

Wastewater Epidemiology for the Off the Grid Bedouin Community: A Proof-of-Concept Study

Submitted to the Ministry of Environmental Protection

**Authors: Clive Lipchin and Fareed Mahameed,
Center for Transboundary Water Management, Arava Institute for Environmental Studies**

1. Introduction

1.1 The Negev

The Negev is an arid and semi-arid region that covers approximately 60% of Israel (Britannica, 2022b). As seen in **figure 1.i)**, the Negev is roughly the shape of an inverted triangle that is bounded by Egypt's Sinai Peninsula to the West, the Jordan Valley to the East, and the Judean Mountains to the North. Mean annual rainfall is below 300mm across the Negev (Fuks et al., 2017). The Negev, as seen in **figure 1.ii)**, can be divided into six physiographic regions: (a) the Precambrian igneous-metamorphic Eilat hills in the south; (b) the highlands and plateaus of the central Negev; (c) the Beer Sheva basin; (d) sandy areas of the western Negev; (e) the coastal plain in the northwest; (f) the Arava Rift Valley in the east (Singer, 2007).

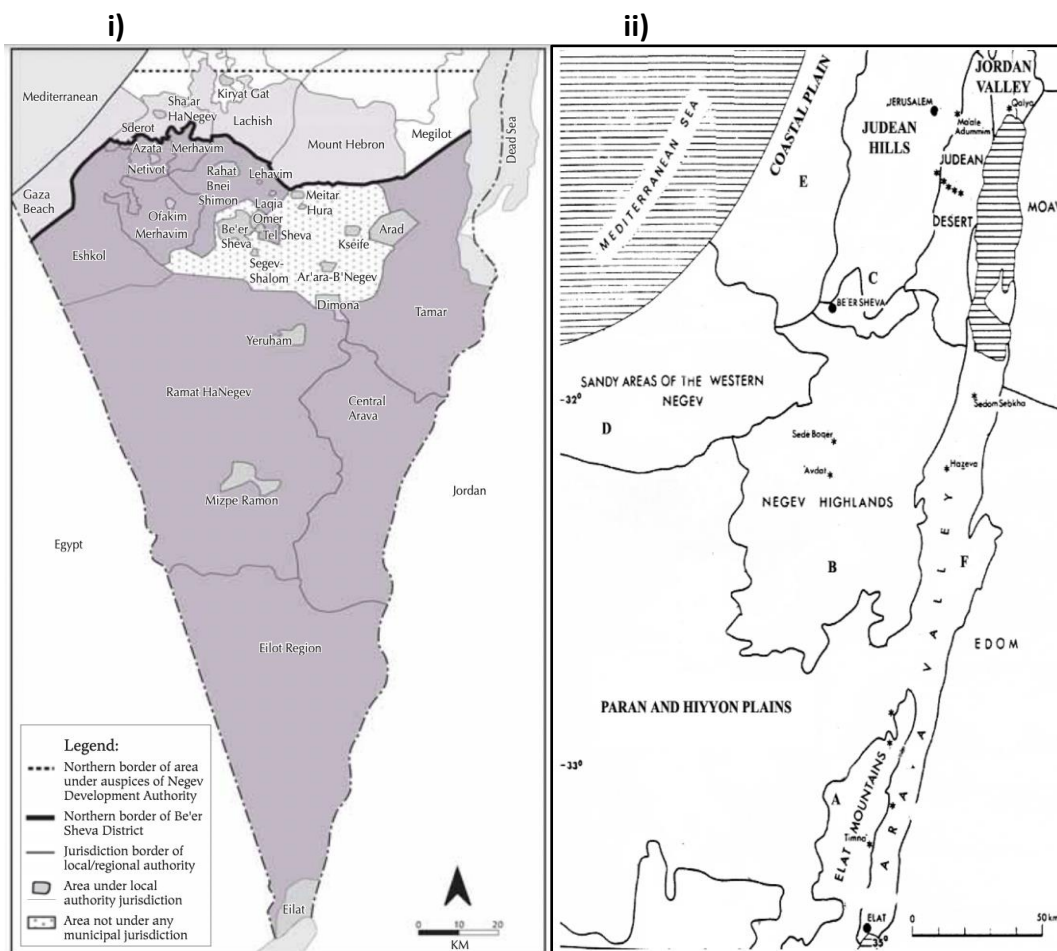


Figure 1.i) Municipal districts in the Negev, southern Israel (Rudnitzky et al., 2012);
ii) Physiographic regions of the Negev (Singer, 2007)

