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Assessment of Chemical Characteristics of the Desalinated Water Used in Household Facilities in Gaza Strip

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Abstract

Access to safe water represents one of the most important basic human needs of the people of Palestine and is vital to a growing economy and a healthy population. Groundwater is the major source of water to the Palestinians. Nowadays, the water crisis in the Strip is multiplying.

The objective of this research is to make an assessment of the desalination plants for the chemical quality for both the inlet (groundwater) and the outlet water (product water) in the desalination plants. The adopted methodology depends on many approaches that were used in an integrated manner to achieve the objectives of this research. Samples from both the inlet and outlet water from 88 desalination plants have been collected by the researcher. The main chemical parameters have been analyzed in the inlet and outlet water of the desalination plants.

The study proved that the current private desalination monitoring program by the concerned authorities should be developed, enhanced and intensified. The study also revealed that the current private desalination plants were established randomly and for commercial purposes without any previous planning.

The results have revealed that 80% of the inlet water of the plants does not comply with the WHO guidelines, while 100% of the plants' outlet water has chemical parameter concentrations accepted by the WHO guidelines.

Keywords: Groundwater, contamination, brackish water, desalination plants, Gaza Strip, chemical parameters.

1. Introduction

Access to sufficient quantities of safe water for drinking and domestic uses and also for commercial and industrial applications is critical to health and well being, and the opportunity to achieve human and economic development. People in many areas of the world have historically suffered from inadequate access to safe water. Some must walk long distances just to obtain sufficient water to sustain life. As a result they have had to endure health consequences and have not had the opportunity to develop their resources and capabilities to achieve major improvements in their well being. With the growth of the world population, the availability of the limited quantities of fresh water decreases (WHO, 2011).

Gaza strip suffers from many water problems such as shortage, scarcity, insufficiency, pollution and high salinity. The main source of water in Gaza Strip is the groundwater aquifer. Over pumping due to the increased demands of the high population in the Gaza Strip and low recharges from rainwater have limited the quantity of water available and have further contributed to the degradation of the water quality (Metcalf and Eddy, 2000 and PHG. 2002). Unavailability of a proper sewage system, high distribution of septic tanks, old water networks, frequent interruption of water chlorinating and interruption of water supply play a major role in increasing the microbiological water contamination which lead to an increase in health risks of humans (El-Mahallawi, 1999). The people of the Gaza Strip depend on the groundwater for their agriculture, industries, and for household purposes like cooking, washing, cleaning and showering. Long-term overexploitation in the Gaza Strip and constraints by the Israeli occupation in using more groundwater have resulted also in decreasing the supply of tap-water which accompanies low and poor water quality. Furthermore, controlling and monitoring the quality (biological, chemical and physical) of the water wells and water distribution networks at the Gaza Strip are not always possible due to the constraints applied by the Israeli occupation either on the entry of the disinfectants and the instruments required for water quality assurance or sometimes on reaching wells that are located near to hot clash points. Therefore, due to the low reduced quantities, as well as the poor deteriorating qualities of drinking water, the people of the Gaza Strip try to overcome these problems and find other solutions and sources which offer good safe drinking water, so they start to depend on the marketed desalinated water produced mainly by the reverse osmosis method. As a result, many special and governmental water desalination facilities or small plants were established to market the desalinated water for people in order to overcome the low and poor quality of groundwater. The limited data about microbiological and chemical water quality for the few past years in the Gaza Strip are not enough to be judged. However, recent reports by the Ministry of Health (MoH, 2010) mentioned that about 19% of groundwater, 27% of desalinated water and 20% of water network samples are microbiologically contaminated by Total Coliform while 13%, 14% and 12% by Fecal Coliform bacteria respectively. Monitoring and controlling programs of water quality in the Gaza Strip should be evaluated and developed.

Water may contain chemicals which can be beneficial or harmful to our health. Many chemicals find their way into our drinking water supply through different natural processes and human activities. Naturally occurring chemicals, such as arsenic, fluoride, sulfur, calcium and magnesium, are generally found in groundwater. Human activities can add other chemicals such as nitrogen, phosphorous and pesticides to our ground, surface and rain water. Many developing countries are experiencing a rise in industrial activity with no strict compliance to environmental rules and regulations. As a result, water sources are increasingly becoming contaminated with industrial chemical waste (CAWST, 2009). While microbiological contamination is the largest public health threat, chemical contamination can be a major health concern in some cases. Water can be chemically contaminated through natural causes (e.g. arsenic, fluoride) or through human activity (e.g. nitrate, heavy metals, and pesticides) (UNICEF, 2008).

