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A Systematic Literature Review and Recommendations on Water Usage in the Gaza Strip

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Foreword

More than ninety per cent of the water offered to the population in the Gaza Strip has been classified as unsuitable for human consumption. Although there are many plans to improve the situation, it will take time before the situation is significantly improved and current availability of potable water and plans for future improvements do by no means fill estimated needs. Based on the facts and the international literature, clear recommendations should be given on the usage of the available water in the Gaza Strip.

As part of the initiative to support the establishment of the Palestinian National Institute of Public Health (PNIPH), a project managed by World Health Organization (WHO), the Norwegian Institute of Public Institute (NIPH) was commissioned to collaborate with PNIPH/WHO to provide the population in the Gaza Strip with clear advice on how to mitigate the health risks from the water available to the population (see Annex I for Terms of Reference). The specific objectives were:

1. To conduct a review of all published white and grey literature on water quality and health in Gaza in order to identify all studies on water quality that have been conducted in Gaza;
2. To review international guidelines for water quality and usage;
3. To propose practical recommendations on the usage of the available water in Gaza and on how the population in Gaza can mitigate health risks associated with the use of the available water based on available data; and
4. To assess whether there are gaps in knowledge regarding water quality in Gaza and propose additional studies or improvements to monitoring, if necessary.

This report is the result of the collaboration. In the printed version, the table of the literature review will be added.

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Summary

Water quality in the Gaza Strip has been severely compromised due to increasing salinity of groundwater, contamination of water resources with fertilisers, pesticides and solid waste, and lack of adequate water and sewage treatment options. Damaged and destroyed infrastructure due to the ongoing conflict with Israel as well as the ongoing blockade of the Gaza Strip, which has prevented materials for repairs and reconstruction from being imported into the area, have further complicated the situation. Although these circumstances require that public health and water authorities in the Gaza Strip pursue long-term solutions for addressing the significant lack of potable water, the current population of Gaza is dependent on the existing water resources, despite the insufficient quantity and questionable quality. Therefore, as part of the initiative to support the establishment of the Palestinian National Institute of Public Health (PNIPH), a project managed by the World Health Organization (WHO), the Norwegian Institute of Public Institute (NIPH) was commissioned to collaborate with PNIPH/WHO to provide the population in the Gaza Strip with clear advice on how to mitigate the health risks from the water available to the population.

A literature review was conducted in order to identify all studies conducted on water in the Gaza Strip. In the literature describing contaminants to the water supply in Gaza, salt was the most notable cause of decreased water quality, followed by nitrates and infectious organisms. Despite the volume of studies on water quality in general, few studies specifically assess the link between water quality and health effects. Only nine articles presented studies examining the association between drinking water and morbidity in Gaza Strip. The findings of the literature review suggest that consumption of water of poor quality leads to increased morbidity in the Gaza Strip. The recommendations proposed in the literature predominantly stressed the overall need for improved water resources. Targeted studies are needed to investigate the burden of disease associated with water from different sources and districts in the Gaza Strip, including an estimation of long term effects of consuming substandard water.

A review of the Palestinian and international water quality guidelines was conducted in order to propose practical recommendations on the usage of the available water in Gaza and on how the population in Gaza can mitigate health risks associated with the use of the available water based on available data. The most common water sources in Gaza were identified, including piped water, water from tank vehicles (desalinated water from treatment plants), bottled water and home desalinated piped water. Rooftop harvested rainwater was also considered as an alternate source of water. Recommendations on usage of water from different sources for different purposes (such as consumption, hygiene, amenity use, productive use and irrigation) were developed based on the results of the literature review and expert consultation. In addition, several vulnerable groups were defined, including infants up to six months of age, children six months to five years of age, pregnant or lactating women, and the elderly. Specific advice for vulnerable groups was developed, including not drinking piped water even after boiling. Infants should be exclusively breastfed. Otherwise, if infants are fed by milk formula, bottled water may be used as a source of water. However, due to lack of evidence that bottled water is microbiologically safe, the water need to be boiled before use, especially for vulnerable groups. To the desalinated water distributed by tank vehicles chlorine is currently not added during transport. This should be encouraged to ensure safe water to the customers. If desalinated water cannot be guaranteed to be safely stored and treated (disinfected) it should be boiled before consumed. Recommendations for improvements to water quality monitoring in the Gaza Strip were also proposed, including screening for heavy metals, radioactivity and pesticides every five years, for chemical parameters four times a year, and for microbial parameters every month.

The recommendations presented in this document are inherently limited, as it is unacceptable to recommend that people consume water that is substandard according to the WHO water guidelines. Risk groups can be targeted to ensure that exposure to the most harmful contaminants are avoided. The implementation of these recommendations may require information campaigns that assist the population to differentiate water from different sources for different uses.

Acronyms

CMWU	Coastal Municipality Water Utility
FAO	Food and Agriculture Organization
NIPH	Norwegian Institute of Public Health
PNIPH	Palestinian National Institute of Public Health
PWA	Palestinian Water Authority
RO	Reverse Osmosis
TDS	Total Dissolved Solids
UNRWA	United Nations Relief and Works Agency for Palestine Refugees in the Near East
WHO	World Health Organization

Note of the authors

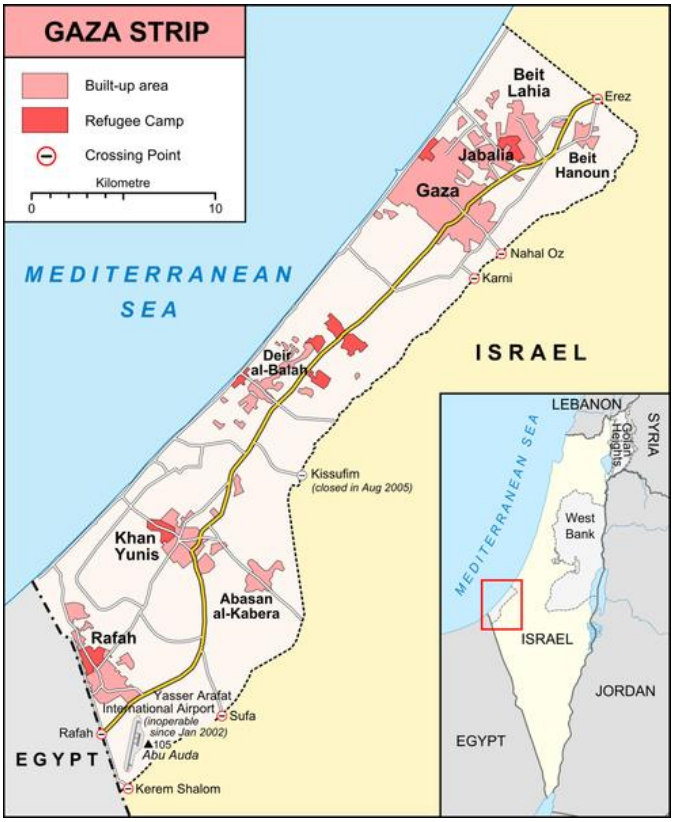
The current investigation was conducted before the initiation of the 2014 Israel-Gaza conflict. It is therefore still unknown to which extent our conclusions and recommendations are applicable to the current situation regarding water access, availability and quality in the area.