1.2 Bedouin Populations in the State of Israel

During the early 1950s and until 1966, the State of Israel attempted to concentrate the Bedouin population within the ‘al-Siyāj’ (سياج) zone under military administration (The Regional Council for the Unrecognized Villages in the Negev & Negev Coexistence Forum for Civil Equality, 2019). In the 1960s a movement began for ‘planned towns,’ which were created on state lands by the government to further limit nomadic lifestyles and unplanned settlements through the promise of providing public services (Medzini, 2012). As the unrecognized villages of Bedouin continued, the Israeli government transitioned their approach from planning towns to recognizing some of the settlements that existed. The condition upon recognition was that no additional settlements would be legalised. The government created incentives for moving to planned towns and some Bedouin either moved or stayed in the newly recognized settlements, some however, continued to live in the unrecognized settlements. Deeming transitioning to centralised living as an infringement on their civic, economic, and territorial rights, those who continued to live in the unrecognized villages hoped the government would eventually feel compelled to accept the reality of the settled areas. As a result of this, Bedouin communities are classified as either ‘recognized’, ‘in the process of being recognized’, or ‘unrecognised’.

In 2021, the State of Israel recorded an overall population of approximately 9.3 million, of which the Bedouin population constituted approximately 3% of the population (Ben Gurion University of the Negev, 2022). This study will focus on the 73,000 people, 0.8% of Israel’s population, that lives in “unrecognised villages” as well as the “recognized villages” that still lack infrastructure. This study will be limited to the Besor–Hebron–Be’er Sheva watershed in the Negev. Home to approximately 900,000 people, this region contains over 95% of unrecognised villages (Haj-Yahya et al., 2021; Negev Coexistence Forum for Civil Equality, 2014). This study will focus on the recognized and unrecognised Bedouin villages without sanitation infrastructure.

1.3 Village Recognition

While the planned towns were constructed with infrastructure, the goal of recognizing villages is ultimately to provide infrastructure to the existing community. While some recognized villages have achieved this, there are many villages that have been recognized and have yet to gain access to sanitation infrastructure (Association for Civil Rights in Israel, 2019b). Therefore, while the legal status may have changed to recognized, and the villages appear on maps, there remain both recognized and unrecognised villages reliant on decentralised methods of meeting infrastructural needs.

The residents and communities living in the unrecognised villages in the Negev live without connection to an electric grid, maintained road systems, and other infrastructure (Rudnitzky et al., 2012; Haj-Yahya et al., 2021). As the lands on which these communities live are regarded as State lands, any structures built are considered illegal and can face demolition (Rudnitzky et al., 2012). Further, without centralised resources from the government and dependable housing structures, these communities primarily rely on diesel generators for electricity which create air and noise pollution. Without garbage removal services, the Bedouin often resort to burning their garbage which further pollutes the air. As a result of

their living conditions and the concessions made to meet their needs, there are many health concerns for the Bedouin communities living in unrecognised villages.

