

Short communication

Water usage in the Gaza Strip: recommendations from a literature review and consultations with experts

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استخدام المياه في قطاع غزة: توصيات تستند إلى مراجعة للأدبيات واستشارات للخبراء

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الخلاصة: لقد كانت جودة المياه في قطاع غزة منقوصة بشدة نتيجة لتزايد الملوحة والتلوث ببعض الملوثات وعدم وجود خيارات كافية لمعالجتها. ولتقديم النصيحة لسكان قطاع غزة بشأن كيفية التخفيف من المخاطر الصحية الناجمة عن المياه قمنا بوضع توصيات حول استخدام المياه ذات المصادر المختلفة لأغراض مختلفة (مثل: الاستهلاك، والنظافة، والاستخدام في أسباب الراحة، والاستخدام في الأغراض الإنتاجية، والري)، وذلك استناداً إلى مراجعة الأدبيات واستشارة الخبراء. وقد وضعت نصائح محددة للعديد من الفئات الضعيفة؛ بما في ذلك الرضع والأطفال والنساء الحوامل أو المرضعات وكبار السن. إن التوصيات التي سبق وضعها قاصرة أصلاً، إذ أنه من غير المقبول أن يوصى باستهلاك مياه دون المستوى المعياري. ومع ذلك فإنه ريثما يتم إيجاد حلول طويلة الأجل يمكن أن تستهدف الفئات الضعيفة لضمان تجنب تعرضها للملوثات الأكثر ضرراً. إن تنفيذ هذه التوصيات قد يتطلب تنظيم حملات إعلامية لمساعدة السكان على تمييز استعمال المياه ذات المصادر المختلفة في الاستخدامات المختلفة.

ABSTRACT Water quality in the Gaza Strip has been severely compromised due to increasing salinity, contamination with pollutants, and lack of adequate treatment options. To provide the population of the Gaza Strip with advice on how to mitigate health risks from water we developed recommendations on using water from different sources for different purposes (such as for consumption, hygiene, amenities, and irrigation) based on a literature review and consultation with experts. Specific advice was developed for several vulnerable groups, including infants, children, pregnant or lactating women, and elderly people. The recommendations are inherently limited, as it is unacceptable to recommend consuming water that is of substandard quality. However, pending long-term solutions, information can be targeted to vulnerable groups to ensure that exposure to the most harmful contaminants is avoided. The implementation of these recommendations may require information campaigns to assist the population in differentiating water from different sources for different uses.

Utilisation de l'eau dans la Bande de Gaza : recommandations reposant sur une analyse documentaire et des consultations d'experts

RÉSUMÉ La qualité de l'eau dans la Bande de Gaza a été grandement compromise du fait de l'augmentation de la salinité, de la contamination par les polluants, et du manque d'options de traitement appropriées. Afin de conseiller la population de la Bande de Gaza sur la façon de réduire les risques sanitaires liés à l'eau, nous avons mis au point des recommandations pour l'utilisation de l'eau provenant de différentes sources en vue d'usages variés (consommation; hygiène; utilisation des infrastructures y compris le lavage des voitures et l'arrosage de la pelouse, production et irrigation), sur la base d'une analyse documentaire et de consultations d'experts. Des conseils spécifiques ont été mis au point pour différents groupes vulnérables tels que les nourrissons, les enfants, les femmes enceintes ou allaitantes, et les personnes âgées. Les recommandations mises au point sont nécessairement limitées ; il est en effet inacceptable de recommander la consommation d'une eau ne répondant pas aux normes. Cependant, en attendant de solutions sur le long terme, les groupes vulnérables peuvent être ciblés afin de garantir que l'exposition aux contaminants les plus dangereux soit évitée. La mise en place de ces recommandations pourrait nécessiter des campagnes d'information pour aider les populations à reconnaître l'eau de différentes sources en vue d'usages variés.

