus pandemic. Therefore, even though SARS-CoV-2 virus is not an influenza virus, the scope and impact of the COVID19 pandemic is analogical to the pandemic influenza, which had been predicted as imminent to occur (UK Government 2017).

On 30th January 2020, the World Health Organisation (WHO) declared the COVID19 a health emergency of international concern (WHO 2020a). The COVID 19 pandemic is caused by an infectious disease agent, i.e. a virus, and can therefore be classified as a first-generation disaster (Bulíkova *et al.* 2011). As of 25th June 2020, there have been 9,296,202 confirmed cases of COVID-19, including 479,133 deaths worldwide (WHO 2020b). As the morbidities and mortalities keep climbing on a daily basis, the primary health outcomes of the disasters have been devastating globally and the human cost of the COVID19 pandemic has been staggering. Currently there is no vaccine against the COVID19, which has been approved and is being used for the vaccination of the global population. Therefore mitigation, mainly non-pharmaceutical interventions and public health strategies, are used to contain and to limit the spread of COVID19. Personal hygiene forms a core part of those interventions and strategies to contain the SARS-CoV-2 virus.

Access to sufficient volumes of potable water, which is microbially safe for human consumption and domestic uses is critical for the maintenance of hygiene and thus prevention of the spread of COVID19 (Hyde 2020). Armitage and Nellums (2020) stated that access to water and sanitation is a challenge in many places on Earth, and population in low-income settlements in urban areas could be particularly vulnerable. Neal (2020) stated that a re-alignment of the priorities and functioning of the water sector, as well as uses of water in general, are a must. Parts of South Africa have been experiencing water quality problems since at least 2011 (Luyt *et al.* 2011; Tandlich *et al.* 2014; Malema *et al.* 2019) and drought since at least 2015 (Monyela 2017). Previous studies by the author and his collaborators indicate that municipal potable/drinking water has suffered from faecal contamination in Makana Local Municipality in the Eastern Cape Province of South Africa (Luyt *et al.* 2011).

On 15th March 2020, a national state of disaster was declared in South Africa (South African Government Gazette 2020a). From 27th March 2020, the entire territory of South Africa was placed under lockdown, i.e. movement of the population was limited to staying at home and only leaving personal dwellings/households to perform very limited activities (South African Government Gazette 2020b). Examples include purchase of groceries and or visiting a doctor's surgery (South African Government Gazette 2020b). Provision of drinking/potable water to the households, i.e. the taps not running dry would have been the most important task for the South African government at local, provincial and national level. For this, the National Department of Water and Sanitation has been rolling out a programme for the installation of water storage facilities across the territory of South Africa (All Africa 2020). Access to drinking/potable water is critical to wash hands and to maintain personal hygiene. At the same time, the microbial safety of the provided drinking water is also of the essence during the COVID19 pandemic. This is mainly to prevent the outbreak of diarrhoeal diseases which can cause cascading effects of the COVID19 pandemic.

Citizen science is a concept where the laymen/persons who have not received a formal scientific training perform data collection on topics of scientific interest/research (*e.g.* Angala *et al.* 2019). The author has worked and collaborated with other researchers over the past decade on the development, usage and benchmarking of the H_2S test kit against standard indicator microorganism test for microbial water quality (Luyt *et al.* 2011; Tandlich *et al.* 2014; Malema *et al.* 2019). The H_2S test kit is a viable tool to perform testing for faecal contamination of drinking water in areas where formal laboratory access is logistically a challenge (Luyt *et al.* 2011; Tandlich *et al.* 2014; Malema *et al.* 2019). The correspondence rates, along with the rates false positive and false negative results, in the analysis of rainwater was recently published on by Malema *et al.* (2019).

Use of the kit in citizen science monitoring was also conducted previously (*e.g.* Angala *et al.* 2019; Nqowana 2019). It is assumed in further text of this

study that there is similarity in the monitoring performance of the H_2S test kit and the standard indicator mcroorganisms in the detection of faecal contamination in the Makana municipal drinking water and the rainwater in the Eastern Cape Province of South Africa (Malema *et al.* 2019). The author reports the results of a one-location monitoring of microbial water quality just before and during the strictest phase of the COVID19 nationwide lockdown in South Africa. Data was collected in isolated settings without or with limited access to a formal laboratory, and using the tools of citizen science. The author is a formally-trained scientist, but the tools used here are those that would be available to the citizen scientists, with limited equipment and laboratory assistance.