Background

The Gaza Strip

The Gaza Strip is approximately 365 km^2 and home to more than 1.7 million people who live in five governorates (Figure 1). The population is projected to grow even further, estimated to reach 3.7 million inhabitants by 2035. Currently, the Gaza Strip has the sixth highest population density in the world. The population is young, with children under 18 years composing over 50% of the territory's inhabitants. Over 74% of the population is registered with the United Nations Relief and Works Agency (UNRWA) as refugees, of whom over 43% reside in one of eight refugee camps in Gaza. The demography of the area is very much linked to the political conflict, which has limited the movement of goods and people in and out of Gaza, increasing the poverty and unemployment rates to unprecedented numbers. This complex political and socio-economic context has in turn placed significant pressure on the environmental resources of the area – and lead to a serious deterioration in water quality and quantity. Shortages of water and declining quality associated with over-extraction of the coastal aquifer and increasing salinity of the groundwater resources linked to seawater intrusion are critical in the context of a large and growing population. The United Nations report 2020 says that Gaza will not be livable in just few years if the current situation continues [1].

Figure 1. Governorates of the Gaza Strip



Source: Wikipedia

In addition to a lack of water, the situation is further exacerbated by damaged or destroyed infrastructure due to the ongoing conflict with Israel. For example, during Operation Cast Lead in 2008/2009 at least 11 major wells and over 30 kilometers of water networks were destroyed [2]. The ongoing blockade of the Gaza Strip has prevented materials for repairs from being imported into the area in order to enable reconstruction. Other factors that affect the water quantity and quality in the Gaza Strip include lack of electricity, lack of funding for large scale desalination plants, contamination of the aquifer, contamination of seawater, lack of experience and lack of economic resources, in addition to the significant tension between Israel and the Palestinians over ownership of water rights and adherence to agreements over water management. These factors have posed a tremendous challenge for the population to access sufficient clean water. As a result of the growing population, the domestic water demand is projected to grow from 91 million m^3/year to 199 million m^3/year in 2035. In this context, the World Health Organization (WHO) has highlighted the gaps and needs for sufficient safe water, sanitation and reinforced hygiene, and has emphasized them as a priority for reducing morbidity and mortality in the Gaza Strip.

Water sources, quality and access

This section provides a description of the water sources and main contaminants in the Gaza Strip. An overview of these water quality characteristics are summarized in Table 2.

Water from the coastal aquifer

Water resources in Gaza are essentially restricted to the coastal aquifer, which extends from Haifa in the North to Sinai desert in the South to Hebron Mountain in the East. Water from the aquifer is drawn from deep wells. The population of Gaza relies on water from the aquifer for domestic, agricultural and industrial purposes. The aquifer is recharged by different water sources, such as rainfall (primary source), water network leakage, wastewater collection system leakage, agricultural return flow and recharge storm water ponds. The extraction from the coastal aquifer is estimated at 170 million m^3/year (2010) whereas the annual sustainable yield of the aquifer within the geographical boundary of Gaza is widely quoted as 55 million m^3/year [3]. The water level is reportedly dropping by 20-30cm per year [4]. The United Nations has warned that the aquifer might be unusable in 2016 and the damage will be irreversible by 2020. Results from regular chemical and physical water testing of wells from 2010 (total 169 wells), 2011 (total 173 wells) and 2012 (193 wells) in Gaza are presented in Table 1 below:

Table 1 Overview of water quality in the registered wells in the different governorates in Gaza (169 in 2010, 173 in 2011 and 193 in 2012).

		Nitrate as NO_3^- mg/l	Total dissolved solids (TDS) mg/l	Fluoride as F^+	Chloride as Cl^- mg/l	Conductivity mS/cm at 20°C	Sulphate as SO_4^{-2} mg/l	Alkalinity mg/l $CaCO_3$	Hardness mg/l $CaCO_3$	Calcium as Ca^{+2}	Manganese mg/l Mg^{+2}	Pottasium as mg/l K^+	Sodium as mg/l Na^+	pH
		Values from wells in all the governorates												
Spring 2010	Median	106	1531	1,0	518	2470	148	251	496	90	67	4	318	7,8
	Max	524	18414	2,3	11476	29700	1163	571	9610	2160	1022	320	4440	8,9
	Min	11	241	0,0	53	389	4	52	103	17	15	1	25	6,1
Fall 2010	Median	129	1519	1,0	524	2450		275	467	84	60	4	320	7,7
	Max	417	18476	2,0	8281	29800		600	7446	1307	1014	92	4725	8,5
	Min	14	231	0,1	50	372		23	102	13	10	1	21	6,7
Spring 2011	Median	121	1559	1,0	558	2515	152	278	458	84	62	4	360	7,5
	Max	528	16616	1,9	9116	26800	1447	797	4419	764	683	105	5000	8,8
	Min	12	257	0,3	49	415	15	69	83	18	7	1	34	6,7
Fall 2011	Median	87	1612		526	2600	156	243	435	78	63	5	400	7,5
	Max	335	13578		7605	21900	1080	521	3159	725	442	100	3940	8,4
	Min	8	311		64	502	4	108	113	19	15	1	27	6,8
2012 (full year)	Median	95	1581		541	2550	181	248	455	84	60	5	420	7,8
	Max	396	18476		10272	29800	1521	571	4351	650	662	140	5600	8,6
	Min	14	295		72	476	9	99	94	16	13	1	27	6,8
		WHO guidelines for drinking water												
		50	1000-1200, min 100, optimum level 250-500*	1,5	250	400	500	200	200	Min 30	min 10 optimum 20-30	12	200	6,5-9,5
		Palestinian Water Authority guidelines for drinking water												
		70	1500	1,5	600	400	400	400	600	100-200	150	12	200	6,5-9,5

The results in table 1 are based on regular chemical testing of wells in Gaza which consist of two samples per year for each well, one during spring and one during fall. From the results, it is apparent that the levels of certain parameters (such as total dissolved solids, nitrates and chloride) vary substantially from minimum to maximum, but show less variation from spring to fall samples. As these results are aggregated from a number of wells, there are individual differences in quality for each well which are not reflected in table 1.

