Assessment of health and well-being effects associated with the challenging drinking water situation in the Gaza Strip, Palestine: Study Protocol

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Abstract

Background: The water supply of the Gaza Strip has been unstable and under strain for decades, resulting in major issues with drinking water quality, reliability, and acceptability. In 2018, between 25-30% of Gazans did not have regular access to running water. Progressive deterioration of water infrastructures and concerns over the quality of piped water have resulted in a complex mix of drinking water sources used in the Gaza Strip. The challenges of safe water provision in the Gaza Strip could potentially have severe adverse effects on the health and well-being of the population.

Objective: The main objectives of the survey were to determine the quality of drinking water at the household level and to investigate the association of various health outcomes with water quality at household level in the Gaza Strip.

Methods: We conducted a cross-sectional household survey in North Gaza, Gaza and Rafah governorates between January and March 2023. We selected households from a subsample of a representative cross-sectional survey conducted in the Gaza Strip in the year 2020 with persons aged 40 years and older. In each household in the 2023 survey, three individuals (two above 40 years and one between 18 and 30 years) were invited to participate. The face-to-face interview included questions on drinking water, mental health and well-being, self-reported diagnoses for selected diseases, use of antibiotics and knowledge about antimicrobial resistance. Additionally, the blood pressure of each participant was measured. Drinking water was sampled from each household and analyzed for microbial contamination, nitrate, sodium and mineral content.

Results: We visited a total of 905 households and interviewed a total of 2’291 participants. In both age groups more female participants were interviewed (57% (914/1’615) in those 40 years and older; 59% (398/676) in those 18 to 30 year olds). Water samples were obtained from nearly all households (903/905).

Conclusions: The extensive survey components, coupled with drinking water testing and building on an existing survey, allows us to identify a broad set of potential impacts on health and well-being and to track changes over time. This study intended to identify humanitarian and development interventions that could impact the population served most. However, data collection was completed before the escalation of violence in October 2023. Given the impact of the still ongoing escalation, the initial intent of this work is no longer valid, but the results emerging from the survey may still serve as a baseline to assess impacts of the current escalations on physical and mental health as well as on drinking water quality. In addition, our findings could provide important information for rebuilding the Gaza Strip in a more health-promoting way.

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Paper type: Research Protocol

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Keywords: Drinking water; Household survey; Non-communicable diseases; Protracted conflict; Humanitarian crisis

Introduction

Drinking Water Crisis in the Gaza Strip

Water quality has decreased drastically in Gaza over the past two decades. While nearly all residents had access to improved water 25 years ago, 25-30% of Gazans did not have regular access to running water in 2018 [1]. Destruction and deterioration of water infrastructure and concerns over the quality of piped water have resulted in a complex constellation of different types of drinking water sources used in the Gaza Strip.

In addition to the weak infrastructure and reliability, there are major issues with drinking water quality. Only about 4% of the water from groundwater wells is within the World Health Organization (WHO) limits in terms of nitrate and chloride and one out of ten was below the threshold for nitrate (50mg/L) set by the WHO [2, 3]. Four out of five municipal wells did not comply with the safety threshold for salinity (250mg/L) and most of the coastal area is affected by seawater intrusion into the aquifers [2, 3]. Pollution of groundwater and drinking water with toxic chemicals, such as pesticides and heavy metals, is unknown. Approximately 70-80% of people in the Gaza Strip were estimated to use desalinated water as their main source for drinking and cooking [4]. But the desalinated water that many households purchase as an alternative to groundwater is also not free from contamination. Studies from 2014 to 2021 found that piped water, as well as water from desalination plants exhibited high levels of microbial contaminants, including fecal coliforms [5, 6]. In a study conducted in 2018, 33% and 17% of the samples were positive for total coliforms and fecal coliforms, respectively [3]. In addition, nitrate levels in desalinated water are a concern with 14% of samples exceeding the WHO safety threshold [3].

Potential health risks associated with drinking water quality in the Gaza Strip

The significant microbial pollution in the Gaza Strip’s drinking water raises public health concerns. Fecal coliform poses a severe risk for the transmission of water-borne diseases, encompassing various pathogens causing mild infections like acute diarrhea to severe conditions such as chronic diarrhea, dysentery, hepatitis A, typhoid, and cholera [7]. The high microbial pollution is particularly of concern in light of the high levels of antimicrobial resistance (AMR) found in bacteria isolated from human, as well as environmental samples taken at hospitals, farms and in coastal waters [3, 8-10]. AMR further complicates the treatment of some of these infections, posing a particularly pertinent public health problem [11].

In addition, the levels of physicochemical parameters in water sources in Gaza are a public health concern. High nitrate pollution in most drinking water sources indicates that the Gazan population is

at an increased risk for a range of severe diseases, such as colorectal cancer, thyroid disease, neural tube defects, and infant methemoglobinemia [12]. Sodium levels in drinking water sources of the Gaza Strip are outside permissible limits for consumption. Excess intake of sodium can lead to a range of adverse health effects, including obesity, hypertension and subsequent stroke, coronary heart disease, renal disease, osteoporosis and others [13-17]. Additionally, low mineral content in drinking water, such as calcium and magnesium, has been found to have various adverse health impacts. Associated health risks include an increased risk of cardiovascular disease [18-23], caries [24, 25], osteoporosis [26, 27] and potentially various cancers [28-33]. This could be relevant in the Gaza Strip because of the high consumption of desalinated water [4].