Experimental

Temperature calibration and measurement of the ambient temperature during the study

The first task in the project was to devise a low-cost, reliable and laboratory-independent method to monitor the ambient temperature during the H_2S test kit incubations. During the water testing, the ambient temperature was monitored in the lounge, bathroom (sampling site) and the cupboard used to store the H_2S test kit samples at the author's house. This was done using the Thermometer App (Trajkovski Labs, www.trajkovski.net). That measurement was done to establish whether the ambient/incubation temperature for the H_2S test kits was inside the recommended interval of 18 – 25(37) °C (Tandlich *et al.* 2012).

The Thermometer App was downloaded onto the author's cell phone from Google Play store (Alphabet Inc., Mountain View, USA). The temperature values, which were measured using the App during the study, are designated as T_{App} in further text of this article. The T_{App} readings were obtained by placing the cell phone with the active Thermometer App onto the same surface in the respective room in the house or in the cupboard with the H_2S test kit samples (see below), until a constant temperature reading was achieved. The average time for achieving a constant T_{App} value was equal to 2 – 5 min, if the ambient temperatures ranged from 17 to 25 ºC. The T_{App} readings stabilised after about 15 min, around the minimum and maximum temperatures measured in the study (Table 1).

The T_{App} readings were calibrated against the temperature readings taken suing a portable, but accurate thermometer (designated as T_{Real} in further text). The accurate thermometer was purchased from RS Components (product number: RS stock no. 798-9133, Midrand, South Africa). This accurate thermometer was calibrated against the mercury-based thermometers in the author's laboratory in the Faculty of Phamacy at Rhodes University. The two types of thermometers were found to consistently provide the same readings of air temperatures. Therefore the accurate thermometer was used in the study for the T_{App} *vs.* T_{real} calibration.

The T_{App} *vs.* T_{real} calibration was done by taking readings with both methods at the author's house on 10 sampling days during the study (Table 1). If the temperature readings from the App are to be reliable, then there must be a correlation between the T_{Real} values and the T_{App} values. This correlation was investigated using the Spearman's correlation coefficient (*Rho*) using the Social Sciences online calculator (https://www.socscistatistics.com/tests/spearman/default2.aspx). The correlation was also investigated using the Pearson correlation coefficient (*r*) using the same programme (see https://www.socscistatistics.com/tests/pearson/default2.aspx for details).

The *Rho* and *r* values indicated a strong and linear correlation bewteen T_{App} and T_{Real}. Thus an equation was derived using linear regression to convert T_{App} into the T_{Real} for the temperature monitoring during the microbial water quality sampling (Microsoft Excel 2013; Microsoft South Africa, Johannesburg, South Africa). The linear regression-based equation is shown in Eq. 3, the T_{App} readings were taken throughout each sampling day and converted into the T_{Real} (see below).

Microbial water quality monitoring and volume calibration

The microbial water quality monitoring was based on the use of the H_2S test kit and a cell-phone App. All consumables were purchased from the same

suppliers and the H_2S test kits were prepared using the general methodology of Luyt *et al.* (2011) and Malema *et al.* (2019). Those activities had been carried out in a microbiological laboratory in the Faculty of Pharmacy of Rhodes University, Makana Local Municipality before the lockdown began. Minor changes in the logistics of the sampling were required, as compared to Luyt *et al.* (2011) and Malema *et al.* (2019). That was the result of the nationwide lockdown. Sampling was performed on the Makana-supplied municipal drinking/potable water in one sampling location, i.e. a bathroom at the author's house. That sampling took place from 26th March 2020 (Day 0 of lockdown) until 30 days into the lockdown (number of days increasing accordingly to the length into the lockdown period, e.g. 27th March 2020 was day 1 and so on).

All samples were taken in the said bathroom at the author's house from a sink tap/tap in a hand-wash basin. The house is located in Kingswood, which is a middle-class to upper-middle class suburb in the Grahamstown/Makhanda area of Makana Local Municipality. During a particular sampling, the outside of the H_2S test kits and the sampled bathroom tap were surface-sterilised using baby wet wipes (purchased before the onset of the lockdown Crazy Store, Grahamstown/Makhanda, South Africa). The single bathroom tap was opened for 10 seconds and one H_2S test kit was filled to half volume with the sampled drinking water. The H_2S test kit was then closed and hand-shaken for 10 seconds. The process was repeated with 5 H_2S test kit during a single sampling. Therefore a sample in further text represents one set of five H_2S test kits taken on a single sampling occasion/day. The single-sample volume of potable water was measured by taking readings from the house's municipal water meter right before and right after the individual sampling was completed.