Several parameters are far over the limits recommended by the WHO and the Palestinian Water Authority (PWA) Guidelines. For example, the WHO guidelines for drinking-water quality for chloride levels specify a maximum limit of 250 Cl mg/l compared to the PWA Guidelines, which specify a maximum recommended limit of 600 Cl mg/l. The average Cl levels observed in wells vary from 50 mg/l to 11476 mg/l, which is far over the recommended maximum in both sets of guidelines. Similarly, the WHO guidelines for nitrate levels recommend a maximum of 50 mg/l, compared to the PWA Guidelines, which recommend a maximum of 70 mg/l. The average nitrate levels observed in Gaza wells ranges from 8 mg/l to 528 mg/l, also over the recommended limits from both guidelines.

In terms of chemical content, the water is considered undrinkable. As a health concern, the nitrate content is the most worrying due to risk of methaemoglobinaemia, especially for infants. The high content of salt in the aquifer is indicated by several parameters, including the high level of total dissolved solids (TDS). TDS comprise inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium, bicarbonate, chloride, sulfate, and nitrate anions [5]. Salty water does not itself present a health concern; however, it is unacceptable as drinking water, and to a certain extent for personal hygiene (e.g. showering). Another possible concern is that people will seek other sources for potable water that may pose a health risk due to other less apparent contaminants, even though they may be acceptable in terms of low salt content.

The routine testing which these results are based on does not include microbiological parameters. However, sewage is one of the biggest causes of groundwater contamination in the Gaza Strip. High levels of total and faecal coliform counts have been found in water samples collected from groundwater wells [6], particularly surrounding the wastewater treatment pond [7]. Although more than 75% of households surveyed in a 2011 study were connected to wastewater networks, communities in areas such as Juhor ad Dik, Al Qarara and Al Mawasi rely on cesspools at the household level [8]. In addition, the rates of viral meningitis are much higher in the Gaza Strip than in the West Bank [Assessment of the surveillance of meningitis and viral vaccine-preventable diseases in the Gaza Strip focusing on laboratory quality and capacity. Assessment report. WHO, PNIPH, NIPH,

June 2014], which may also be related to poor water quality, although no studies have been conducted to investigate this possible association.

Little information is available about concentrations of heavy metals in water in Gaza. The Coastal Municipality Water Utility (CMWU) performed in 2012 screening of heavy metals[1] in 157 wells in the five Gaza governorates. All sampled wells showed values below the WHO standards except for Iron, Chromium and Strontium [unpublished data CMWU]

In addition to being of poor quality, groundwater provided through the municipal infrastructure is scarce. As of September 2011, the Emergency Water, Sanitation and Hygiene Group of the Palestinian Territories reports that although 98% of Gaza's residents are connected to the water network, only 48% of household have running water four to seven days a week [8]. Most residents of Jabalia, Gaza City and Rafah do not have a permanent water supply and receive water for only 6-8 hours per day several days a week. Together with inadequate disinfection of the piped water, this can lead to suitable conditions for biofilm formation in the distribution network.

Desalinated water

In order to address the increasing salinity in the water supply, the Palestinian Authorities have pursued desalination as a means of increasing the amount of potable water available. The prospects for seawater desalination capacity was determined to be 11 million m^3/year in 2012, increasing to 55 million m^3/year in 2017 and to 130 million m^3/year till 2035 [9].

Desalinated water is obtained through different sources: there are seven **public desalination facilities** run by the CMWU, In addition there are at least 40 **small scale private plants** and more than 20,000 **reverse osmosis (RO) housing units**, which are often unregulated, from which most of the available desalinated drinking water is produced. Typically, the water feeding into these units is chlorinated piped water that is stored in rooftop storage tanks. The quality of water desalinated from these units can vary. Domestic desalination units do not incorporate any treatment (such as mineralization or disinfection through UV or chlorination) and filters must be regularly changed to reduce contamination. A substantial proportion of the Gaza population obtains drinking water from unregulated sellers of desalinated water.

Drinking water from desalination plants is sold on the market by water tankers. As much as 83% of the population use water from tanker cars as the primary household water source [8]. According to a water quality monitoring campaign conducted in 2009, the water from desalination plants is good,

[1] Parameters analyzed were Aluminium, Antimony, Arsenic, Cadmium, Chromium, Cobalt, Copper, Mercury, Lead, Manganese, Nickel, Selenium, Strontium, Iron, Zinc and Silver

both in terms of chemical and microbiological content [10]. However, due to a non-hygienic handling of the water in distribution, (e.g. lack of cleaning and chlorination of transport water tanks, contamination of the nozzle on water transport tanks, contamination of customer transport containers, lack of cleaning of home storage tanks and unhygienic handling in homes before drinking), bacteriological contamination has been detected in samples taken from distribution points and in samples taken from household storage tanks [10]. A prerequisite for ensuring good drinking water quality sold from vendors is that systematic control of the quality of the water exists, such as a licensing system and/or assessments of vendors overseen by the water authorities.

Another potential long-term health effect is the absence of minerals in the treated water, which is still debated. As the vast majority of the population of Gaza are permanent or long-term residents, the long-term effects from the water quality is of relevance and the effects of long-term consumption of demineralized water should be considered from a policy point of view (e.g. whether treated water sold from tank vehicles should be mineralized before distribution).

Many residents of Gaza store desalinated water from private vendors in rooftop tanks. A study from the West Bank regarding the population's knowledge, attitudes and practices about water and hygiene indicated that 73% of respondents never cleaned their water storage tanks and that knowledge regarding safe water practices could be improved. Cleaning of storage tanks may also be unsatisfactory in the Gaza Strip.

Bottled water

Bottled water available in Gaza is both produced locally (using the aquifer as a source) and imported from the West Bank, Israel, Jordan, Turkey and Egypt. It is estimated that 80% of the total amount of bottled water consumed in Gaza is imported, according to information provided by managers of major stores in Gaza (personal communication). This percentage varies from 30 to 90% depending on the areas and economic status of the different populations throughout the Gaza strip. In theory, bottled water produced outside Gaza is tested and monitored before being permitted to be imported. If results comply with the quality standards, then the importing company is allowed to import the bottled water to Gaza. For the period between the entry of bottled water on the market until consumption, samples may be taken randomly by the Ministry of Health. For bottled water produced locally in Gaza, three random samples must be taken twice a year to check for compliance (personal communication).