Beyond the physical health effects, the dire water situation in the Gaza Strip can also affect mental health and cognitive functions through different pathways [34]. Insecurity about water quality and availability, as well as potentially high water prices, can trigger stress and affect well-being. Chronic stress is linked to severe and interlinked physical and psychological health problems, including depression and anxiety disorders and associated cardiovascular diseases [35, 36]. Additionally, the lack of water can cause fatigue, which impacts mood stability and cognitive function and can increase anxiety or irritability [35]. Dehydration can further contribute to difficulties in concentration, reaction time, memory, and reasoning [35, 36].

Knowledge gaps and objectives

Existing evidence highlights numerous potential public health risks in the Gaza Strip, with persistent knowledge gaps in associated health determinants and outcomes. Water quality is primarily assessed at their source (e.g. groundwater wells and desalination plants), neglecting the mixing of water from different sources, different water distribution systems and water tanks widely used for storage. Inadequate distribution and improper storage practices can further contribute to contamination, while possible treatment at the household level before consumption could improve water quality. Additionally, evidence on the magnitude of health conditions related to low drinking water quality (e.g. diarrhea, diseases related to high nitrate or sodium, conditions related to low mineral consumption) is incomplete. Given the complex system of water production, delivery, storage and treatment, and the potential contamination of water sources along the water chain, quantifying the related health conditions allows to estimate the impact of the water system on public health. A better understanding of the impact of water quality and availability on health could help in priority setting and to identify potential targeted interventions in the water sector. Additionally, there is no data on the presence of AMR pathogens in Gazan household drinking water. There is insufficient data on practices and knowledge of antibiotics and AMR of the population, which is important to better address the multi-sectoral challenge of emerging AMR. Addressing these gaps in an integrated manner at the level of individuals and households is crucial for targeted interventions and prioritized health initiatives.

Against this background, the International Committee of the Red Cross (ICRC) initiated a health impact assessment of selected essential services (electricity, water, wastewater and food security) in the Gaza Strip to inform the determination of strategic priorities for its interventions. This paper presents the protocol of a household survey conducted as part of the ICRC-mandated health impact assessment. The main objectives of the household survey were to determine what contaminants (e.g. microbial contamination, nitrate, sodium and mineral content) persist in drinking water at the household level and to investigate the health conditions (e.g. kidney disease, osteoporosis, methemoglobinemia and mental health issues) associated with water quality at the household level. Ultimately, this will provide a more comprehensive understanding of the interplay between drinking water, health conditions and mental health in the Gaza Strip.

Methods

Project design

We conducted a cross-sectional household survey in the Gaza Strip from January to March 2023. For the 2023 survey, we revisited a sub-sample of households from a survey conducted in 2020. This minimized the potential burden on study participants while maximizing synergies with existing data. In addition, this study design allows for more in-depth analyses, including an assessment of changes over time as, we can use some of the indicators from the 2020 survey as a baseline for the 2023 survey.

The 2020 survey was a representative, cross-sectional, anonymous household survey implemented by Al-Quds University, the American University in Beirut, Imperial College in London and the Palestinian NGO Juzoor. It included 4’576 people from 2’443 households and focused on dietary patterns and non-communicable diseases (NCDs). Among others, the 2020 survey included modules on self-reported risk factors for NCDs (e.g. food consumption, physical activity, or smoking), psychosocial health and self-reported NCDs (e.g. diabetes, hypertension, cardiovascular and respiratory diseases). In addition, they conducted blood pressure and anthropometric measurements. The 2020 survey is described in more detail in two publications from Abu Hamad et al. 2022 [37] and Basu et al. 2024 [38].

Ethical Clearance

Ethical approval had been granted by the Helsinki Committee of the Palestinian Health Research Council in the Gaza Strip (Date: 06.06.2023, number: PHRC/HC/1141/22), the Ethikkommission Nordwest- und Zentralschweiz (Date: 09.01.2023, statement ID: AO_2022-00076) and the ICRC internal ethics review board (Date: 26.01.2023, proposal number: 2301_JAN and validation reference: LDPCORE 23/00006 - CGB/bap). The Ministry of Interior and Ministry of Health in Gaza also reviewed and approved the survey tools and the full study protocol.
The household survey involved no collection of biological samples and only a minimal time burden on participants. The survey addressed mental health issues that can be sensitive. Due to the complicated political situation, a large part of the Gazan population suffers from mental health problems. However, the questionnaire survey merely assessed the mental health status. No traumatic events were discussed and no in-depth discussion of any mental health problems took place, thereby reducing the potential burden on participants.

Project population, inclusion and exclusion criteria

Study area and population
Households were sampled in North Gaza, Gaza and Rafah governorates, to represent the diversity of settlements in the Gaza Strip. Gaza governorate with Gaza City is the economic and administrative center of the Gaza Strip. It is home to a socioeconomically diverse population and has an extremely high population density of 13’000 inhabitants per square kilometer. In Rafah, the southernmost governorate of the Gaza Strip, a large part of the population lives in poverty and many of the refugee and rural populations are located in this area. Saltwater intrusion into the aquifer is particularly problematic in Rafah and water quality parameters, such as nitrate levels, are the worst in all areas of the Gaza Strip [39]. North Gaza is frequently affected by violent escalations with Israel. Poverty levels are similar to Rafah, making the area particularly vulnerable to the health effects of poor water

quality. Large parts of the land are used for agriculture, and wastewater irrigation projects are being implemented in North Gaza. The main wastewater collection facility is located in the north.
Figure 1 shows the distribution of clusters in the Gaza Strip visited in the household survey. For each cluster, we visited between a minimum of 12 and a maximum of 15 households and interviewed between one and three participants in each household.