The municipal water meter at the author's house was not calibrated by Makana Local Municipality since 2015. Therefore a citizen-science based calibration of the water meter was performed by the author after the lockdown level decreased, i.e. after the 1st June 2020. This was done with the minimum necessary use of laboratory resources. For the calibration, 3 five-litre plastic bottles were taken from the author's house. The water meter reading was taken from the municipal water meter and it was recorded. Then a single of those bottles filled up to the brim in the bathroom at the author's house. Right after the individual water bottle was filled to the brim, another reading was taken from the municipal water meter. The sampling with 5 litre bottles was repeated three times in total. All three bottles were then transported into the laboratory at Rhodes University and weighed using a Micro T7E balance (Premier Scale Services, Johannesburg, South Africa). The weight of each 5 litre bottle, when filled with the sampled municipal drinking water was recorded. The water was then emptied out of the bottles and the inside of the bottles was dried. All of the five-liter bottles were weighed again and volume of each 5 litre bottle was calculated using Eq. 1.

$$Volume\ of\ sampled\ water = \frac{(m_{water} - m_{bottle})}{\rho} \quad (1)$$

In Eq. 1, m_{water} is the weight of the five-litre bottle filled with sampled water in kg. At the same time, $m_{botttle}$ is the weight of the empty five-litre bottle in kg and ϱ is the density of water at the average T_{Real} in the author's house and the laboratory at the Faculty of Pharmacy. The ϱ value was calculated as 998.4305 $kg.m^{-3}$.

After the particular sampling, the five H_2S test kits were kept at room temperature in dark. Colour change from brown to black was monitored for 72 hours, as mentioned in Tandlich *et al.* (2014) and Malema *et al.* (2019). A negative H_2S test kit was recorded and was considered negative for faecal contamination, if the liquid colour inside it remained brown after 72 hours of incubation. On the other hand, an H_2S test kit was recorded as positive for faecal contamination, if the liquid inside it turned black after 72 hours of incubation. Results of the water samples were evaluated in the following way. Each municipal water sample was assigned a score (X) of 0, 1 or 2. The score 0 was assigned to a sample, if all five H_2S test kits were negative for the faecal contamination on a particular sampling occasion (Nhokodi *et al.* 2016; Malema *et al.* 2019). The sample was assigned a score of 1, if 1-4 H_2S test kits were positive for the faecal contamination (Nhokodi *et al.* 2016; Malema *et al.* 2019). Finally, the sample was assigned a score of 2, if all five H_2S test kits were positive for the faecal contamination (Tandlich *et al.* 2014; Nhokodi *et al.* 2016; Malema

et al. 2019). Then the average H_2S test kit score (X_{avg}) was calculated using Eq. 2.

$$X_{avg} = \frac{\sum_1^{12} X_i}{12} \quad (2)$$

In Eq. 2, X_i stands for the score in a particular one of the 12 samples taken at the author's house during the study. If the potable water, supplied by Makana Local Municipality to the auhtor's house, was free of faecal contamination and microbially safe for human consumption, then the X_{avg} value was not statistically significantly different from 0 at 5 % level of significance. If the potable water, supplied by Makana Local Municipality to the author's house, was not free of faecal contamination and microbially safe for human consumption based on the H_2S test kit results, then the X_{avg} value would be statistically and significantly different and higher than 0 at 5 % level of significance. The *X* data statistical testing was tested for normality using the Kolmorogov-Smirnov test at 5 % level of significance (see https://www.socscistatistics.com/tests/kolmogorov/default.aspx for details).

Periodically throughout the study, blank samples were taken by pouring the Oasis water was into 5 sterile H_2S test kit. The Oasis water is the reverse-osmosis-treated water from Oasis (Grahamstown/Makhanda, South Africa). Based on preliminary results which were obtained before the current study had begun, the Oasis water was found to be free of faecal contamination. This was the case at the point of purchase and during storage of up to 7 – 9 weeks (data not shown). During the study, the blanks were prepared by pouring 20 mL of Oasis water into five sterile H_2S test kits using. Blank sampling, processing and incubations were conducted a similar procedure, as stated for the samples above. All blanks were negative for faecal contamination throughout the study. Therefore results of the study shown in Table 2 were not influenced by the sampling process, sample processing or incubations during the study.