Abu Mayla A. et al. (2010) found average TDS concentration ranges from 720 mg/L in the North to 2709 mg/L in Gaza governorate. Cl concentration ranges from 181 mg/L in the North to 772 mg/L in Gaza governorate. The average concentration of NO3- ranges from 97 mg/L in the North to 139 in Gaza Governorate. The level of TDS, Cl- and NO3- were higher than the WHO standard, i.e., 1000, 250 and 50 mg/L, respectively, for the entire Gaza Strip governorates, except in the North governorate where the concentration of TDS was less than standard. For TDS, about 49% of drinking municipal water wells exceeds the WHO standard (1000 mg/L). The percentage ranges from 4% in the North governorate to 81% in Middle zone. Like TDS, the concentrations of Cl- in 58% of municipal water wells were higher than the WHO standard (250mg/L) and range from 8% in the North to 94% in the Middle zone governorate.

Al-Khatib M., et al., 2011 mentioned that during the years 2009-2010, the water salinity of the domestic wells varied between 235 mg/L in northern Gaza and 6206 mg/L in Gaza governorate. The highest degree of salinity was shown in northern Gaza and Khanyounis. The mean nitrate concentration is high at 199 mg/L and is attributed to intensified agricultural activities and excess use of fertilizer. About 86% of the examined samples exceed the maximum permissible concentration of 50 mg/L set by the World Health Organization (WHO). Concentrations of sodium (Na+) and chloride (Cl-) vary respectively between 16 mg/L in the North governorate and 1400 mg/L in Gaza governorate and from 43 to 3119 mg/L during the study period. The highest concentration levels characterize the wells situated in the North, Gaza and Khanyounis. Most of the tested wells exceed the WHO limitation of 250 mg/L for chloride concentration. Concentration of sulfate varies between 0.9 mg/L in the north and 600 mg/L in Rafah governorates. The concentration of HCO3 in domestic wells varies from 131 to 601 mg/L, with a maximum record for Gaza governorate. Calcium (Ca+2) concentrations ranged between 22 mg/L in Khanyounis and 518 mg/L in north Gaza. It was also noted from the distribution of calcium in the governorates that the calcium concentration increases in the north of Gaza and the middle governorate. Magnesium (Mg+2) concentrations fluctuate between 12 mg/L in Rafah governorate and 287 mg/L in Gaza governorate and are always associated with magnesium and calcium to form the water hardness. Potassium (K+) concentrations are relatively low compared to the concentrations of other cations, with values varying between 0.78 mg/L in North governorate and 30 mg/Lin Gaza governorate

2. Study area

The Gaza Strip is a part of the Palestinian coastal plain in the south west of Palestine in the Middle East, where it forms a long and narrow rectangle on the Mediterranean Sea. The Gaza Strip is about 1.33% of the total area of mandate Palestine. The Gaza Strip occupies an area of about 365 Km2; about 45Km long and 5-15Km wide. Gaza Strip is divided into five Governorates: 1) the North Governorate, comprising three towns: Jabalia, Bit Hanoun and Beit Lahia; 2) Gaza Governorate, 3) Mid-Zone contains 5 refugees camps: Deir Elbalah, Maghazi, Burij, Nuseirat and Zwaida, 4) Khanyounis Governorate, and 6) Rafah Governorate (Khalaf, 2005). Figure (1) shows the map of the study area.

Groundwater is considered the main source of fresh water and is of primary importance to the Palestinians in the Gaza Strip (Al-Agha, 1995). Moreover, the Palestinian Water Authority (PWA) purchases a big quantity of water from the Israeli water company Mekorot (PWA, Water supply report, 2012). Groundwater is recharged from several sources including rainwater, return from irrigation, sewage infiltration and seawater intrusion (PEPA, 1994). Pumped for people of the Gaza Strip, groundwater is mainly from municipal wells which are basically used as the main source of drinking water, while some people have opened their own wells in their homes. On the other hand, there are many wells used for agricultural purposes.