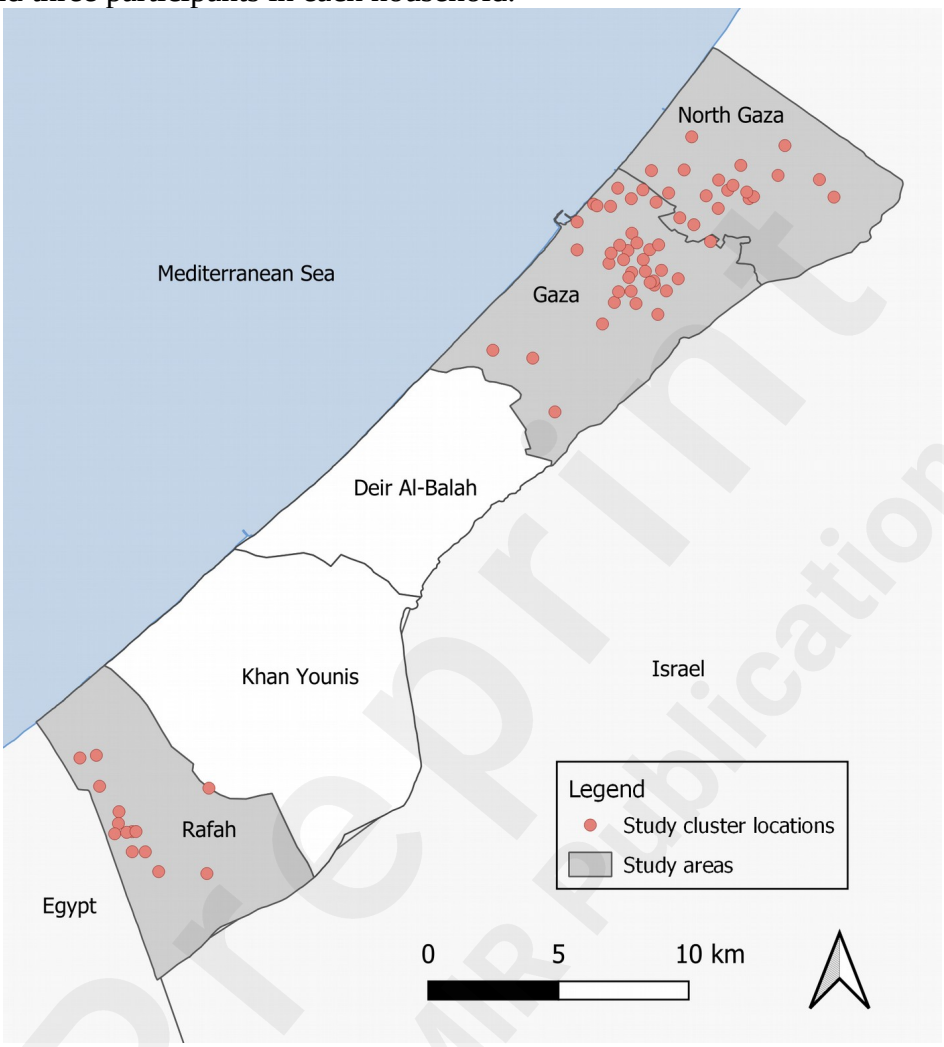

Figure 1: Study clusters included in the household survey in the Gaza Strip. In each cluster up to 15 households were included in the survey.

Sampling and recruitment

The 2020 survey was a representative, cross-sectional, anonymous household survey of persons older than 40 years living in all five governorates of the Gaza Strip. Using a systematic cluster random sampling method, the 2017 Population and Housing Census served as the sampling frame to select enumeration areas for each governorate [37]. 163 clusters proportionate to the population size in the five governorates were selected. In each cluster 15 households were sampled. In each household one eligible female and one eligible male were interviewed [37].
We used stratified random sampling to select the study population for the 2023 survey from a complete list of households included in the 2020 survey. In total, we randomly picked 905 households proportional to the population in the three study areas.

We invited all respondents from the 2020 survey in the selected households to participate in the 2023 study. For a household to be eligible for inclusion in the 2023 survey, at least one of the respondents from the 2020 survey needed to be present. Otherwise we revisited the household up to four times before they were considered lost to follow-up. If the original respondents had moved since the 2020

survey or refused to participate, the household was replaced by another yet unsampled household in the same cluster. If only one original participant was present or agreed to participate, the second respondent was replaced by a new participant over the age of 40.

In addition, we randomly selected one respondent between 18 and 30 years from all available household members in that age group present at the time of the survey. If none were available in the initial household, an additional household in the same building was randomly selected. To select the additional household, the floor and then the apartment door were randomly selected. In case there was no available respondent between 18 and 30 years in the additionally selected household, the procedure was repeated. No additional respondents were selected if no respondents between 18 and 30 years of age were available in the whole building.
Each household was visited by two field workers. All field workers were female and already part of the 2020 survey team. Having female interviewers visiting the households make participation for female household members easier and more comfortable as they can remain without a headscarf. All participants in the household survey were required to sign a formal informed consent form prior to participation in the study. The survey was administered face-to-face, with the interviewer capturing data electronically on a tablet.