1.4 Rights

1.4.1 Schools

Though the locations of villages remain unrecognised, the populations are recognized as citizens of Israel and are therefore entitled to education under the compulsory education law enacted in 1949 (Center for Israel Education, n.d.). The compulsory education law requires the state to ensure free, available, and accessible education for every child (Association for Civil Rights in Israel, 2019a). Therefore, even without a physical address, each village is legally entitled to education facilities and therefore regional councils were formed as an executive arm to legally collaborate with the Ministry of Education and to oversee education services provided. The Abu Basma regional council was established in 2005, and since 2012 has been split into the Al-Kasom Regional Council and the Neve Midbar Regional Council to manage the growing populations and schools. Though the regional councils do oversee schools in unrecognised villages, they primarily operate schools in recognised villages that provide education for approximately 18,000 students from the neighbouring unrecognised villages (Association for Civil Rights in Israel, 2020).

1.4.2 Water Conditions

The legal right to water in Israel falls within the bounds of Israel's "Basic Right to Human Dignity and Liberty" (Negev Coexistence Forum for Civil Equality, 2014). Villages are classified as either "connected" or "unconnected" in their water resources based on their access to Mekorot (Israel's national water company) services (Negev Coexistence Forum for Civil Equality, 2014). 'Connected' communities are those that have been granted the authority to independently connect to nodes along Mekorot's water pipelines. The connection to the water pipeline, however, is typically a 1-inch pipe that provides shared access and therefore can be insufficient to service the Bedouin communities. Due to geographic conditions, there remain situations in connected communities where families residing at the periphery, continue to experience living conditions similar to unconnected communities. 'Unconnected' communities are those that have not been authorised to connect to the water pipeline and as a result, rely on purchasing water from private suppliers and storing water in tanks.

1.5 Wastewater Practices

Unrecognised Bedouin villages are not connected to the centralised sewage system and therefore 97.9% rely on open gutters and cesspits to dispose of wastewater (Rudnitzky et al., 2012). As the government does not recognize the community's location, it does not provide services to the community. The sewage infrastructure becomes the responsibility of the community of residents and therefore they must install and maintain the systems (Negev Coexistence Forum for Civil Equality, 2014). Cesspits are the most common form of wastewater storage in unrecognised Bedouin villages. Cesspits hold wastewater for short periods of time until they are emptied, and though they should be constructed to be water-tight to contain pathogens, this is often not the reality (Adegoke & Stenström, 2019). Even though cesspits aren't designed to release effluent, effluents percolate into the surrounding soil which poses a contamination hazard to groundwater. Faecal contamination of groundwater is a leading concern for public health and the operation and maintenance of cesspits has many vulnerability points for exposure, especially in regard to emptying

processes. If the cesspits are emptied infrequently the wastewater will percolate into the soil and groundwater, and there is a risk of overflow. Poor management is often due to the financial burden of maintaining the cesspits (Thafer et al., 2022). In the neighbouring West Bank, emptying cesspits were found to cost families 6% of the household's monthly income (Al-Atawneh et al., 2017)

Cesspits designed poorly with insufficient management pose threats to the health of the local population, the environment, and the health of the watershed.

2. Wastewater Epidemiology

Groups of scientists in countries such as the Netherlands, the US, and Israel have begun using wastewater testing as a non-invasive way to measure the prevalence of disease such as the coronavirus in their communities (Singer et al., 2023). The data can be used to gain a sense of how many people may have had the virus asymptotically in addition to those showing symptoms for the disease. Testing for the virus in wastewater raises the prospects of using urban sewage control as a non-invasive tool for early detection of infections in the population and can be used to indirectly monitor the spread of the virus. This testing can lead to early detection of its possible reappearance, thus allowing recognition and restriction of any new epidemic outbreaks more quickly and identification of high infection hot-spots that can then be quarantined from the rest of the population. Continuous monitoring of the virus in wastewater can also help predict future outbreaks of the disease and allow authorities the time needed to act accordingly to curtail another outbreak. However, the current studies underway are focusing on centralized wastewater treatment facilities that service large urban populations (Yaniv et al., 2023). Little is yet known on the spread of COVID-19 and other diseases in wastewater for communities whose wastewater remains untreated or poorly treated, left flowing in the environment, or collecting in poorly managed cesspits. This research is being carried out in the Bedouin community in southern Israel to assess the exposure of the community to COVID-19 by monitoring the wastewater being discharged into cesspits. In addition, the study also looked at a suite of chemical sweeteners as an indication of the nutritional status of the Bedouin population.