3. Methodology

An experimental analytical study design has been used with a cross-sectional method for data collection and water sampling for chemical analysis, where it depends on collecting samples from all small and large desalination units or facilities in the Gaza Strip. The chemical results of groundwater and desalinated water were recorded, counted, and analyzed. The experimental design for this research has been chosen because it is simple and appropriate for this kind of public health study.

The samples of the study were taken from all the five governorates of the Gaza strip including groundwater and desalinated water samples. The samples collection lasted from the 1st Jan. until the middle of April 2012. Sampling was performed according to Standard Methods for the Examination of Water and Wastewater (20th edition, APHA, 1999).

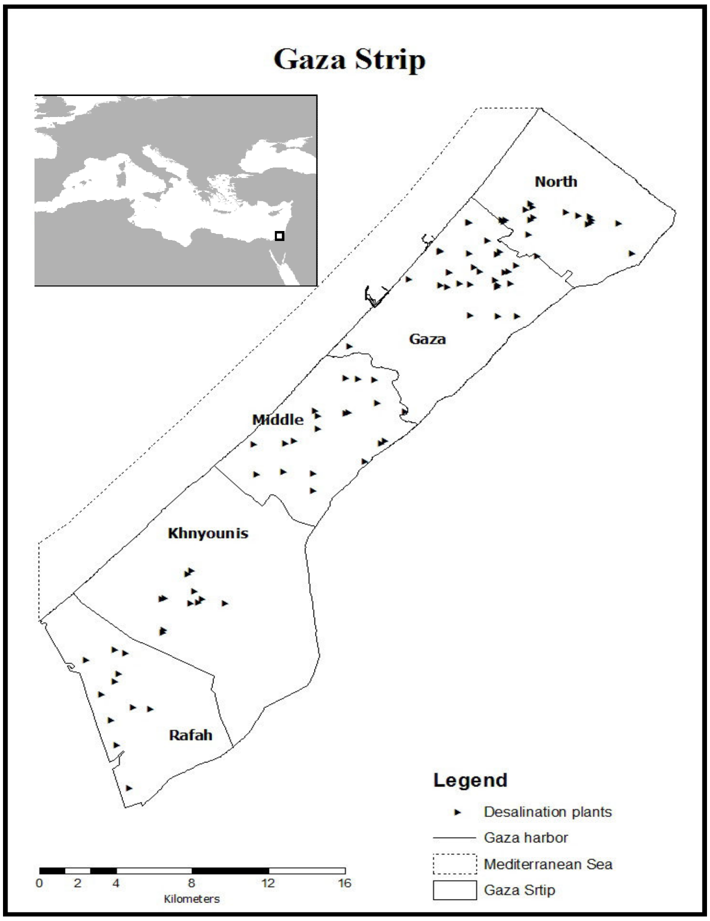


Figure 1: Study area and locations of desalination plants in Gaza Strip, a total of 88 plants were studied.

Water samples for the chemical analysis were gathered with polyethylene (plastic) 1000ml containers, which didn't need to be sterilized as in the microbiological bottles. In order to take the samples for chemical analysis, the water should be left to drain 2-3 minutes to ensure that the sample will be representative. After 2-3 minutes the plastic container was washed from 1-3 times from the water which the sample will be taken from in order to avoid any residual water from previous samples, then the samples were taken and stored in the ice box and transported to the laboratory.

A number of 315 samples were collected from all the Gaza Strip governorates. In each governorate the samples were recovered from the desalination plants, desalination plant wells, desalinated water tanks and desalinated water distribution cars. Every desalination plant has its own water well used for producing water for desalination. It also has some tanks which are distributed in the governorate used for selling produced water and equipped cars for distributing the desalinated water. 88 desalination plants were found to be distributed randomly in Gaza Strip: 17, 29, 20, 11 and 11 are found in the North, Gaza, Middle, Khanyounis and Rafah governorates respectively. The water samples were delivered to the MoH laboratory for TC and FC examination. 88 and 87 samples were delivered to the MOH laboratory for chemical analysis from desalination plants and desalination plant wells respectively. The MoH laboratory is guided by the American Standard Methods for the Examination of Water

and Wastewater, procedures for the microbiological and chemical analysis according to APHA (1999).
The number of samples of different water resources from each governorate is shown in (Table 1), while (Figure 1) shows the distribution and geographical location of the desalination plants in Gaza Strip governorates.