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Introduction

The Gaza Strip is approximately 365 km² and home to more than 1.85 million people who live in 5 governorates (1). The population is projected to grow to 3.7 million inhabitants by 2035 (2). One of the main challenges facing the growing population is access to potable water. Water in the Gaza Strip is sourced primarily from the coastal aquifer, which has been infiltrated by the Mediterranean sea, leading to increased salinity in the groundwater. Extraction from the coastal aquifer in 2010 was estimated to be 170 million m³/year, but the annual sustainable yield of the aquifer within the Gaza Strip is estimated to be 55 million m³/year (3). Contamination of water resources with fertilizers, pesticides and solid waste, as well as a lack of adequate water and sewage treatment options, including desalination facilities, has further compromised the quality of the water (4, 5). It is estimated that the water extracted from the coastal aquifer will be unusable by as early as 2016, with the damage becoming irreversible by 2020 (6). In addition, damage to and destruction of the infrastructure due to the ongoing conflict with Israel and blockade of the Gaza Strip has gone unrepaired, which further complicates the situation (7).

It is essential that the public health and water authorities in the Gaza Strip pursue long-term solutions for the worsening water crisis. However, the population relies on the existing water resources, despite the insufficient quantity and questionable quality. Therefore, as part of an initiative to support the establishment of the Palestinian National Institute of Public Health (PNIPH), the Norwegian Institute of Public Health (NIPH) was commissioned by the World Health Organization (WHO) to collaborate with the PNIPH, WHO and the Palestinian Ministry of Health to provide the population in the Gaza Strip with clear advice on how to mitigate health risks from water.

Water sources in the Gaza Strip

Piped water in the Gaza Strip generally originates from the coastal aquifer, which extends from Haifa to the Sinai desert to Hebron Mountain. Water from the aquifer is drawn from deep wells and is used for domestic, agricultural and industrial purposes. However, the quality of the water sourced from the coastal aquifer has been severely compromised due to the infiltration of seawater and contamination from chemicals, such as pesticides and fertilizers (8,9).

Desalination has been pursued as a means of increasing the amount of potable water in the Gaza Strip. Currently, there are 7 public desalination facilities run by the Coastal Municipalities Water Utility, at least 40 small-scale private desalination plants, and more than 20 000 households using reverse osmosis units. Drinking water from desalination plants is sold from water tankers. As much as 83% of the population uses water from tankers as their primary source of household water (10). According to a water-quality monitoring campaign conducted in 2009, the water from desalination plants is of good microbiological and chemical quality (11). However, bacteriological contamination has been detected in samples taken from distribution points and in samples taken from household storage tanks, owing to contamination from non-hygienic handling and storage (12).

Bottled water in the Gaza Strip is both produced locally (using the aquifer as a source) and imported from Egypt, Israel, Jordan, Turkey and the West Bank. It has been estimated that 80% of the total amount of bottled water consumed in the Gaza Strip is imported, according to information provided by managers of large stores in Gaza (S. Lubbad, Public Health Laboratory, Palestinian Ministry of Health, personal

communication, 2012). Due to a lack of systematic monitoring of the production and import of bottled water, there is limited information about the overall microbiological quality.

The harvesting of rainwater, commonly practiced in the West Bank (13), is not generally conducted by private households in the Gaza Strip. A 2008 study found that residents of the Gaza Strip would be willing to adopt on-site rooftop rainwater filtration systems in urban areas where land is available, but financial incentives from local authorities would be necessary to make this alternative more attractive (14). Given that the long-term annual average rainfall in Gaza is 327 mm, with uneven geographical distribution and large fluctuations in quantity from year to year (9), and there is hardly any precipitation from May through September, the viability of rainwater collection as major source of water in the Gaza Strip is limited.

Methods

Review of literature and water-quality guidelines

To develop evidence-based recommendations for water use, a literature review was conducted to identify all studies related to water in the Gaza Strip. The search for peer-reviewed literature was conducted during July 2013 in the Ovid MEDLINE and Scopus databases, using general and specific terms related to "water" and "Gaza". Titles and abstracts were screened for relevance by two reviewers. Relevant articles were classified into thematic areas. Any recommendations proposed in the literature for addressing water quality in the Gaza Strip were extracted in order to potentially support the recommendations developed by the NIPH.

A total of 304 article titles were obtained using the search terms. Of these, 87 relevant original articles were

identified and classified under 11 thematic areas. Only nine studies (15–23) examined the association between water quality and health effects (Table 1). In the literature describing contaminants in the water supply in the Gaza Strip, salt was the most notable cause of decreased water quality, followed by nitrates and infectious organisms. There is negligible information about the health effects of specific contaminants in the Gaza Strip, such as heavy metals and pesticides. The recommendations proposed in the literature predominantly emphasized the overall need to improve water resources. The full methods and results of the literature review and review of water guidelines are presented in a report by the NIPH and PNIPH (24).