Rapid urbanization and modernization in Bedouin communities have led to changes in dietary patterns, with increased consumption of processed foods that are often high in calories, sugar, and unhealthy fats. This shift in diet, coupled with limited access to fresh fruits, vegetables, and other nutritious foods, can contribute to health issues such as obesity, diabetes, and cardiovascular disease.

Efforts have been made by both governmental and non-governmental organizations to address these issues and improve the nutritional status of Bedouin communities in the Negev. These efforts include initiatives to increase access to healthy foods, promote nutrition education, and improve healthcare services. However, this is the first study of its kind that actually quantifies the nutritional status of the Bedouin population via wastewater sampling.

Wastewater monitoring could provide early, efficient, and localized data about the increase or decrease of coronavirus levels in a population as well as the nutritional status of the population. Wastewater monitoring could provide early warnings of disease outbreaks. It

could provide data needed about when to end lockdowns and when to reinstitute them. Measuring viruses in wastewater in effect can test an entire population as opposed to expensive individual testing of symptomatic individuals only. This study will gather data on virus levels in wastewater and attempt to assess how communities that are under-served by wastewater and sewage infrastructure are at risk of infection from untreated or partially treated wastewater. Data already suggest that Israel's Bedouin populations, many of which rely on inefficient porous cesspits to store sewage, are especially at risk of infection.

The research will vastly improve the capacity of communities and stakeholders to effectively combat the current pandemic and also future outbreaks of this and/or other viral diseases. It will lead to better overall wastewater management in the region through the linkage of wastewater treatment to public health. Further, due to the testing for sweeteners the study will also contribute to the understanding of the nutritional status of the Bedouin population and can help to develop public health campaigns for better and healthier nutritional choices on behalf of the population.

3. Methodology and Study Area

The wastewater sampled for this study came from the toilets of the Al-Furaa school located in the Al-Furaa unrecognized village (figure 2). The average flow rate from the toilets was 10 cubic meters per day. Sampling was done over a 24-hour time period. Samples were taken for analysis once a week over a three-month period. Samples were collected via inserting a passive sampler into the sewage collection cesspit located behind the toilets. The passive sampler was designed by the wastewater sampling company KanDo. It was made up of a tube filled with an absorbent sanitary pad (figure 3).