Sample size calculation
The sample size calculation was based on the objective of estimating the prevalence of various NCDs. For the questionnaire survey, we assumed a prevalence of 50% as the most conservative assumption. The respondent groups (i.e. female and male above 40 years and additional household members between 18 and 30 years) will be analyzed separately. Therefore, the resulting sample size indicates the required number of individuals in each group. The sample size was calculated using the following formula:

Equation 1: Formula used for the sample size calculation for the 2023 households survey

$$n = \frac{Z^2 * P(1-P) * deff}{d^2 * RR}$$

Where Z is the z-value (1.96, corresponding to a 95% confidence interval), P is the expected prevalence (50%), d is the precision (5%), deff is the design effect (2), and RR is the response rate (0.9, based on non-response rate in baseline survey (96.6%) and estimated proportion of respondents remaining at the same location since the baseline survey (95%)). The resulting sample size is 854 households, corresponding to potentially 2’562 individual respondents. This was rounded up to 900 households in case of data quality issues, corresponding to potentially 2’700 respondents (1’800 aged 40 years and older and 900 aged 18 to 30 years).

Study modules
The 2023 household survey consisted of three modules: (i) a questionnaire, (ii) blood pressure measurements, and (iii) a drinking water sample. Figure 2 displays an overview of the three modules and the components of each module.

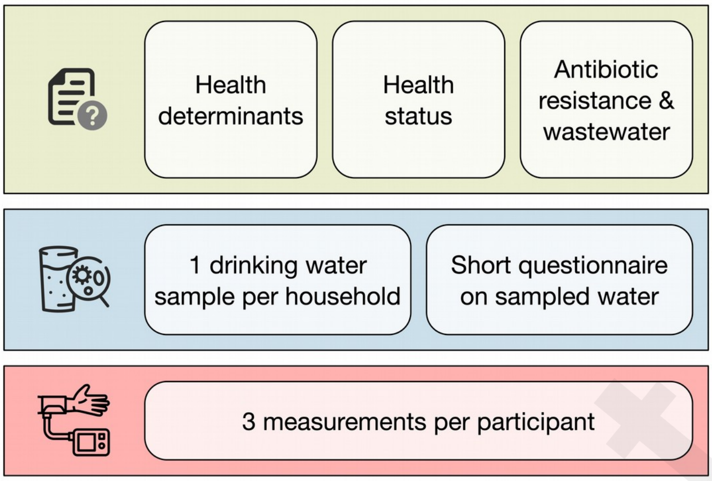

Figure 2: The three modules of the 2023 household survey and their components: questionnaire (green), drinking water sample (blue) and blood pressure measurements (red).

Questionnaire

The questionnaire was structured around three major parts:

1. Health determinants: (i) drinking water source, storage and consumption; (ii) recreational activities (e.g. swimming in the sea) and perception of the environment; and (iii) social network.
2. Health status: (i) self-reported mental health and well-being; and (ii) self-reported diagnoses/ diseases for selected NCDs and communicable diseases, including diarrheal symptoms of participants and the children under five in the household reported by the parents.
3. Consumption on antibiotics and knowledge about antibiotics and AMR, attitudes towards wastewater irrigated crops and perception of the environment on the influence of health.

When applicable, we used and sometimes adapted established questionnaires and survey items to build this questionnaire. When applicable, we used and sometimes adapted established questionnaires and survey items to build this questionnaire. When applicable, we used and sometimes adapted established questionnaires and survey items to build this questionnaire. When applicable, we used and sometimes adapted established questionnaires and survey items to build this questionnaire. When applicable, we used and sometimes adapted established questionnaires and survey items to build this questionnaire. Table 1 lists the different questionnaires that were used for the household survey. For most of the questionnaire not all the questions were applied in our household survey. The column survey items included in our questionnaire lists the items from the respective questionnaire that we adopted and included in the survey. lists the different questionnaires that were used for the household survey. For most of the questionnaire not all the questions were applied in our household survey. The column survey items included in our questionnaire lists the items from the respective questionnaire that we adopted and included in the survey. lists the different questionnaires that were used for the household survey. For most of the questionnaire not all the questions were applied in our household survey. The column survey items included in our questionnaire lists the items from the respective questionnaire that we adopted and included in the survey. lists the different questionnaires that were used for the household survey. For most of the questionnaire not all the questions were applied in our household survey. The column survey items included in our questionnaire lists the items from the respective questionnaire that we adopted and included in the survey. lists the different questionnaires that were used for the household survey. For most of the questionnaire not all the questions were applied in our household survey. The column *survey items included in our questionnaire* lists the items from the respective questionnaire that we adopted and included in the survey.

Table 1: Overview of established questionnaires used in the household survey questionnaire

Questionnaire name	Survey items included in our questionnaire	Source
Multiple Indicator Cluster Surveys (MICS): Water quality testing questionnaire	• Water sources for o Drinking o Cooking o Hygiene and bathing • Treatment of water at the household level	UNICEF, MICS6 Questionnaires - Water Quality Testing Questionnaire, 2020 [40]
Household Water Insecurity Access Scale (HWIAS)	• Water availability and quantity • Water safety and quality • Emotions related to water access and security	Tsai et al. 2016 [41]
The WHO STEPwise approach to non-communicable disease risk factor surveillance	History of selected NCDs: • Raised blood pressure • Diabetes • Raised total cholesterol • Cardiovascular diseases • Chronic respiratory diseases • Cancer	Household survey 2020 (Abu Hamad et al. 2022) [37]; Sibai et al. 2009 [42]; WHO STEPS [43]
WHO Oral Health Questionnaire for Adults	• Oral health and hygiene • Dental health and hygiene	WHO, Oral Health Surveys - Basic Method, 2013 [44]
Questionnaire on self-reported skin complaints	• Skin complaints and irritations • Skin diseases	Dalgard et al. 2003 [45]
General Health Questionnaire 12-Items (GHQ-12)	• Mental disorders • Mental health problems • Mental disturbances • Psychosocial health	Anjara et al. 2020, Goldberg et al. 1997, Goldberg et al. 1979 [46-48]
Health-related quality of life (WHOQOL-BREF)	• Quality of life and well-being • Individuals' perceptions of their position in life	WHO, Programme on mental health - WHOQOL User Manual, 1998 [49]
Antibiotic resistance: Multi-country public awareness survey	• Antibiotics use and knowledge • Antimicrobial resistance knowledge	WHO, Antibiotic resistance: multi-country public awareness survey, 2015 [50]
Attitudes towards wastewater reuse	• Attitude towards wastewater reuse and wastewater irrigated crops • Perception of water and environment	Friedler et al. 2006 [51]