A review of the Palestinian Water Authority's (PWA's) and international water-quality guidelines was conducted to propose practical recommendations based on the data about using the water available in the Gaza Strip and how the population could mitigate the health risks associated using it. For some parameters, the PWA's guidelines (11) are less restrictive than WHO's guidelines (25). Those PWA parameters that differ from WHO's guidelines are generally related to natural chemical constituents in the water. When compared with the results from regular testing for chemical contaminants in wells in the Gaza Strip from 2010 (169 wells), 2011 (173 wells) and 2012 (193 wells), levels for several parameters exceeded the limits recommended by WHO and the PWA (Palestinian Water Authority, personal communication, 2013). For example, from 2010 to 2012 the average chlorine levels observed in wells varied from 50 mg/L to 1 1476 mg/L, which exceeds the recommended maximum in both WHO's and the PWA's guidelines (WHO's guidelines specify a maximum of 250 mg/L and the PWA specifies 600 mg/L). Nitrate levels up to 528 mg/L also exceeded the recommended limits in both guidelines (WHO's guidelines: maximum 50 mg/L; PWA guidelines:

70 mg/L). Although the routine testing of wells does not include microbiological parameters, high levels of total and faecal coliform bacteria have also been found in water samples collected from groundwater wells, particularly those near wastewater treatment ponds, resulting from contamination with sewage (10,26).

Results

Development of recommendations for water usage

The evidence collected through the literature review was presented to experts and key stakeholders in the Gaza Strip and Norway by the Palestinian Ministry of Health, the NIPH, the PWA, the Coastal Municipalities Water Utility and WHO. Through a consultative process, recommendations were developed about using water from different sources for different purposes (consumption; hygiene; amenities, such as car washing or lawn watering; production; and irrigation) (Table 2). Water used for consumption and hygiene has direct consequences for human health, both in relation to physiological needs and for controlling diverse infectious and non-infectious waterborne diseases. Water used for amenities (such as for watering lawns) may not directly affect human health, but water used for production (such as for raising animals, or for small-scale horticulture or construction) may be critical to sustaining livelihoods and, therefore, may have considerable indirect influence on human health. Water used for irrigation, such as for growing vegetables, demands significant amounts of water and was considered to be a separate category. In addition, the following vulnerable groups were defined

- Infants up to 6 months of age were considered to be at risk for methaemoglobinemia (or "blue baby

syndrome"), for which the most common environmental cause is high levels of nitrates in drinking water. Other groups potentially susceptible to this condition include pregnant women and people deficient in glucose-6-phosphate dehydrogenase or methaemoglobin reductase (27).

- Children between 6 months and 5 years of age have an increased risk of morbidity and mortality from diarrhoeal diseases, generally resulting from the consumption of contaminated food and water.
- Pregnant women or lactating women may have an increased risk of, and severity of, illnesses, such as hepatitis E, from specific waterborne pathogens due to immune alterations that occur with advancing pregnancy (28,29). In addition, contaminants such as pesticides can cross the placenta from the mother to the fetus, harming fetal development.
- Elderly people are predisposed to a greater frequency and severity of infections than the general population due to factors such as the presence of multiple underlying medical conditions, a weakened immune system, malnutrition, age-related changes in the gastrointestinal tract, the concurrent use of different medicines, delays in diagnosis, or a delayed or diminished response to therapy, or some combination of these (30).

Specific advice was developed for vulnerable groups, including not to drink piped water even after boiling (Table 3). We also recommended that infants should be exclusively breastfed. If infants are fed formula, bottled water may be used for the formula. However, due to a lack of evidence that bottled water is microbiologically safe, the water needs to be boiled before use.