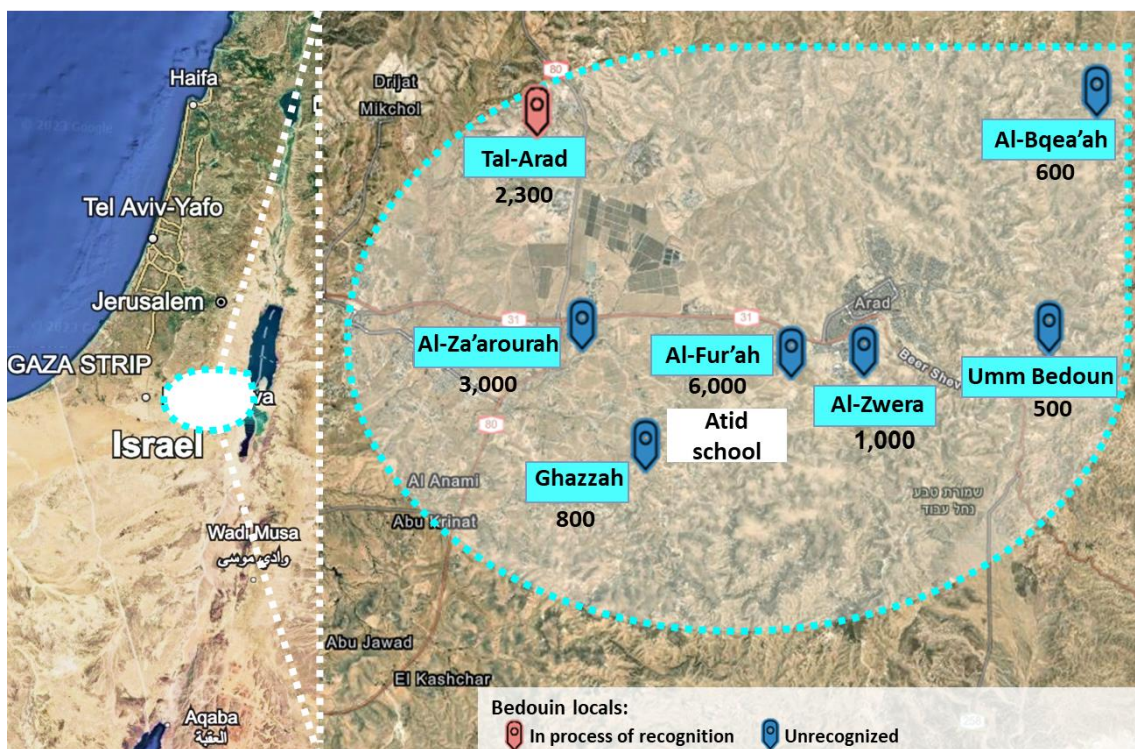


Figure 2: Study area showing location of the Al-Furaa school



Figure 3: Passive sampler used in the study designed by KanDo

Samples were taken to the laboratory of the Department of Biotechnology Engineering at Ben Gurion University for analysis. Polymerase chain reaction (PCR) analysis using quantitative real-time PCR (qPCR), were employed to assess the presence of SARS-CoV-2, other pathogens and sweeteners.

4. Results

Table 1 shows a list of the sweeteners that were tested and their concentration per date of sampling.

Dates	Concentrations ($\mu\text{g/ml}$)							
	Saccharine	Ace-K	Aspartame	Sucralose	Mannitol/ Sorbitol	Xylitol	Maltitol	Isomalt
14/02/2023	13.5	-	-	2.531	17.925	-	-	-
19/02/2023	7.858	-	0.386	-	0.276	-	3.085	0.172
21/02/2023	3.529	3.41	0.227	0.768	1.181	9.015	-	-
26/02/2023	0.418	-	-	0.76	-	-	-	-
28/02/2023	0.085	0.471	-	0.255	0.086	0.822	-	-
05/03/2023	0.22	-	-	0.613	1.65	-	0.024	-
12/03/2023	0.343	-	-	0.396	3.606	7.157	0.026	-
19/03/2023	0.088	-	-	0.493	0.15	-	-	-
26/03/2023	0.132	-	-	0.1	0.493	-	-	-
28/03/2023	0.173	-	0.247	0.554	11.599	25.962	-	0.277
02/05/2023	3.356	-	-	5.941	27.07	-	-	0.727
07/05/2023	0.243	-	-	1.147	1.406	9.816	-	7.346
14/05/2023	1.186	-	-	-	46.985	51.128	2.251	2.581
21/05/2023	0.346	-	-	0.653	6.26	15.868	-	-
28/05/2023	1.616	-	-	3.141	3.879	5.191	0.2	0.053
11/06/2023	0.529	-	-	1.831	28.687	25.975	10.375	12.708
13/06/2023	0.39	-	0.721	1.691	11.873	32.249	0.997	1.664

Table 1: Concentration of sweeteners tested in this study. The darker the green color the higher the concentration.

From the table, mannitol/sorbitol and xylitol were shown to have relatively high concentrations. Mannitol and sorbitol are commonly used as sugar substitutes or sweeteners in a variety of food products, particularly those marketed as "sugar-free" or "diet" options. Xylitol is a sugar alcohol commonly used as a sweetener in various food products, particularly those marketed as sugar-free or low-sugar options.

Figure 4 shows the concentration of SARS-CoV-2 that were found in the wastewater samples. The data show the presence of SARS-CoV-2 before Ramadan but not after Ramadan.