Due to lack of systematic monitoring of bottled water, both production and import, there is only a few reports about the overall microbiological quality of bottled drinking water consumed in Gaza. Analyses published in 2013 of eleven brands of imported bottled water and four brands of locally

bottled waters found that 50% of samples from locally bottled waters and 36% of imported waters had total bacterial counts over the permitted standard in Palestine, while 75% of the locally bottled water and 45% of imported waters had detectable total coliform bacterial counts [11]. Unpublished results from water tests conducted in 2013 by the public health laboratory in Gaza found that 46.8% (132/282) and 13.3% (8/60) of the samples from local bottled water and imported bottled respectively were contaminated with either pseudomonas, total coliforms or faecal coliforms. Based on the available information on microbiological quality in bottled water, it is not possible to conclude that bottled water is a safe water source for consumption.

Harvested rainwater

The harvesting of rainwater, commonly practiced in the West Bank [12] is not generally conducted by private households in Gaza. However, this could potentially be considered as a means of supplementing household water supplies. Rainwater is very low in mineral content, which may have a long-term health effect (see concern under water from desalination plants). There is also risk of water being contaminated while being handled and stored in the households. Analyses of storm water runoff collected from rooftops suggest that this water source has low concentrations of chloride and nitrate and the water quality is close to the limits set by WHO for drinking purposes [13]. A 2008 study found that residents of Gaza are willing to adopt on-site rooftop rainwater filtration in urban areas where free land is available, but financial incentives from local authorities would be necessary to make this alternative more attractive [14].

Table 2 Overview of main water sources in the Gaza Strip

Water source	Primary means of delivery	Availability	Treatment	Usage	Affordability	Main problem
Coastal aquifer (groundwater)	Municipal pipelines and wells	Estimated groundwater extraction for 2009 from the aquifer is ca. 166.7 MCM annually; 98% of Gaza's residents are connected to the water network but supply is intermittent[15], with 39% of households reporting running water only 2-3 days a week [8]; some areas not connected to network	Chlorination	85%+ use network water for domestic purposes [8]	CMWU provides domestic water to households at the rate of NIS 1.08/CM	Nitrates; Salinity
Desalination plants (seven public desalination plants and 40+ small private plants	Trucks; jerry cans		Desalination. No certainty of further treatment, such as chlorination.	73 – to 87% use desalinated water for drinking [15] [8]	NIS 35/ m^3[8]	Cost; Low mineralization, possible; contamination with microorganisms if not handled or treated properly
Bottled water	Private sale; locally produced or imported from outside of Gaza		No information available			Cost; quantity, potential contamination with microorganisms
Rainwater	Privately collected in rooftop tanks or external catchment areas	Limited by amount of rainfall	Home treatment and/or filtration? No regular chlorination performed at household level [16]	Not commonly used in Gaza per today		Quantity; high contamination with microorganisms during distribution/storage [16]

Aims and objectives

The public health and water authorities in the Gaza Strip need to pursue long-term solutions for addressing the significant lack of sufficient potable water. If the current problems are not addressed urgently, water resources will not be sufficient for the growing population. However, as the current population of Gaza is dependent on the existing water resources, despite the limited quantity and questionable quality, public health authorities are obligated to recommend ways to reduce the detrimental effects. As part of the initiative to support the establishment of the Palestinian National Institute of Public Health (PNIPH), a project managed by WHO, the Norwegian Institute of Public Institute (NIPH) was commissioned to collaborate with PNIPH/WHO to provide the population in the Gaza Strip with clear advice on how to mitigate the health risks from the water available to the population (see Annex I for Terms of Reference). The specific objectives were:

1. To conduct a review of all published white and grey literature on water quality and health in Gaza in order to identify all studies on water quality that have been conducted in Gaza;
2. To review international guidelines for water quality and usage;
3. To propose practical recommendations on the usage of the available water in Gaza and on how the population in Gaza can mitigate health risks associated with the use of the available water based on available data; and
4. To assess whether there are gaps in knowledge regarding water quality in Gaza and propose additional studies or improvements to monitoring, if necessary.

Literature review

A literature review was conducted in order to identify all studies that have been conducted on water in the Gaza Strip. A detailed report of the methodology and results of the literature review is provided in **Appendix I**. The search for peer-reviewed literature was conducted in the Ovid MEDLINE and SCOPUS databases using general and specific terms related to "*water*" and "*Gaza*" on July 17, 2013. Titles and abstracts were screened for relevancy by two reviewers. Articles presenting original studies on water in the Gaza Strip were read full text. A snowballing technique was used to identify additional sources from the references of the articles obtained through the systematic search. In addition, staff of the WHO Gaza-sub-office identified and collected all available grey literature (including reports, academic theses and conference presentations) on water in Gaza that have been produced by universities, governmental authorities and non-governmental organizations.

Relevant original peer-reviewed articles identified were classified under twelve thematic areas (1) Geology, geomorphology and hydrology, 2) Groundwater and vulnerability of the coastal aquifer, 3) Water management and recharge, 4) Desalination, 5) Nitrates, 6) Iodine and fluorides, 7) Pesticide, 8) Waste water, 9) Infectious Diseases, 10) Knowledge, attitude and practices, 11) Radiation and 12) Other. In addition, several reports, master or doctoral theses, guidelines and notes and abstracts were examined. 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.

Nine presented studies examining the association between water consumption and health outcomes (Table 3). Five studies addressed gastrointestinal infections, of which four found an association between specific water sources and gastroenteritis. The fifth study found that lack of public water access at home was independently predictive of diarrhea. One study found a significant positive association between methaemoglobine levels in infants and nitrate concentration in groundwater. One study found an association between low levels of iodine in groundwater and iodine deficiency in children. One of two studies examining fluoride levels found a positive correlation between high fluoride concentrations in groundwater and occurrence of dental fluorosis among school children.

The remaining articles presented studies on water quality that do not examine the association with health outcomes. In the literature describing contaminants to the water supply in Gaza, salt was the most notable cause of decreased water quality, followed by nitrates and infectious organisms. Although many studies have been carried out on water in Gaza, few studies examine the association between water and health, and none examine the long-term effects of consumption of poor quality

water. In addition, there is negligible information available on the health effects of specific contaminants such as heavy metals and pesticides in Gaza.