In addition to blanks being processed, the surface of the sampled sink tap was tested periodically for the presence of potential faecal contamination. Twenty mL of Oasis water was poured into a sterile H_2S test kit and the content was hand-shaken with the kit lid on. After the liquid turned brown inside the kit, a sterile cotton swab was submerged into the liquid. That moistened swab was used to swipe the faucet of the sampled sink. The process was repeated for the neck of the tap and the pipe leading into the sink. The cotton part of each swab was then cut with sterile scissors (sterilised with 70 % isopropanol hand sanitiser, Buco, Grahamstown/Makhanda, South Africa). Twenty mL of Oasis water was added and the kit was closed with the lid. Contents were hand-shaken and the H_2S test kits were incubated in the same fashion as samples or blanks. All of the swab kits were all found to be negative for faecal contamination after 72 hours of incubation. Therefore, the surface sterilisation with the baby wet wipes was efficient in prevention of cross-contamination of the H_2S test kits from the bathroom sink tap at the author's house (the samples tap). Based on this observation and the negative blanks, any faecal contamination detected in the potable municipal water at the author's house originated from the distribution system or lack of treatment by Makana Local Municipality.

Results and Discussion

Temperature calibration and measurement of the ambient temperature during the study

The values of T_{App} and the T_{Real} are shown in Table 1. Usage of the Spearman's correlation to describe the relationship between the independent and the dependent variable implies that there is a the relationship between the two, but this is not necessarily linear. The *Rho* value for the T_{App} and the T_{Real} was equal to 0.9908 and the value was statistically significant on the 5 % level of significance (*p*-value = 0). Therefore there was a general correlation between the T_{App} and the T_{Real}. The Pearson correlation coefficient value (*r*) for the T_{App} and the T_{Real} was equal to 0.9902 and the value was statistically significant on the 5 % level of significance (*p*-value < 0.00001). The relationship between the two variables was linear, based on the *r* value. The final equation from the linear regression analysis can be seen in Eq. 3.

$$T_{Real} = 0.7803 + 0.8298 \times T_{App};\ R^2 = 0.9822 \quad (3)$$

Temperature readings from the study and related to the microbial samples incubations can be found

Table 1. Results of temperature calibration between the readings from the Trajkovski Lab App (T_{App}) and the accurate thermometer (T_{Real}).

T_{App} (°C)	T_{Real} (°C)
14	12
17	15
18	15
29	25
23	20
21	19
21	18
24	20
25	23
36	30

in Table 2. As it can be seen, the T_{Real} ranged from 17 to 29 °C. The minimum value of T_{Real} was observed on days 13, 21 and 30 of the strictest phase of the national lockdown in South Africa. This is outside of the interval from 18 to 25(37) °C which was previously reported as the optimum incubation temperature (Tandlich *et al.* 2012). Results of the H_2S test kit might have been influenced by the fluctuations of the ambient temperature at the author's house. However, this influence was likely minimal from a practical point of view, as the majority of the temperature readings were inside the optimum ambient temperature interval. On the other hand, the temperatures on days 13, 21 and 30 also icnreased above 17 °C for parts of the respective day.

Microbial water quality monitoring and volume calibration

The average sampled volume of municipal potable water per single sampling was equal to (5.5 ± 0.2) litres. During the calibration of the water meter, the average volume of sampled water, based on the water meter reading, was on average also equal to (5.5 ± 0.2) litres. The volume of sampled water based on the weighing is equal to (5.1 ± 0.1) litres. The calculator for the Social Sciences, used in other test in this paper did not allow for the calculation due to low number of replicates. Therefore the Mann-Whitney test at 5 % level of significance was performed using the Statology Calculator (see https://www.statology.org/mann-whitney-u-test-calculator/ for details). The test criteria were as follows: the *U* statistic = 11; *p*-value = 0.4895 for the two-tailed test. Therefore, the volume readings based on the water meter and the weighing method/citizen-science calibration were not signifcantly different at 5 % level of significance.

Table 2. Results of the microbial water quality in Makana Local Municipality from 26th March 2020 (Day 0) and the lockdown days (Day 1 to Day 30 in the lockdown).