Table 1: The number of samples of the different water resources from each governorate.

Governorate	Desalination plants
North	17
Gaza	29
Middle	20
Khanyounis	11
Rafah	11
Total	88

3.1 Data analysis

Data were computer-analyzed using Excel and SPSS programs to calculate the chemical contamination percentage of water by comparing the water quality between desalination plants inlet water and desalination plants outlet water for each governorate in Gaza Strip according to international standards and guidelines.

4. Results

The desalinated water (desalination plant outlet water) and the groundwater (desalination plant inlet water) were analyzed for selected chemical water quality parameters including electrical conductivity (EC), total dissolved solids (TDS), pH, Chloride (Cl^-), Nitrate (NO_3^-), Sulfate ($SO4^2$-), total hardness ($CaCO_3$), Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Sodium (Na^+) and Potassium (K^+). This part of the discussion will represent and focus on the most important quality parameters: pH, TDS, Cl^-, NO_3^-, SO_4^{-2}, Ca^{+2}, Mg^{+2}, Na^+, and $K^{+.}$ The average concentrations of the chemical parameter of pH, TDS, Cl^-, NO_3^-, and Na^+ will be compared with the WHO standards, while Ca^{+2}, Mg^{+2} and K^+ will be compared with the Palestinian Standards Institution (PSI), because the WHO does not issue guidelines for Ca^{2+}, Mg^{2+} and K^+ in drinking water. Desalinated water plants were given codes instead of their real names upon the request of the owners, so as not to damage their respective owners.

4.1. Average concentrations of chemical parameters of the desalination plants' outlet water in Gaza Strip governorates

The pH values in 88 samples collected from the desalination plant outlet water in Gaza Strip were measured. In addition, 65 desalination plants showed compliance in terms of pH in Gaza Strip and they were within the range recommended by the WHO of 6.5-8.5, while 23 plants showed non-compliance and the values are lower than 6.5. On the other hand, there were no plants found to be higher than the value of 8.5. However, the samples of the desalination plants which show non-compliance were represented by a percentage of 26.1% as shown in Figure (2). The average concentrations of chemical parameters analyzed in the desalination plant outlet are shown in Figure (3).

Figure: (2): Percentage of non-compliance of pH values in the desalination plants in Gaza Strip.

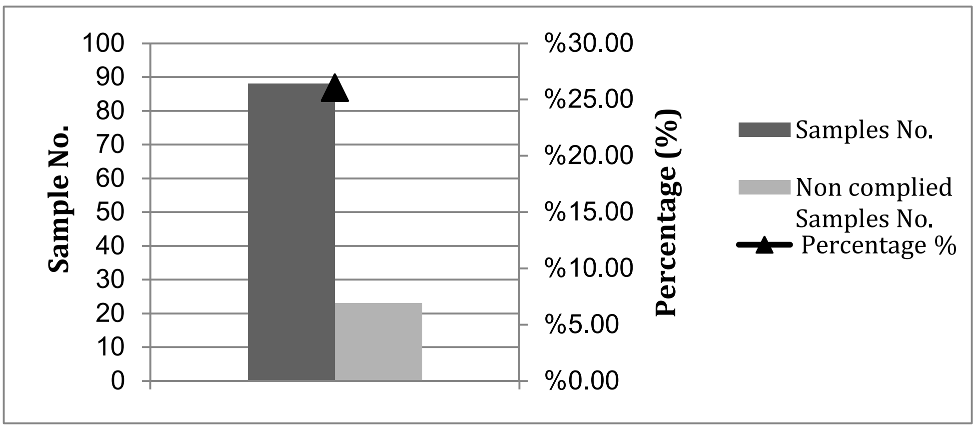
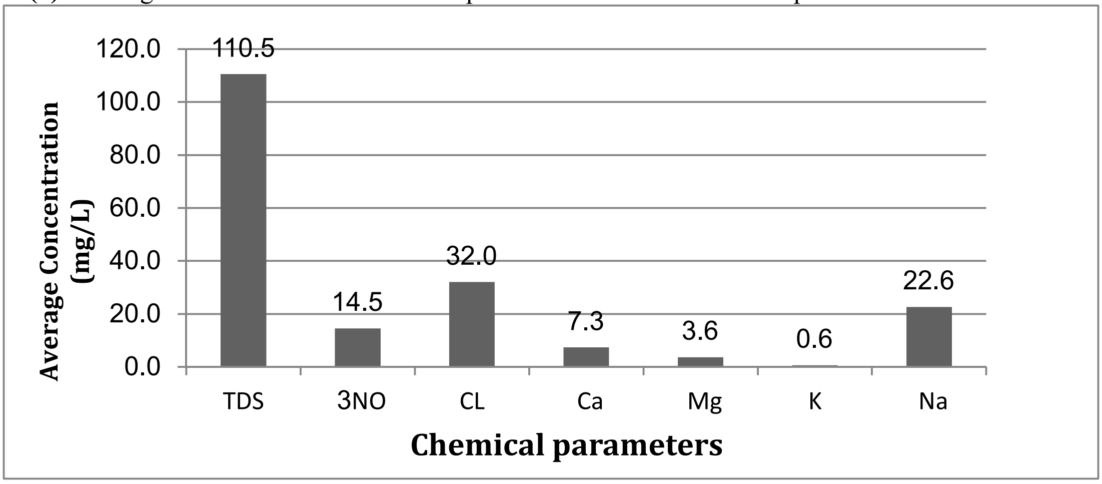