The recommendations proposed in the literature predominantly stressed the overall need for improved water resources. Many documents presented specific recommendations that could be of interest at the political level, including negotiating water rights with neighboring countries and prioritizing conservation of the Wadi Gaza. Other recommendations were more technical and were appropriate for the service delivery level, such as the selection of sites for treatment, management of effluent and leachate, and strategies for monitoring water quality. Several documents stressed the need for construction and/or maintenance of the water delivery and sanitation infrastructure, including pipelines. Recommendations for the population level frequently addressed the need for increased awareness regarding water quality, and hygiene and sanitation practices, including the regular cleaning of rooftop tanks.

A detailed description of the recommendations proposed by each of the articles is included n **Appendix I**.

Table 3 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 [17]	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 χ^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 [18]	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 [19]	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 [20]	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 µg l/g Cr and only 1% excreting less than 50 µg 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
Diarrhea [21]	Aboutier 2011	Four governorates of Gaza (Gaza – 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 [22]	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 (χ^2=260, P<0.001) and cleaning of tanks (χ^2=863, P<0.001). Diarrhea strongly associated with source of drinking water (χ^2=793, P<0.001), full-day supply (χ^2=8.7, P<0.1) and cleaning of water tanks (χ^2=27.3, 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 and

							reconstructing the infrastructure.
Diarrhea [6]	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 [23]	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 [24]	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

Review of international and Palestinian drinking water quality guidelines

In the Table 4, the quality standards set by the WHO and the PWA for relevant drinking water quality parameters are presented. Values for some of the same parameters from the European Union water directive are also listed.

Table 4 WHO and PWA guidelines for drinking water

pH	Conductivity mS/cm at 20°C	Total dissolved solids (TDS) mg/l	Nitrate as NO_3^- mg/l	Chloride as Cl^- mg/l	Sulphate as SO_4^{-2} mg/l	Alkalinity mg/l $CaCO_3$	Hardness mg/l $CaCO_3$	Calcium as Ca^{+2}	Magnesium mg/l Mg^{+2}	Fluoride as F^+	Pottasium as mg/l K^+	Sodium as mg/l Na^+
WHO guidelines for drinking water												
6,5-9,5	400	1000-1200, min 100, optimum level 250-500*	50	250	500	200	200	Min 30	min 10 optimum 20-30	1,5	12	200
PWA guidelines for drinking water												
6,5-9,5	400	1500	70	600	400	400	600	100-200	150	1,5	12	200
European Council Directive 98/83/EC on the quality of water intended for human consumption												
6,5-9,5			50	250	250					1,5		200

A review of water quality guidelines has shown that national and international water quality standards are generally based on the WHO guidelines. In few cases, guidelines are less restrictive than the WHO guidelines for specific parameters. This is the case for PWA, which mandate several parameters which deviate from the WHO guideline values (Table 4). Those parameters that differ from the WHO guidelines are parameters that are concerns in the Gaza Strip and are generally related to natural chemical constituents in the water. These are not directly of health concern, with the exception of nitrate, which is most often related to anthropogenic activities such as agriculture.

Recommendations

The result of the literature review and review of water quality parameters confirm that there are many obstacles to having sufficient, good quality water for the population in the Gaza Strip. The depleting coastal aquifer, the primary source of groundwater in the area, will not be a viable source of water for many more years. The literature review also substantiated that the water available for consumption in the Gaza area is generally substandard, particularly due to increasing salinity and nitrates content. The current water resources are insufficient to meet the needs of the population in many areas and will not improve if the current situation is maintained. It must be stressed that only long term, large scale solutions will be sufficient to address the water crisis in the Gaza Strip, a fact of which experts are well aware. If the high extraction rate continues the aquifer will dry up in a few years. Many publications, both white and grey literature, present recommendations for alternative water supplies and improving water quality, which are described in the full results of the literature review in Appendix I. Many of these recommendations are long-term strategies, although it is unknown to which degree these recommendations are being followed. The literature review also reinforces that there are many different actors engaged in research on water resources in the Gaza Strip. The benefits of this research could be enhanced by maintaining a systematic and continuous overview of all the work that is being done to try to reduce duplication of activities, and coordinate and compile all the available information.

One of the objectives of the literature review was to determine the consequences of consumption of substandard water in the Gaza Strip. Although substantial research has been undertaken on water quality in general, few studies investigate the association between human health and water quality. While evidence that water is of poor quality is necessary to target interventions, studies examining the direct impact on human health are required to substantiate the negative effects. One of the most important questions, which cannot currently be fully answered, is what are the impacts, both short-term and long-term, of consumption of low quality water by the population of the Gaza Strip?

The following specific recommendations are based on the findings from the systematic review of grey and white literature available on water quality in Gaza and expert consultation at the NIPH and PNIPH/WHO. In addition, relevant recommendations on water management included in published reports from international agencies have been taken into account.

Recommendations on water usage

The limited access to safe drinking water in Gaza is thoroughly documented through the literature review. There are four potential sources of water in Gaza that may be seen as available for the population:

- Piped water (not desalinated)
- Desalinated water:
    - Water from tank vehicles (desalinated in treatment plants)
    - Home desalinated piped water
- Bottled water
- Rooftop harvested rainwater (not currently a significant source of domestic water but can potentially be considered as an alternative source)

These sources have some characteristics that affect the possible use for various purposes such as for drinking, making food, general hygiene and for irrigation and animals. By taking into consideration the quality of the water from the sources available, the usage and the different population groups, such groups vulnerable to poor water quality, this section attempts to set out recommendations for usage of water and how to mitigate health risks for the population in Gaza, given the current situation on access to water.