Sampling day	T_{Real} (°C)	X_i (dimensionless)
0	20 – 22	1
1	21 – 24	1
2	25 – 29	0
3	22	1
5	22 – 23	1
7	23	1
10	22 – 23	0
13	17 – 21	1
17	21	0
21	17 – 22	1
24	23 – 27	2
30	17 – 21	1

The *X* values for all 12 samples are shown in Table 2. Eight out of 12 samples (67 %) had a score of 1, i.e. on 8 sampling occasions between 1 and 4 H_2S test kits were positive for faecal contamination. Three of the twelve samples or 25 % were free of faecal contamination, i.e. had a *X* value of 0. One sample had a score of 2 and this occurred on day 24, when all five H_2S test kits were positive for faecal contamination. Microbial water quality for the Makana municipal water supply was comparable just before the strictest lockdown phase and during its duration. Compared to the results of Nhokodi *et al.* (2016), the current study had a lower proportion of the municipal water samples which are free of faecal contamination, i.e. 25 % *vs.* 72 %.

The *X* data statistical testing was tested for normality using the Kolmorogov-Smirnov test at 5 % level of significance. Data was found not to be significantly different from a normal distribution (*D*-statistic = 0.36849, *p*-value = 0.05723). Next, the *t*-test at 5 % level of significance was run to check whether X_{avg} was statistically significantly different from 0. The X_{avg} value was equal to (0.83 ± 0.57) and it was statistically and significantly different, as well as higher, than 0 (*t* statistic = 5, *p*-value = 0.0002-0.0004, at: https://www.socscistatistics.com/tests/tsinglesample/default2.aspx). That means the average *X* value (or level of faecal contamination of the tested drinking water) in Makana Local Municipality was

higher than 0, i.e. there is significant indication that potable water in Makana Local Municipality was microbially contaminated during days 0 – 30 of the strictest phase of the national lockdown in South Africa. This, however, only applies to the author's house. Next, the *t*-test at 5 % level of significance was rerun to check whether X_{avg} was statistically significantly different from 1. The X_{avg} value was not statistically significantly different from 1 (*t* statistic = -1; *p*-value = 0.3388). Therefore the municipal supply of drinking water at the Kingswood suburb in Grahamstown/Makhanda was intermittently contaminated with faecal contamination during the 0 – 30 days of the strictest phase of the national lockdown in South Africa. There were no occurence of diarrhoeal diseases at the author's house during the sampled period. However, it has to be stated that the municipal water supply was not used for drinking. The domestic uses of the municipal drinking water were greywater production and cooking.

Results of the current study indicate that microbial water quality could have occurred in Makana Local Municipality during the lockdown. These findings should, however, be treated with caution, as only one sampling location could be sampled. That was the result of taking place during the strictest phase of the COVID19 lockdown in South Africa, i.e. the limited movement of the population. Further sampling is currently ongoing and it began once the limitations on movement have been eased across South Africa, i.e. after 1st June 2020. Ongoing sampling will be exnpanded from the middle-class and upper-middle-class neighbourhood to include the communal taps that are used to supply in low-income settlements around Makana Local Municipality. These will be an extension of the networks and working relationship with stakeholders which have already been established (Nqowana 2019).

Citizen science in water resource management has been studied by various authors in South Africa (*e.g*. Graham and Taylor 2018). Building of community of practice focused on various aspects of the water resource management and the use of web platforms have been utilised (Graham and Taylor 2018). Many citizen-science water quality monitoring programmes have been ongoing around South Africa and the world. In Makana Local Municipality, a web-based tools to report problems with water service delivery had been developed some time ago (MobiSAM 2020). These and similar strategies have been instrumental in the improvement of tools for improved water management in South Africa, empowerment of the population in water-related matters and in increasing some capacity in the water sector in the govenrment sphere around the country.

Collaboration between Rhodes University and the Technical University of the Liberec, both of which the author is currently associated with, has been underway since 2019. It will be focused on the bench-marking the citizen science approach from this study against the best practices from the European Union. In addition, the citizen science approach and relevant best practices will be benchmarked for the disaster risk and emergency management space through the The International Emergency Management Society (TIEMS). This is an ongoing engagement of TIEMS on COVID19 (Tandlich *et al*. 2020).

Conclusions

Data on microbial quality of municipal water supply during the lockdowns are necessary for maintenance of hygiene measures and to curb the COVID19 spread. In addition, microbial quality of drinking water supplies that are available to the South African population must be maintained in compliance with the regulatory requirements. This is necessary to prevent the development of cascading disasters impacts during the COVID19 lockdowns. Prevention of the cascading effects of disasters is critical to prevention of drainage human and other resources from the public health COVID19 campaigns. Preliminary data from this study provide a snapshot of possible problems with microbial water quality in the Makana Local Municipality in the Eastern Cape. Further research is ongoing.

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Conflict of Interest

The author declares that they have no conflict of interest.

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