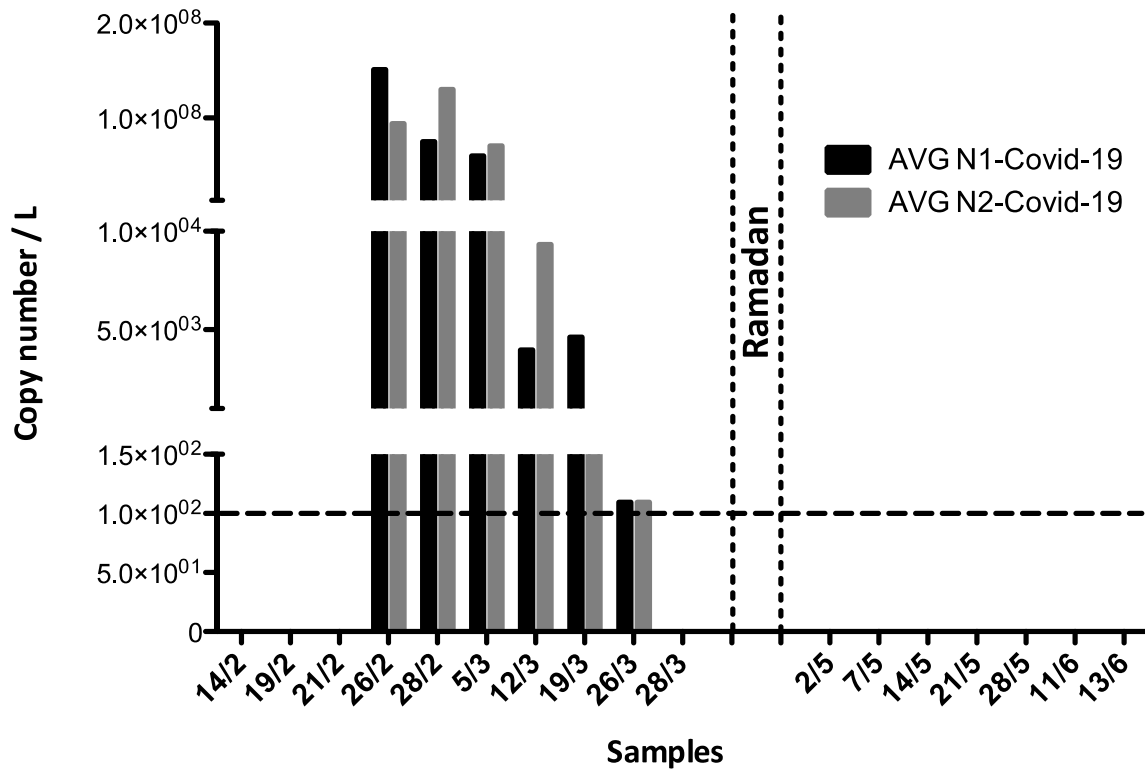


Figure 4: The concentration of SARS-CoV-2 that were found in the wastewater samples (2023)

Figure 5 shows the concentrations of pathogens in the wastewater samples. The data show that pathogens are found relatively consistently for all sampling dates.