Identified vulnerable groups in the population

Exposure to water of poor quality will affect certain population groups disproportionately. Health status and age are defining some of the risk groups. In addition, some population groups will have higher hydration requirements than others. For the purpose of mitigating health risks related to poor water quality, the following groups have been identified:

- Infants up to six months – Newborn babies are especially vulnerable to water quality due to the risk for methaemoglobinemia or “blue baby syndrome”. The most common environmental cause of this condition is high levels of nitrates in drinking water. In the body, nitrates are reduced to nitrites. The nitrites react with haemoglobin (Hb) in the red blood cells to form methaemoglobin, affecting the blood's ability to carry enough oxygen to the cells of the body [25, 26]. The Hb of young infants is more susceptible to metHb formation than that of older children and adults. Other groups potentially susceptible to metHb formation may include pregnant women and people deficient in glucose-6-phosphate dehydrogenase or metHb reductase [27]
- Children between six months and five year – Diarrhoeal disease is a leading cause of child mortality and morbidity in the world, and mostly results from contaminated food and water sources. Children who die from diarrhoea often suffer from underlying malnutrition, which makes them more vulnerable. Most deaths are due to severe dehydration and fluid loss [28, 29]
- Pregnant women or lactating women – Immune alterations with advancing pregnancy may result in increased risk and severity of disease for specific transmissible pathogens. In

practice, there is not general evidence on this for all the infections and there is some disagreement in the literature. However, for specific waterborne infections, such as Hepatitis E, this association is clear and obstetrical complications and fulminant hepatitis occurs more frequently during pregnancy [30, 31] In addition to this, water may contain specific elements, such as pesticides, that can cross the placenta from the mother to the fetus, harming fetal development.

- Elderly – With older age, infections in general are more frequent and often more severe due to factors such as the presence of multiple underlying medical conditions, weakened immune system, malnutrition, age-related changes in the gastrointestinal tract (decreased motility and production of gastric acid), concurrent use of different drugs, delayed diagnosis, and/or delayed or diminished response to therapy [32]

Proposed water usage categories

Domestic water usage can be divided into the following categories, associated with varying degrees of health risks [33]:

- Consumption (drinking and cooking)
- Hygiene (including basic needs for personal and domestic cleanliness)
- Amenity use (for instance car washing, lawn watering)
- Productive use (e.g. animal watering, construction and small-scale horticulture)

The two first categories have direct consequences for human health, both in relation to physiological needs and in the control of diverse infectious and non-infectious water-related disease. The third category is not directly affecting human health. Water used in production, however, may be critical for the urban poor sustaining livelihoods and therefore has considerable indirect influence on human health.

In addition to the proposed categories mentioned above, there are also agriculture activities that are especially water-demanding, such as growing vegetables. Water for irrigation purposes should therefore be considered as a separate category.

In terms of guidelines for water quality standards for irrigation water, the content of salt in the water is of relevance, for instance expressed in TDS. According to the Food and Agriculture Organization (FAO) [34], the guiding values for TDS are as follows:

Table 6 FAO guidelines for TDS for irrigation water

Potential Irrigation Problem		Units	Degree of Restriction on Use		
			None	Slight to Moderate	Severe
Salinity*(affects crop water availability)*					
	TDS	mg/l	< 450	450 – 2000	> 2000

As a general comparison with the measured content of TDS in the water from wells along the Gaza strip, which are in the range of 1850-2060 mg/l TDS in 2010 and 2011 (mean of results over the years), we see that the quality of the water is on the “severe” end of the scale when it comes to restriction of use. However, there is variable tolerability for different vegetables and plants.

Advice on water usage for the population

Based on the precarious water situation in the Gaza Strip, advice on usage must be considered as a means of mitigating health risks for the population as a minimum standard and should not be considered long-term solution as these are not sustainable practices. Advice on water usage, taking into account the different water sources, purposes and at-risk groups, are presented in the tables below:

Table 7 Advice on water usage taking into account different water sources available

Water usage	Water sources				
	Piped water (not desalinated)	**Water from tank vehicles *(desalinated water from treatment plants)**	**Home desalinated piped water**	**Bottled water**	**Rooftop harvested rainwater****
Main problems	High in salt nitrates and TDS; unknown for pesticides and radiation, limited for heavy metals	Microbial contamination due to non-hygienic handling of the water in distribution low in minerals	Quality varies as domestic desalination units are often not regulated	Suspicion of being microbiologically contaminated***	Not commonly practiced at household level; microbial contamination
Consumption	No	Only if the water is ensured hygienic safe by undertaking safe storage and household disinfection	Only if the water is ensured hygienic safe by undertaking safe storage and household disinfection	Yes, if properly disinfected (risk of being microbiological contaminated)***	Not used currently, but may be considered if treated appropriately (filtration + disinfection), and by undertaking safe storage
Hygiene	Yes, but will probably be limited where the water is too salty	Yes, but with the awareness that the water coming from this source might contain microbiological contaminants	Yes, but with the awareness that the water coming from - this source might contain microbiological contaminants	Yes (but likely unaffordable)	Not used currently, but may be considered if treated appropriately (filtration + disinfection), and by undertaking safe storage
Amenity use	Yes	Yes	Yes	N/a	Not used currently, but should not be a problem for this category (given that possible turbidity is acceptable for the user)
Productive use	Yes, but not for drinking water to animals if it is too salty	Yes	Yes	N/a	Yes
Irrigation	Depending on the plants/vegetables, but will in general be too high in salt content	N/a	N/a	N/a	N/a (assumed that this category produce only small amount of water)

*It is assumed that water distributed through tank vehicles is desalinated seawater, which suggests that nitrate levels are not problematic

**Rainwater is not currently a significant source of domestic water but can potentially be considered as an alternative source

***As stated in the background section of this report, there are some uncertainties regarding the quality of bottled water. There is not enough evidence to document the quality of bottled water currently distributed and consumed in Gaza

Table 8 Advice on water consumption taking into account the vulnerable groups

Identified vulnerable groups:	Water for consumption				
	Piped water (not desalinated)	**Tank vehicles (desalinated water)***	**Home desalinated piped water**	**Bottled water**	**Rooftop harvested rainwater****
Infants up to 6 months	No, not even if boiled	Only if the water is ensured to be safe by undertaking safe storage and household disinfection, such as boiling	No, not even if boiled	Yes, if properly disinfected (due to risk of being microbiological contaminated)***	Not used currently, but may be considered if treated appropriately (filtration+disinfection), and by undertaking safe storage
Children from 6 months up to 5 years	No, not even if boiled	Only if the water is ensured to be safe by undertaking safe storage and household disinfection, such as boiling	After boiling, if the water is not ensured to be safe by undertaking safe storage and household disinfection	Yes, if properly disinfected (due to risk of being microbiological contaminated)***	Not used currently, but may be considered if treated appropriately (filtration+disinfection), and by undertaking safe storage
Pregnant and lactating women	No, not even if boiled	Only if the water is ensured to be safe by undertaking safe storage and household disinfection, such as boiling	No, not even if boiled	Yes, if properly disinfected (due to risk of being microbiological contaminated)***	Not used currently, but may be considered if treated appropriately (filtration+disinfection), and by undertaking safe storage
Elderly	No, not even if boiled	Only if the water is ensured to be safe by undertaking safe storage and household disinfection, such as boiling	After boiling, if the water is not ensured to be safe by undertaking safe storage and household disinfection	Yes, if properly disinfected (due to risk of being microbiological contaminated)***	Not used currently, but may be considered if treated appropriately (filtration+disinfection), and by undertaking safe storage

*It is assumed that water distributed through tank vehicles is desalinated seawater, which suggests that nitrate levels are not problematic

**Rainwater is not currently a significant source of domestic water but can potentially be considered as an alternative source

***As stated in the background section of this report, there are some uncertainties regarding the quality of bottled water. There is not enough evidence to document the quality of bottled water currently distributed and consumed in Gaza

Consumption of water may be differentiated into water for drinking, washing of food items and for cooking.