Figure (3): Average concentrations of chemical parameters of the desalination plants' outlet water in Gaza Strip



The average total dissolve solids (TDS) concentration in Gaza Strip was 100.5mg/L while NO_3^- was 14.5mg/L, and Ca_2^+ was 7.3mg/L. However Mg_2^+, K^+ and Na^+ recorded averages of 3.6mg/L, 0.6mg/L and 22.6mg/L respectively. On the other hand all the average concentrations were within the range of the WHO standards and the Palestinian Standards Institution (PSI) for drinking water.

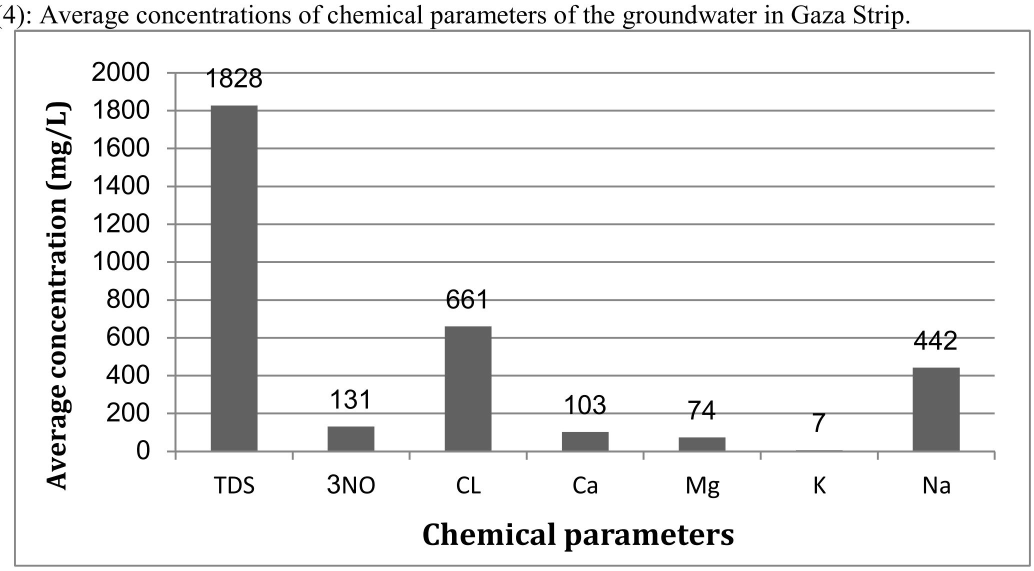
4.2. Average concentrations of chemical parameters in the groundwater (inlet) in Gaza Strip governorate

The pH values in the groundwater had a high compliance in terms of pH with the WHO standards (6.5- 8.5). 1 sample (1.14%) out of 88 desalination plants' inlet water samples was higher than the standards, at 8.6 in R-5. Table (2) shows the pH values in the desalination plants' inlet water samples in all governorates of Gaza Strip.
The average concentrations in the groundwater show a great difference than that of the desalination plants' outlet water. The average concentrations of the chemical parameters of TDS, NO_3^-, Cl^- and Na^+ registered values higher than that of the WHO standards, while Ca^{+2}, Mg^{+2} and K^+ registered higher values than that of the Palestinian Standards Institution (PSI) for drinking water. Table (2) and Figure (4) summarize and illustrate the average concentrations of chemical parameters in the groundwater in Gaza Strip (Figure 4).