Blood pressure measurements

At the end of the interview, we measured each participant's blood pressure using oscillatory blood pressure monitoring devices. For each participant, we took three measurements with a break of at least three minutes between each measurement. We asked participants to follow a standardized protocol to ensure standardized blood pressure measurements. Participants had to refrain from eating or drinking for at least 30 minutes and ensure their bladder was empty before the measurement. Prior to the measurement, participants had to sit comfortably in a supported position for a minimum of five minutes. During the measurement, they had to keep both feet flat on the ground, with their legs uncrossed. The arm with the cuff was rested at chest height on a table and the cuff was put on bare skin. Finally, there was no talking during the measurement to minimize any potential disturbances. The field workers advised participants with a high blood pressure measurement (systolic blood pressure above 140 mmHg or diastolic blood pressure above 90 mmHg) to visit a doctor for further

assessments.

Drinking water sampling

In addition, we collected a drinking water sample in all households for subsequent analyses. The samples were tested for nine common water quality parameters (Table 2) by the Coastal Municipalities Water Utility laboratory in Gaza City. The sample was taken from the source the respondents usually use for drinking. Approximately 100 ml was collected using sterile containers and stored on ice in a cool box at 4-6°C. Within six hours, the samples were transported to the laboratory and analyzed within 30 hours of collection. From 10% of the households an additional water sample was taken and analyzed at a different laboratory for quality control. Per household, a brief questionnaire was administered to collect data regarding the water source and any filtration or purification methods used in the household. The questions were based on the water quality testing questionnaire from MICS6 [40].

Table 2: Overview of measured water quality parameters.

Water quality parameter	Abbreviation	Unit
Total coliform	TC	CFU/100 ml
Fecal coliform	FC	CFU/100 ml
Nitrate	NO_3-N	mg/L
Sodium	Na^+	mg/L
Calcium	Ca^{2+}	mg/L
Magnesium	Mg^{2+}	mg/L
pH	pH	-
Electrical conductivity	EC	µS/cm
Total dissolved solids	TDS	mg/L

Among households whose water tested positive for fecal coliform in the first round of sampling, 90 were selected for a second round of water sampling. They were selected based on high fecal coliform counts, geographic distribution and drinking water sources. The second sample was taken four weeks after the first sample and analyzed for AMR bacteria. Of these 90 households, 10 households were selected for additional water chain testing. Starting from the point where household members accessed their drinking water, the water chain was followed and a sample was taken at each potential contamination site. Examples of sample locations are the faucet in the kitchen, the rooftop storage tank, the pipe from a water tanker truck or the refill pipe at a desalination plant. The number and location of water samples taken varied for the water chain testing depending on the drinking water source used in the households.

Data Analysis

Data analyses are ongoing and results are expected to be published in 2024 and 2025. Data analysis is performed with R and RStudio software [52, 53]. In a first step, we plan to publish mainly descriptive results to give an overview of the data gathered. The different drinking water sources' respective water analysis results will be described and compared. Potential reasons for observed differences between water sources will be investigated further. In a second analysis step, water quality and water-related health conditions will be compared. Data from the 2020 survey will be integrated to investigate the change of the health status over time. Additionally, we intend to delve

into the mental health burden among residents in both the 2020 and 2023 surveys, aiming to investigate temporal trends or disparities. Furthermore, we will explore the determinants of mental health within the Gaza Strip, considering various socio-economic, environmental, and psychosocial factors that could influence mental well-being by including data from the 2020 and 2023 survey and external data sources such as data from ACLED (Armed Conflict Location and Event Data) [54]. Taken together, these analyses will provide a comprehensive understanding of the complex interplay between water quality, health outcomes and mental well-being in the Gaza Strip.

Results

We visited a total of 905 households, interviewed 2’291 participants and collected water samples in 99.8% (903/905) of the households. Figure 3 shows the study area and population in the 2020 and 2023 surveys and how the reduction of included study clusters led to a decrease in the study population.