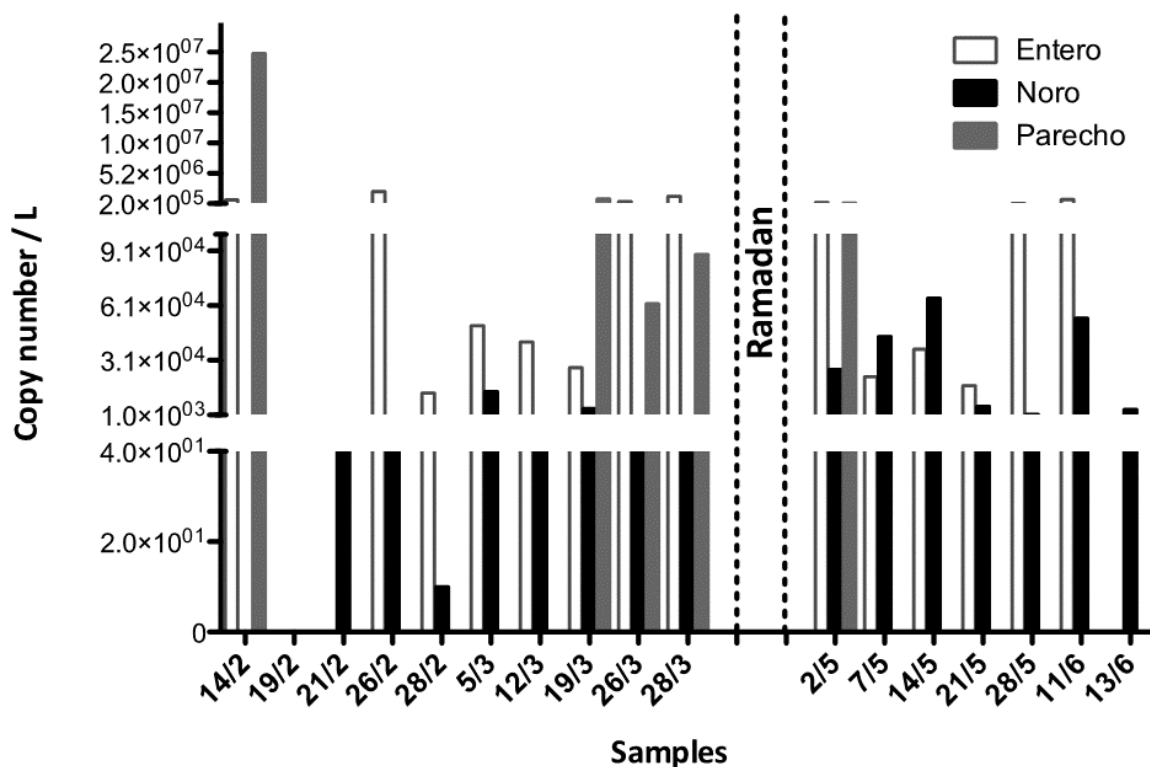


Figure 5: The concentrations of pathogens in the wastewater samples (2023)

5. Conclusions

This study serves as a proof of concept that wastewater epidemiology studies can be undertaken in off the grid communities where wastewater is being collected in cesspits or septic tanks. The study showed the efficacy of the use of a passive sampler to collect sewage samples. The data from the lab analysis indicates that concentrations of viruses (SARS-CoV-2), pathogens and sweeteners can all be detected in the wastewater. However, at the current moment it is not possible to determine patterns in the data that can be linked to certain types of behavior in the population. Further research is required in order to establish linkages between the data and the behavior and dietary choices of the population. Nevertheless, it is clear from this study that wastewater epidemiology, as a non-invasive means to understand the public health conditions of the Bedouin community living in unrecognized communities, is a valid methodology that can assist public health professionals to better understand the health of the population and to implement appropriate public health measures.

6. Acknowledgements

This study was funded in part by a grant from the Israeli Ministry of Environmental Protection. The authors are grateful to the assistance of KanDo water sampling company for the use of their passive sampler and for collection of the wastewater samples. The authors are also grateful to the lab of Prof. Ariel Kushmaro, Department of Biotechnology Engineering at Ben Gurion University for the lab analysis. Finally, the authors are grateful to the staff, teachers and students at the Al Furaa school for allowing us to make use of the school premises for taking of the samples.