Discussion

The water-use recommendations that we developed are inherently limited, as

Table 1. Studies examining the association between drinking water and health in the Gaza Strip

Risk	First author Year	Location	Objective	Design	Sample size	Risk measure RR, OR, Prev(%)	Recommendations
Nitrates	Abu Naser 2007	Three areas of Gaza Strip (Jabalia, Gaza City and Khan Younis)	To determine the factors associated with high methaemoglobin (Met-Hb) levels in infants and the relationships with nitrate concentration in drinking water wells	Descriptive cross- sectional and analytical study	338 infants	Significant positive association between Met-Hb and boiled water for formula $\chi^2=6.91, P = 0.009$	Importance of exclusive breastfeeding for infants <6 months old, and the choice of a suitable source of water for these children
Fluorides	Shomar 2004	Five governorates of Gaza	To determine the average levels of fluoride in groundwater and topsoils of the Gaza Strip; to determine the levels of fluoride in the prepared tea and tea leaves used in Gaza; to identify the major fluoride minerals in soil that may supply groundwater with fluoride ions; to determine the dental fluorosis index (DFI) for schoolchildren	Cross- sectional	353 school children (from 24 schools in 5 governorates)	Linear regression analysis found a correlation ($r =$ 0.72) between levels of fluoride in drinking water and the Dental Fluorosis Index	There are a number of wells in the northern area of Gaza that are low both in fluoride and salinity which, when mixed with other wells, will result in water of acceptable quality. Parents, caregivers, water quality experts and health care professionals should judiciously monitor use of all fluoride- containing dental products by children under of 5.
Fluorides	Abuhaloob 2012	Five governorates of Gaza	To determine the history of breastfeeding and dietary behaviours among children in the Gaza Strip and to examine potential associations with the prevalence and severity of dental fluorosis	Cross- sectional study	350 children and their mothers (Stratified cluster random sample from 5 governorates)	No association between breastfeeding, drinking formula, and use of mineral vs. tap water, and start of tea drinking and dental fluorosis.	To develop an appropriate prevention strategy to reduce the fluoride intake to a suitable level in order to prevent dental fluorosis and other potential health hazards.
Iodine	Sack 2000		To examine the relationship between low groundwater iodine and iodine deficiency and school children.	Descriptive study	Water samples collected from 44 groundwater sources (not in Gaza). Urine samples from 728 children	Children from Gaza had very high urinary iodine excretion (93% excreting more than $140 \mu\text{g l/g Cr}$ and only 1% excreting less than $50 \mu\text{g l/g Cr}$.	Several areas with low urinary iodine excretion are found in the study. Gaza is one of the areas with less proportion of children with low urinary iodine excretion. Most of the areas studied in the article were found to be iodine deficient. Therefore authors recommend that The Palestinian territory and Israel should monitor the iodine status using the WHO recommended criteria, especially in areas known to be iodine deficient

Table 1. Studies examining the association between drinking water and health in the Gaza Strip

Risk	First author Year	Location	Objective	Design	Sample size	Risk measure RR,OR, Prev(%)	Recommendations
Diarrhea	Aboutier 2011	Four governorates of Gaza (Caza - Al Zaitoun, Sabha, Northern - Jabalia, Middle - Der Al Balah, Al Nusairat, Khan Younis - Bander Khan Younis)	To investigate the impact of water resources and poverty on diarrhea occurrence in patients attending primary health care centres	Matched case control study	266 patients (recruited from 6 primary health care centers in 4 governorates)	Public water access at home OR 0.046 ($P = 0.0083$) CI (0.005 - 0.454) (Lack of public water access at home = independently predictive of diarrhea. Non-consumption of bottled water was associated with diarrhea in the univariate analysis but did not remain in the multivariable was	Efforts should be made to implement guidelines in order to better manage diarrhea, especially in children. Palestinians should be helped to improve access to and quality of water, including repairing and improving partly destroyed water and sewage networks and allowing the importation of necessary materials into Gaza.
Diarrhea/ Parasites	Abu Mourad 2004	Nuseirat Refugee Camp	To assess the socioeconomic-demographic, environmental health and hygiene conditions associated with intestinal parasites and diarrhea in Nuseirat Refugee Camp of Gaza Strip	Cross-sectional study	1625 households (stratified sample from eight Blocks)	Intestinal parasites strongly associated with source of drinking water ($\chi^2=260$, $P<0.001$) and cleaning of tanks ($\chi^2=863$, $P<0.001$). Diarrhea strongly associated with source of drinking water ($\chi^2=793$, $P<0.001$), full-day supply ($\chi^2=8.7$, $P<0.1$) and cleaning of water tanks ($\chi^2=273$, $P<0.001$).	Effort should be focused on the following interventions: Promote health-education programmes Urgent introduction of awareness and educational programmes to improve the environmental health awareness Establish multidisciplinary approach among all related sectors to overcome environmental and health-related problems Support community involvement for solving the above mentioned problems Co-operation and fund-raising for improving the and reconstructing the infrastructure.