Regarding the **infants up to 6 months**, exclusive breastfeeding is strongly recommended. It is not advised to use any other sources than bottled water (assuming no microbiological contamination) for milk formula and other drinking liquids. However, due to lack of evidence that bottled water obtain a safe microbiological quality, bottled water should be boiled before use to infants. Other water sources are not advised to use because of the risk of "blue baby syndrome" linked to the nitrate content of piped water (from the aquifer), and also due to the risk of poor microbiological quality of water from tank vehicles or in the roof collected water if these are not properly cleaned at regular intervals. Boiling or otherwise disinfecting the water does not remove nitrate. However, according to a water quality campaign [10], the content of nitrate is within acceptable levels in the desalinated water from tank vehicles. Therefore boiling water from this source may be considered as a method to make the water acceptable drinking-quality for the baby.

The current scientific literature does not provide sufficient evidence of the causal relationship between maternal exposure to nitrates in drinking water and adverse reproductive outcomes. Since there are still quite a lot of uncertainties in this topic, we do not recommend **pregnant women** to use piped water for consumption [35]. Tank water can be consumed if it can be safely stored and treated through home disinfection.

Regarding the **other vulnerable groups**, nitrate in water used for cooking (water based food as soup) may also be of health concern if the levels exceed the WHO guidelines. However, using water for cleaning of food may be considered as lesser of health concern when it comes to nitrate, but may be if the source is microbiologically contaminated causing diarrhoeal diseases. Therefore, water for washing of food items should be filtered or boiled. Good information about maintenance procedures for these filters and how to store the filtered water in a safe way is essential.

Dissemination of information to the public

Appropriate communication strategies are required to ensure the advice is understood. When communicating with the public, public health authorities and water authorities should focus on the following points:

- Increase public awareness of importance of good quality drinking water and differing quality by source of water
- Encourage prioritization of water of best quality for drinking

- Improve information to private vendors on the importance of chlorination, hygienic transport and correct handling
- Stress the importance of safe water storage at household level

Recommendations for improved monitoring of water quality

Chemical and microbiological parameters: The description of current examination of the water in Gaza states that testing for certain chemicals in tap water (i.e. Na, K, Ca, Mg, sulphate, carbonate, bicarbonate, nitrate, chloride and TDS) is routinely done two times a year (spring and autumn) and "regularly"[2] for desalinated water and for bottled water. For microbiological testing of the different waters, the frequency is not mentioned. According to international standards the key parameters for chemical water quality should be analyzed at least four times a year for reporting to the authorities. The following microbial parameters should be analyzed monthly: Total coliforms (TC), fecal coliforms (FC) and fecal Streptococcus (FS). The following standards for microbial parameters should be followed:

- Bacteriological methods for drinking water (EU Council Directive 98/93/EC):
- WHO (2011) Guidelines for Drinking-water Quality, fourth edition, Geneva, ISBN: 97892 4 154815
- ISO 5667 Part 1-4. Water Quality – Sampling

Regarding desalinated water, there might be an issue related to the low content of minerals, however, the health effects caused by water as an exposure route is debated. It may be relevant for Gaza, due to the vast use of desalinated water, to consider the guidelines for desalination water treatment, specifying the minimum content of the relevant elements such as calcium and magnesium and TDS to avoid the possibility of adverse effects arising from long-term consumption of drinking water with an ultra-low mineral content [36]

As the quality of water bottled distributed and consumed in Gaza is currently unclear, better monitoring to ensure the compliance of this water source should be conducted, As microbial contamination due to non-hygienic handling of the water in distribution occurs, standards and procedures for water testing, tankers and distribution points have to be established to secure hygienic water quality [10]. Also, advice on disinfection of desalinated tank water and advice on mitigation of risks associated with home storage of water should be given to the population. Such

[2] As stated in reports from water testing in Gaza. In general, water testing on a regular basis over some time series will give a good basis to evaluate the water quality situation. It is important that the tested water represent the delivered water to the consumers. Whether it is every week or every month will often depend on the size of the water works or on the production routines (ex. testing of produced batches).

advice could include the following measures: 1) Chlorination is widely used and regarded as a safe way of ensuring hygienically safe water. We strongly recommend chlorinating water during transport in order to minimize the risk of contamination during the water distribution process. Measures to avoid smell and taste of the drinking water must be undertaken to keep the water acceptable for drinking. 2) Boiling is also an often used method for disinfection, especially in emergency settings such as after floods etc. The water need to boil for approx. a minute with a lot of motion in the water to be ensured properly disinfection, 3) UV-radiation is a common used method for disinfection. This method requires an installation with some knowledge of operation and maintenance. In some areas, "natural" UV-disinfection is practiced by letting water in transparent bottles be exposed to sunlight, for example, by letting the bottles with water lay on the roof for a certain amount of time.

All analyses should be done according to international standards and by laboratories skilled to perform the actual analyses. Preferably, only laboratories accredited for the particular analyses should be used.

Heavy metals: Up to now only limited testing has been done for heavy metals, radioactivity and pesticides. CMWU performed in 2012 screening of heavy metals[3] in 157 wells in the five Gaza governorates. All sampled wells showed values below the WHO standards except for Iron, Chromium and Strontium. However, it is important to have more specific information about the concentrations, particularly for strontium, as infants and young children who ingest too much strontium can develop strontium rickets, a deformity of the long bones in the legs. The US Environmental Protection Agency (US EPA) has developed three health advisory levels (HALs) for acceptable Strontium levels in drinking water. HALs are not regulatory levels or legally enforceable standards, but serve as an estimate of acceptable strontium levels in drinking water at which a person would not be expected to develop any health problems related to strontium exposure. The authority of Gaza should establish regular test programmes for heavy metals, including Strontium, as high concentrations could be of health concern. A screening for heavy metals[4] should be performed within a time interval to monitor the situation. An interval of five years should be sufficient as these parameters are regarded as relatively stable. Since some heavy metals can leak out from the distribution system materials, including taps, samples from the taps at the household level also should be included in a screening for heavy metals.