7. References

- Adegoke, A., & Stenström, T. (2019). *Cesspits and Soakpits*. <https://doi.org/10.14321/waterpathogens.58>
- Al-Atawneh, N., Mahmoud, N., Van der Steen, P., & Lens, P. N. L. (2017). Wastewater characteristics in partially sealed cesspit: Case study from Beit Dajan, Palestine. *Linnaeus Eco-Tech*. <https://doi.org/10.15626/Eco-Tech.2014.054>
- Association for Civil Rights in Israel. (2019a, September 9). *Start of the school year at the Al-Kasom Regional Council*. ACRI - English. https://www.english.acri.org.il/post/_133
- Association for Civil Rights in Israel. (2019b, December 31). *The Unrecognized Bedouin Villages in the Negev*. ACRI - English. https://www.english.acri.org.il/post/_148
- Association for Civil Rights in Israel. (2020, January 10). *The Ministry of Education is Violating the Rights of 18,000 Students*. ACRI - English. https://www.english.acri.org.il/post/_149
- Ben Gurion University of the Negev. (2022, January 22). *Demographic Characteristics of the Bedouin Population in the Negev*. Ben Gurion University of the Negev. <https://in.bgu.ac.il/humsos/negevSus/SYBSN/Pages/demographics.aspx>
- Britannica, T. (2022c, March 31). *Bedouin*. Encyclopedia Britannica. <https://www.britannica.com/topic/Bedouin>
- Britannica. (2022a). *Beersheba*. <https://www.britannica.com/place/Beersheba>
- Britannica. (2022b, March 31). *Negev*. Encyclopedia Britannica. <https://www.britannica.com/place/Negev>
- Fuks, D., Ackermann, O., Ayalon, A., Bar-Matthews, M., Levi, Y., Maeir, A., Weiss, E., Zilberman, T., & Safrai, Z. (2017). Dust clouds, climate change and coins: Consilience of palaeoclimate and economy in the Late Antique southern Levant. *Levant*, 49. <https://doi.org/10.1080/00758914.2017.1379181>
- Haj-Yahya, N. H., Khalaily, M., Rudnitzky, A., & Fargeon, B. (2021). *Statistical Report on Arab Society in Israel: 2021*. The Israel Democracy Institute. <https://en.idi.org.il/articles/38540>
- Medzini, A. (2012). Bedouin Settlement Policy in Israel: Success or Failure? *Horizons in Geography* / בגאוגרפיה אופקים, 79/80, 37–48. <http://www.jstor.org/stable/23718580>
- Negev Coexistence Forum for Civil Equality. (2014). *Thirsty for (the Right) to Water*. Negev Coexistence Forum for Civil Equality.
- Rudnitzky, A., Abu Ras, T., & Abraham Fund. (2012). *The Bedouin population in the Negev*. Abraham Fund Initiatives.
- Singer, A. (2007). *The Soils of Israel*. Springer Berlin.
- Singer, A. C., Thompson, J. R., Filho, C. R. M., Street, R., Li, X., Castiglioni, S., Thomas, K. V., & Singer, A. C. (2023). A world of wastewater-based epidemiology. *Nature Water*, 1(May), 408–415. <https://doi.org/10.1038/s44221-023-00083-8>
- Thaher, R. A., Mahmoud, N., Al-Khatib, I. A., & Hung, Y.-T. (2022). Cesspits as Onsite Sanitation Facilities in the Non-Sewered Palestinian Rural Areas: Users' Satisfaction, Needs and Perception. *Water*, 14(6), 849. <https://doi.org/10.3390/w14060849>
- The Regional Council for the Unrecognized Villages in the Negev, & Negev Coexistence forum for Civil Equality. (2019). *The Arab Bedouin indigenous people of the Negev/Nagab*. <https://www.ohchr.org/sites/default/files/Documents/Issues/IndigenousPeoples/C SO/National Coexistence Forum for Civil Equality.pdf>

Yaniv, K., Craddock, H. A., Mahameed, F., Shagan, M., Salah, I., Lakkakula, S., Resnick, K., Haber, C., Davidovitch, N., Moran-gilad, J., Kushmaro, A., & Lipchin, C. (2023). Wastewater monitoring of SARS-CoV- in on-grid , partially and fully o -grid Bedouin communities in Southern Israel. *Frontiers Water*, 5.