Table 1. Studies examining the association between drinking water and health in the Gaza Strip (concluded)

Risk	First author Year	Location	Objective	Design	Sample size	Risk measure RR,OR, Prev(%)	Recommendations
Diarrhea	Yassin 2006	Gaza governorate	To assess the contamination level of total and faecal coliforms in water wells and distribution networks, and their association with human health in Gaza Governorate, Gaza Strip	Cross-sectional study?	150 residents of Gaza City (sampling strategy unspecified)	Self-reported diarrhea highest among people drinking municipal water vs. desalinated/home-filtered water (OR =1.6, CI 0.5-4.75), people with municipal water networks 4-5 years old (OR = 3.43, CI 0.16-20.06) and people with interrupted water supply (OR = 2.2, CI 1.07-4.55)	Establishment of a proper sewage system in this governorate is a priority Regular maintenance of water networks is necessary to reduce breakages in pipelines. Interruption of the water supply should be minimized. Regular cleaning of water roof tanks and proper disinfection are recommended (2/3 interviewees don't clean the tanks)
Diarrhea	Abu Amr 2008	Khan Younis Governorate	To assess the contamination level of total and faecal coliforms in water wells and distribution networks over the past 7 years, and their association with human health in Khan Younis Governorate, Gaza Strip	Cross-sectional study	210 residents of Khan Younis Governorate (sampling strategy unspecified)	Self-reported diarrhea highest among people drinking municipal water vs. desalinated/home-filtered water (OR =2.03, CI 0.77-5.54), people with municipal water networks 4-5 years old (OR = 1.96, CI 0.5-7.75) and people with interrupted water supply (OR = 4.61, CI 2.06-10.4)	Establish a proper sewage system in this governorate is a priority Regular maintenance of water networks is necessary to reduce breakages in pipelines. Interruption of the water supply should be minimized. Regular cleaning of water roof tanks and proper disinfection are recommended (2/3 don't clean the tanks)
Yersinia enterocolitica	El Qouqa 2011	Pediatric departments of three hospitals	To identify risk factors for infection with Y. enterocolitica and identify presenting signs and symptoms specifically associated with developing infection.	Matched case control study	600 cases from pediatric departments of three hospitals	Compared to unmatched controls, in multivariable analysis non-chlorinated water supply (aOR 3.05, P=0.049) was independently associated with infection.	More attention to the alleviation of malnutrition. Increased supervision of the water supply by local health departments. Further studies needed to investigate more risk factors and the main sources of Yersinia enterocolitica

Table 2 Recommendations about using water from different sources^a

Water use	Water source Piped water (not desalinated)	Water delivered by tankers (desalinated water from treatment plants)	Piped water desalinated at home	Bottled water	Rooftop-harvested rainwater ^b
Main problems	High in salt, nitrates and TDS; unknown levels of pesticides and radiation; limited data about heavy metals	Microbial contamination occurs due to non- hygienic handling of the water during distribution; water is low in minerals	Quality varies as domestic desalination units are often not regulated	Uncertainty about microbiological contamination^c	Not commonly used at the household level; risk of microbial contamination
Consumption	Should not be consumed	Should be consumed only if water safety can be ensured by disinfecting and storing safely	Should be consumed only if water safety can be ensured by disinfecting and storing safely	Can be consumed but must be properly disinfected due to the risk of microbiological contamination ^{c**}	Currently not used for consumption, but may be considered for consumption if treated appropriately (with filtration plus disinfection) and stored safely
Hygiene	Can be used for hygiene needs, but use will probably be limited in areas where the water is too salty	Can be used for hygiene needs but with awareness that water coming from this source might contain microbiological contaminants	Can be used for hygiene needs but with awareness that water coming from this source might contain microbiological contaminants	Can be used for hygiene needs but is likely to be unaffordable for these uses	Currently not used for hygiene needs, but may be considered for hygiene needs if treated appropriately (with filtration plus disinfection) and stored safely
Amenities	Can be used for this category	Can be used for this category	Can be used for this category	Not applicable	Currently not used for amenities, but should not be a problem for this category, if possible turbidity is acceptable to the consumer
Production	Can be used for production, but use as drinking water for animals will be limited if it is too salty	Can be used for production	Can be used for production	Not applicable	Can be used for production
Irrigation	Can be used depending on the plants/ vegetables, but in general will be too salty	Not applicable	Not applicable	Not applicable	Not applicable (it is assumed that this category produces only a small amount of water)