[3] Parameters analyzed were Aluminium, Antimony, Arsenic, Cadmium, Chromium, Cobalt, Copper, Mercury, Lead, Manganese, Nickel, Selenium, Strontium, Iron, Zinc and Silver

[4] Same as footnote 3

Recommendations for further studies

The following gaps in knowledge related to water quality and human health in the Gaza Strip were identified:

Epidemiological studies assessing burden of disease associated with consumption of low quality water in the Gaza Strip are needed. As of today only nine studies have examined the association between water consumption and health outcomes, mainly focused in diarrheal diseases. These studies do not show the whole picture of burden of disease related to low quality of water. Epidemiological studies and quantitative risk assessments using data on water quality could give some estimates on acute and chronic illness, such as dental fluorosis, renal illnesses and cancers linked to chemical and microbiological contaminants in drinking water as well as those linked to low mineral content in desalinated water. Public health authorities could consider investigating whether the high rates of viral meningitis are associated with poor water quality in the area

The literature review shows that there is no clear overview of the occurrence of contamination with heavy metals, pesticides as well as radiological contaminants in the Gaza Strip. These are chemical constituents of health concern and are therefore of great relevance when giving advice for water usage. Water for distribution from aquifers, desalination (tanks) as well as bottled water should be screened. Concerning pesticides, some of them are analyzed for and detected, but not in a systematic way. There exist a list of used pesticides that are available on the market, but the breakdown products from these are not tested for in the water sources. Further **research into the levels of heavy metals and pesticide contamination in water and the resulting effect on human health should be considered**. The Gaza strip is also an area of industrial activities and historical warfare, which indicates that heavy metals are present in the environment. An **overview of the radioactive level in the drinking water in Gaza should be mapped**.

Frequent maintenance of water and wastewater network is needed to reduce breakage of pipelines and wastewater flooding events. A project should also be undertaken to **investigate to what extent the water distribution system deteriorate the quality of the water from the wells**.

Conclusions

This report presents recommendations for use of water and areas in need of further study in the Gaza Strip developed by the Norwegian Institute of Public Health in collaboration with the Palestinian National Institute of Public Health. The recommendations presented in this document are inherently limited, as it is unacceptable to recommend that people can consume water that is substandard according to the WHO water guidelines. Risk groups can be targeted to ensure that

exposure to the most harmful contaminants are avoided. To allow the population to differentiate water from different sources for different uses may require information campaigns. These recommendations have been developed, based on an assessment of the information available, on how best to mitigate the negative health effects of the water currently available to the population to the Gaza Strip.

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ANNEX I Terms of Reference

Background

The Palestinian Authority is establishing a Palestinian National Institute of Public Health (PNIPH). The World Health Organization (WHO) has been given the task of setting up the PNIPH, in close cooperation with the Palestinian Ministry of Health, Palestinian universities, the Norwegian Institute of Public Health, and other stakeholders. The Norwegian Ministry of Foreign Affairs is funding the project.

The aim is to establish the PNIPH by 2014 as a semi-autonomous legal entity under the umbrella of the Palestinian Authority, fully accountable for its professional and technical responsibilities, budget, and staff. The Institute will have a governing board with representatives from key stakeholders and will be able to speak out and publish reports and commentaries on health issues.

The PNIPH is working with the Ministry of Health and other stakeholders on important public health issues. One of these areas is water quality and its impact on the health of the population.

Main reasons for the mission

More than ninety per cent of the water offered to the population in the Gaza Strip has been classified as unsuitable for human consumption. Although there are many plans to improve the situation, it will take time before the situation is significantly improved. Based on the facts and the international literature, clear recommendations should be given on the usage of the available water in the Gaza Strip.

One area is to assess the quality of the water offered to the Palestinian population and its impact on the health of the population and to give recommendations based on international guidelines

The objectives of the mission are

To provide the population in the Gaza Strip with clear advice on how to mitigate the health risks from the water available to the population.

Parties

The two parties are:

- The Norwegian Institute of Public Health (NIPH)
- The Palestinian National Institute of Public Health (PNIPH) Project and the WHO for West Bank and Gaza

Tasks

The NIPH will carry out the following tasks:

- Conduct a systematic literature search on all published scientific work (white literature) about Gaza and concerning water, waste (solid and liquid), sewage and health.
- Conduct a systematic literature review of the white literature and the provided grey literature.
- Collect all international guidelines and recommendations on water quality

- Based on the collected data and in consultation with PNIPH/WHO draft recommendation for water usage in Gaza.
- Assess whether there are gaps in the knowledge and current water monitoring in Gaza that may necessitate further studies.

The PNIPH/WHO will carry out the following tasks:

- Identify, collect and provide NIPH with all available grey literature on water, waste (solid and liquid), sewage and health that has been produced by MoH, PWA and other governmental agencies, by all UN organisations, Foreign missions, NGO's etc. It should include studies and reports on microbes, chemicals, radiation and pesticides.
- Discuss and comment on provisional reports

Expected results and reporting

NIPH will produce a report containing the following:

- Background and introduction to the issue under study (short)
- Methodology and description of the work carried out (short)
- Summary table presenting the white and grey literature and international guidelines and recommendations on water quality and usage
- Discussion and interpretation of the findings
- Identification of possible gaps in the available knowledge
- Detailed and practical recommendations and advice to the population in Gaza on the usage of water and how to mitigate health risks. These should take into consideration:
    - The three main sources of water: 1. Tap water from the aquifer; 2. Tank water from desalination plans distributed by trucks; and 3. Bottled water
    - Usage of water for different purposes like drinking, making food, washing and cleaning food items, clothes and environment, personal hygiene, for irrigation and animals etc.
    - Differential advice to different population groups, especially to infants, children and pregnant women.
    - Possible further deterioration of the water quality.
- Recommendations for improved monitoring of the water quality, if needed
- Recommendations for further studies.

Scientific publications of the work may be considered. Authorship from NIPH and PNIPH/WHO will be according to the rules of the Vancouver Convention.

ANNEX II Literature Review

This annex will be included in the final, printed version of the report