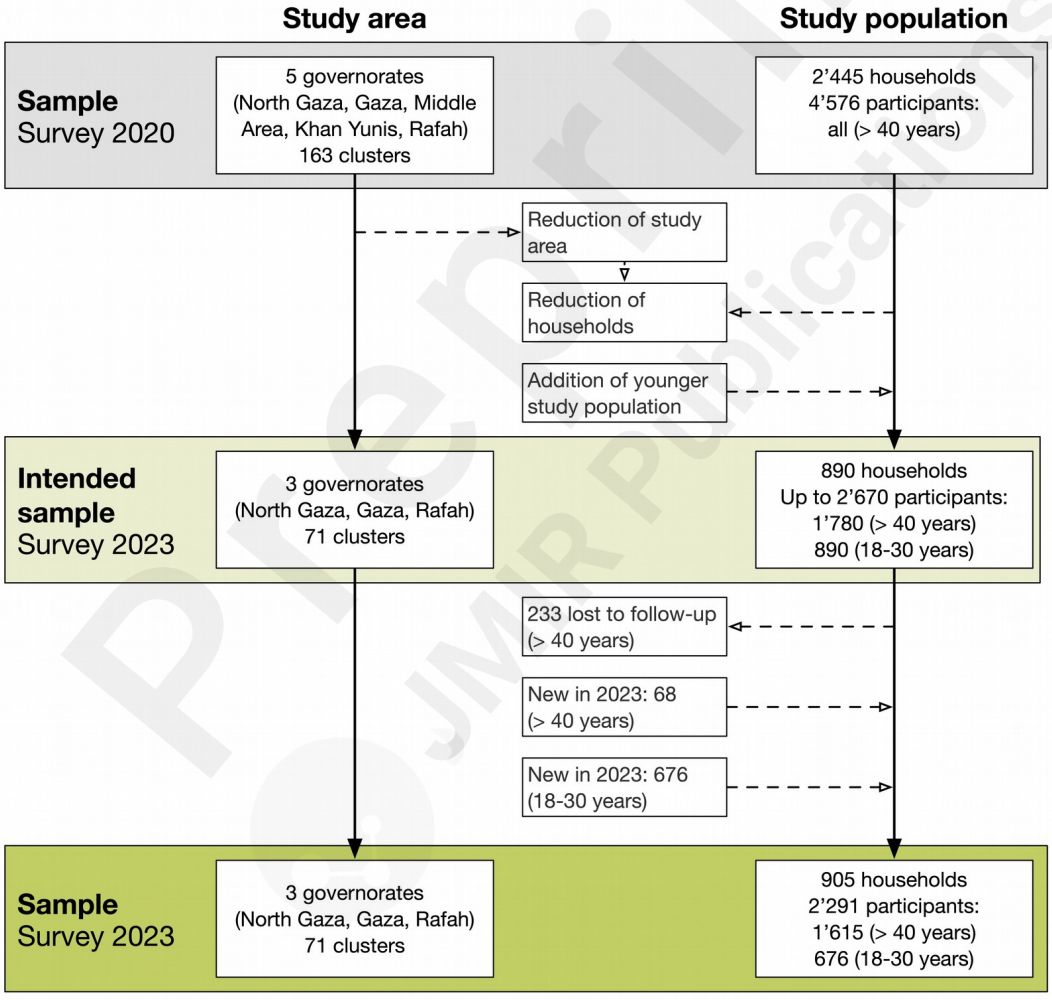

Figure 3: Study area and population in the 2020 and 2023 survey

Table 3 shows an overview of the participants’ characteristics of the 2023 household survey and a comparison with the participants from the 2020 survey. 71% (1’615/2’291) of the participants in 2023 were aged 40+ years and 30% (676/2’291) participants were between 18-30 years old. 96% (1’547/2’291) of the participants aged 40 years or older in 2023 were already part of the 2020 survey. The follow-up rate in 2023 was 77% (1’615/2’097) compared to the 2020 sample in the same study area. In both age groups in 2023, more female participants were interviewed (57% (914/1’615) and

59% (398/676), respectively). This is similar to the participants of the 2020 survey, where 53% (1’071/2’016) were females. A more detailed overview of participant characteristics by governorate is available in the Appendix Table A1.

Table 3: Description of participants of the 2023 household survey and comparison with participants in the 2020 survey

Study year	**2023**	**2020**
Number of households	905	1’065
Number of participants	2’291	2’016
Age group	**40+**	
Number of participants	1’615	2’016
Same as 2020	1’547 (96%)	–
Female	914 (57%)	1’071 (53%)
Age [Mean(min-Max)]	59 (40 – 89)	57 (40 – 118)
Refugee	1044 (65%)	1332 (66%)
Age group	**18-30**	
Number of participants	676	–
Female	398 (59%)	–
Age [Mean(min-Max)]	23 (18 – 30)	–
Refugee	419 (62%)	–

Discussion

We conducted a survey in 905 households with 2’291 participants and collected 903 drinking water samples in the Gaza Strip, achieving a follow-up rate of 77% with the participants from the survey in 2020. Previous studies and measurements suggest high levels of chemical and some microbial contamination in groundwater wells or the drinking water system [3, 5, 6]. We expect to find similar results in our measurements at the household level, but in contrast to previous studies we can directly link water quality to health at the individual level. The widespread use of desalinated water may result in low levels of essential minerals such as magnesium and calcium, which may have implications for public health, but has never been studied in the Gaza Strip.

One strength of our study lies in integrating data from a previous survey on the health status of participants. This approach allows us to observe trends over time and gain a more detailed understanding of the health burden in the Gaza Strip, to identify a broad set of potential impacts on health and well-being and to track changes over time. An additional strength is our water sampling at the household level, which allows us to test the water that the participants consume rather than sampling further up the water chain, after which contamination could occur before consumption.

Our study also has several limitations. The main limitation is the cross-sectional design of the survey. While we have data from 2020 and 2023, we only have data from one survey for several important questions. The majority of the health outcomes included in the survey are NCDs, which develop over the course of a person’s life and with long latency. We lack data on long-term water quality from several years back and we lack data on health outcomes previous to 2020. This temporal alignment means that we cannot establish causation between water quality and health outcomes based on the current dataset. All health information collected in the survey is self-reported and not from medical

diagnoses. To limit wrong answers we used validated questionnaires that have been used in many contexts to screen for NCDs and other health statuses. Furthermore, the repeated sampling allows us to do data quality checks using indicators for non-treatable medical conditions.