^a Water use has been categorized into five types: consumption (drinking and cooking), hygiene (including basic needs for personal and domestic cleanliness), amenities (such as car washing, lawn watering), production (such as, for raising animals or small-scale horticulture, or for construction); irrigation (agriculture that needs water).

^b Rainwater is not a significant source of domestic water but could be considered as a potential alternative source.

^c There are uncertainties regarding the quality of bottled water. There is not enough evidence to document the quality of bottled water currently distributed and consumed in the Gaza Strip.

it is unacceptable to recommend that people consume water that is of sub-standard quality according to WHO's guidelines on drinking water (25). It is

essential that long-term solutions are identified to ease the worsening water crisis. However, in the interim, groups at high risk from drinking contaminated

water can be targeted to ensure that their exposure to the most harmful contaminants is avoided. The implementation of these recommendations may require

Table 3 Recommendations about water consumption for vulnerable groups

Vulnerable group	Water source for consumption				
	Piped water (not desalinated)	Water delivered by tankers (desalinated water from treatment plants) ^a	Piped water desalinated at home	Bottled water	Rooftop-harvested rainwater ^b
Infants ≤ 6 months of age	Should not be consumed, even if boiled	Can be consumed only if water safety is ensured by disinfecting it (for example, by boiling) and storing it safely	Should not be consumed, even if boiled	Can be consumed but must be properly disinfected due to the risk of microbiological contamination ^c	Currently not used for consumption, but may be considered if treated appropriately (with filtration plus disinfection) and stored safely
Children aged 6 months to 5 years	Should not be consumed, even if boiled	Should be consumed only if water safety can be ensured by disinfecting it (for example, by boiling) and storing it safely	Can be consumed after being boiled if safety is ensured by disinfecting and storing safely	Can be consumed but must be properly disinfected due to the risk of microbiological contamination ^c	Currently not used for consumption, but may be considered if treated appropriately (with filtration plus disinfection) and stored safely
Pregnant and lactating women	Should not be consumed, even if boiled	Should be consumed only if water safety can be ensured disinfecting it (for example, by boiling) and by storing safely	Should not be used, even if boiled	Can be consumed but must be properly disinfected due to the risk of microbiological contamination ^c	Currently not used for consumption, but may be considered if treated appropriately (with filtration plus disinfection) and stored safely
Elderly people	Should not be consumed, even if boiled	Should be consumed only if water safety can be ensured by disinfecting it (for example, by boiling) and storing safely	Can be consumed after being boiled if safety is ensured by disinfecting and storing safely	Can be consumed but must be properly disinfected due to the risk of microbiological contamination ^c	Currently not used for consumption, but may be considered if treated appropriately (with filtration plus disinfection) and stored safely

^a It was assumed that water distributed by tankers is desalinated seawater, which suggests that nitrate levels would not be problematic.

^b Rainwater is not a significant source of domestic water but could be considered as a potential alternative source.

^c There are uncertainties regarding the quality of bottled water. There is not enough evidence to document the quality of bottled water currently distributed and consumed in the Gaza Strip.

information campaigns that assist the population in differentiating water from different sources for different uses.

Several measures can be implemented to improve water quality in the short term. Currently, chlorine is not added during transport to the desalinated water distributed by water tankers, so its use should be encouraged to ensure that safe water is delivered to customers. If desalinated water cannot be treated and safely stored, it should be boiled before consumption. Making improvements to

water-quality monitoring in the Gaza Strip is also encouraged, including screening for heavy metals, radioactivity and pesticides every 5 years; screening for chemical parameters 4 times each year; and screening for microbial parameters every month. Targeted studies are needed to investigate the burden of disease associated with water consumed from different sources and districts in the Gaza Strip, including estimating the long-term effects of consuming substandard water.

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