The data collected in this survey provide valuable insights into drinking water quality at the household level and its potential impact on the health and well-being of people in the Gaza Strip. The study design and data collection were completed before the escalation of violence in October 2023. The results emerging form the survey may serve as a baseline to assess impacts of the current escalations on physical and mental health. Additionally, the results from the household survey can provide information regarding the water system from a public health perspective which could be useful in rebuilding the Gaza Strip. Collaborative efforts involving government agencies, non-governmental organizations, and international partners will be essential in addressing the complex challenges facing water sanitation and public health in this process.

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Data availability

The data collected and generated during data collection and analysis of this study will be available from the corresponding author upon reasonable request.

Authors' Contributions

MSW, DD, CB, BAH, TVG and FS contributed to the conceptualization of the study. CB, MSW, BAH, TVG, RR and DD contributed to the implementation of the investigations and project administration. CB, DD, BAH and BNO contributed to data curation, writing—original draft and visualization. MSW, BAH and NPH contributed to supervision, while TVG, FS and RR contributed to funding acquisition. CB, DD, MSW, BAH, TVG, FS, RR, BNO and NPH contributed to writing—review.

Conflict of interest

None declared.

Abbreviations

AMR: Anitmicrobial resistance
ICRC: International Committee of the Red Cross
NCD: Non-communicable disease
WHO: World Health Organization

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Appendix

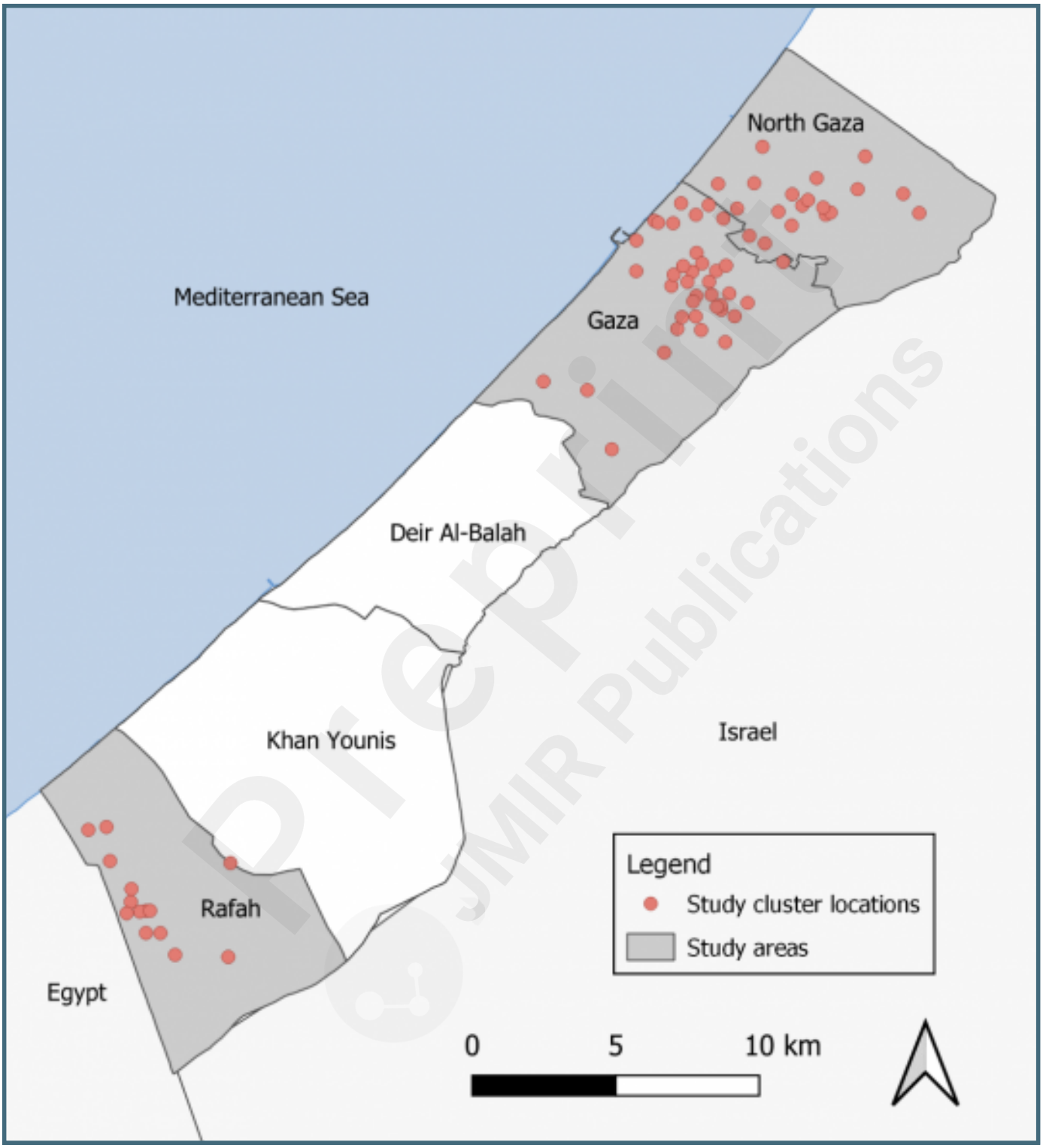
Table A1: Participant characteristics in the 2023 and 2020 survey by governorate.

Study year	**2023**				**2020**			
Study area	**All**	**North Gaza**	**Gaza**	**Rafah**	**All**	**North Gaza**	**Gaza**	**Rafah**
Number of households	905	254 (28%)	469 (52%)	182 (20%)	1’065	285 (27%)	570 (54%)	210 (20%)
Number of participants	2’291	669 (29%)	1’141 (50%)	481 (21%)	2’016	516 (26%)	1‘093 (54%)	407 (20%)
Age group	**40+**				**40+**			
Number of participants	1’615	464 (29%)	817 (51%)	334 (21%)	2’016	516 (26%)	1‘093 (54%)	407 (20%)
Same as 2020	1’547 (96%)	437 (94%)	785 (96%)	325 (97%)	–	–	–	–
Female	914 (57%)	251 (54%)	477 (58%)	186 (56%)	1’071 (53%)	276 (54%)	582 (53%)	213 (52%)
Age [Mean(min-Max)]	59 (40 – 89)	58 (40 – 88)	60 (40 – 89)	58 (40 – 89)	57 (40 – 118)	56 (40 – 87)	58 (40 – 90)	57 (40 – 118)
Refugee	1044 (65%)	363 (78%)	420 (51%)	261 (78%)	1332 (66%)	408 (79%)	603 (55%)	321 (79%)
Age group	**18-30**				–			
Number of participants	676	205 (30%)	324 (48%)	147 (22%)	–	–	–	–
Female	398 (59%)	129 (63%)	194 (60%)	75 (51%)	–	–	–	–
Age [Mean(min-Max)]	23 (18 – 30)	23 (18 – 30)	23 (18 – 30)	23 (18 – 30)	–	–	–	–
Refugee	419 (62%)	146 (71%)	163 (50%)	110 (75%)				

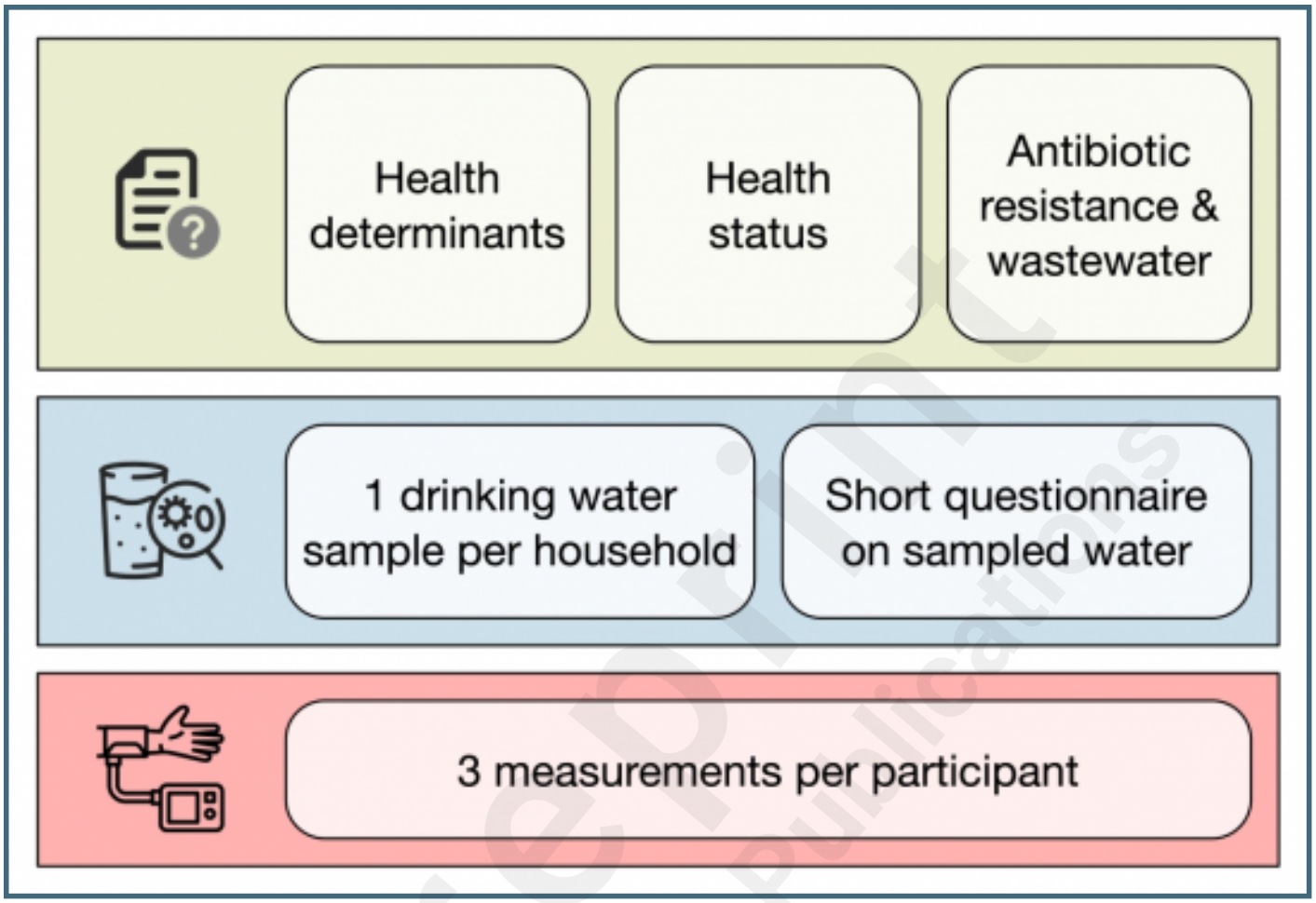
Supplementary Files

Figures

Study clusters included in the household survey in the Gaza Strip. In each cluster up to 15 households were included in the survey.



The three modules of the 2023 household survey and their components: questionnaire (green), drinking water sample (blue) and blood pressure measurements (red).



Study area and population in the 2020 and 2023 survey.