Table (2): Average concentrations of chemical parameters of the groundwater in Gaza Strip.

Chemical parameters	TDS	NO_3^-	Cl^-	Ca^{+2}	Mg^{+2}	K^+	Na^+
Average (mg/L)	1828	131	661	103	74	7	442

Figure (4): Average concentrations of chemical parameters of the groundwater in Gaza Strip.



The average concentration of TDS in Gaza Strip was 1828mg/L and for NO_3^- it was 131mg/L, while Cl^- average concentrations recorded 661mg/L. 103mg/L, 74mg/L, 7mg/L and 442mg/L were the average concentrations of Ca^{+2}, Mg^{+2}, K^+ and Na^+ respectively. The TDS, NO_3^-, Cl^- and Na^+ results were higher than the WHO standards for drinking water. On the other hand, Ca^{+2} average concentrations were higher than the PSI standards, while Mg^{+2} and K^+ were found to be within the range of the PSI standards.

5.0 Discussion

Almost all the desalination plants in Gaza Strip depend on the groundwater as the source of the inlet water which is used for desalination. The quality of the groundwater in Gaza Strip is not the same in all plants.

The desalination process is primarily intended to remove natural ionic contaminants, but some substances are not as well removed as others. The design and efficiency of the desalination plants and the inlet water for the plant play significant roles in this process. The chemical parameter concentrations of the desalinated water (outlet water) and groundwater (inlet water) are discussed below.

Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. For effective disinfection with chlorine, the pH should preferably be less than 8 (WHO, 1993). pH value in the drinking water recommended by the WHO should be between 6.5 and 8.5 (WHO, 2011).

In Gaza Strip, the desalination plants' inlet water (groundwater) shows a high compliance with the WHO guidelines for drinking water in terms of pH parameter. Only one source of desalination plants' inlet water recorded a result higher than the WHO guidelines, in Rafah, in the desalination plant inlet water (number R-5) which recorded a pH value of 8.6. The high compliance of the groundwater in terms of pH according to the WHO guidelines is due to the nature of groundwater and the chemical balance of the formation of the groundwater.

However, 23 desalination plants out of 88 (26%) recorded pH values less than 6.5, while no pH value higher than 8.5 was recorded in Gaza Strip. 2 out of 17 samples, 9 out of 29 samples, 10 out of 20 samples, 2 out of 11 samples and none of 11 samples of desalination plants' outlet water were found to have pH values less than 6.5 in the North, Gaza, the Middle, Khanyounis and Rafah governorates respectively.

pH is controlled by the amount of dissolved CO_2, CO_3^{2-} and HCO^{3-} (P. Domenico and F. Schwartz, 1997). The low pH values in the outlet water of the desalination plants were due to the fact that CO_2 passes through the membranes and HCO^{3-} is rejected (Al-Khatib A. et al., 2009). Since pH is governed by the logarithm of the ratio of hydrogen carbonate to carbon dioxide, the pH of the permeate water is always low. As such post-treatment of desalinated water is not conducted in Gaza Strip; low pH values were observed.

The pH of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems. Failure to do so can result in the contamination of drinking water and in adverse effects on its taste, odor and appearance. Extreme pH values can result from accidental spills, treatment breakdowns and insufficiently cured cement mortar pipe linings (WHO, 2011). However, in general, the lower the pH, the higher the potential level of corrosion (McClanahan & Mancy, 1974; Stone et al., 1987; Webber et al., 1989).

Abu Mayla et al. (2009) has reported that results of 78 samples in Gaza Strip showed that 72.7% of the outlet water samples have pH values less than 6.5, while the rest (27.3%) have pH values between 6.5- 7.1.

The results of 158 desalinated water samples in Gaza Strip had a high percentage (44%) of non-compliance in terms of their pH value compared with the WHO guidelines for drinking water quality. 70 of 158 samples of desalinated water were below the pH value of 6.5 (Al-Khatib A. *et al.*, 2009).

Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and small amounts of organic matter that are dissolved in water. TDS in drinking water originates from natural sources, sewage, urban runoff and industrial wastewater. Salts used for road de-icing in some countries may also contribute to the TDS content of drinking water. Concentrations of TDS in water vary considerably in different geological regions. Owing to differences in the solubilities of minerals, reliable data on possible health effects associated with the ingestion of TDS in drinking water are not available, and no health-based guideline value is proposed. However, the presence of high levels of TDS in drinking water may be objectionable to consumers (WHO, 2011).

Concentrations of TDS from natural sources have been found to vary from less than 30 mg/L to as much as 6000 mg/L, depending on the solubility of minerals in different geological regions (WHO/UNEP, 1989).

In Gaza Strip, the groundwater TDS concentrations range between 360 mg/L and 16616 mg/L in 194 municipal drinking water wells (MOH, 2012). However, the TDS content in some of the desalination plants' inlet water was found within the WHO guidelines, less than 400mg/L, while the average concentration in the groundwater (desalination plants' inlet water) was 1828mg/L. The highest TDS average concentrations were recorded in the

Middle at 2405mg/L, while the lowest average concentration was found in the North governorate (1326 mg/L). TDS average concentration in Gaza, Khanyounis and Rafah were 1523mg/L, 2390mg/L and 1851mg/L respectively. All the average concentrations in the Gaza Strip governorates of the desalination plants' inlet water exceeded the WHO guidelines for drinking water of 1000mg/L.

Many studies have used TDS and Cl^- as an indicator of groundwater salinity contamination in Gaza Strip. The major source of salinity in the aquifer in the Gaza Strip is derived from the flow of natural saline groundwater from the eastern part of the aquifer toward the Gaza Strip. The long-term reduction of the water tables due to over-exploitation has increased the water gradients and rate of water flow toward the Gaza Strip (Abu Mayla Y. *et al.* 2010).

On the other hand, the TDS average concentrations of the desalination plants' outlet water in Gaza Strip was 110mg/L. In Gaza Strip governorates, the TDS content in the desalination plants ranged between 23.7 in the North and 235.6 in Khanyounis. However, the average concentrations were low and were accepted by the WHO guidelines. The highest average concentration was recorded in Khanyounis at 142.5mg/L, while the lowest concentration was found in Gaza at 96mg/L. The North, Middle and Rafah governorates' average concentrations were 99.2mg/L, 107.9mg/L and 138.4mg/L respectively.

Nitrogen (N) is an essential input for the sustainability of agriculture. However, nitrate contamination of groundwater is a worldwide problem. Nitrate is soluble and negatively charged and thus has a high mobility and potential for loss from the unsaturated zone by leaching. Elevated nitrate concentrations in drinking water can cause methaemoglobinaemia in infants and stomach cancer in adults. As such, the US Environmental Protection Agency (USEPA) has established a maximum contaminant level (MCL) of 10 mg/L NO_3-N (50 mg/L NO_3). Groundwater pollution due to point and non-point sources is caused mainly by agricultural practices, localized industrial activities (organic pollutants and heavy metals), and inadequate or improper disposal of wastewater and solid waste (including hazardous materials). Nitrate is the most common pollutant found in shallow aquifers due to both point and non-point sources. With non-point sources, groundwater quality may be depleted over time due to the cumulative effects of several years of practice. Non-point sources of nitrogen from agricultural activities include fertilizers, manure application, and leguminous crops. The extensive use of fertilizers is considered a main non-point source of the nitrate that leaches to groundwater. In addition to agricultural practices, non-point sources of nitrogen involve precipitation, irrigation with groundwater containing nitrogen, and dry deposition. Point sources of nitrogen are shown to contribute to nitrate pollution of groundwater. The major point sources include septic tanks and dairy lagoons. Many studies have shown high concentrations of nitrate in areas with septic tanks (Anayah F. & Almasri M., 2009).

In the Gaza Strip, the average concentration of the nitrate of 88 desalination plants' inlet water (groundwater) was 131mg/L. However, the highest nitrate concentration value (221mg/L) was recorded in Khanyounis governorate, while the lowest value (93mg/L) was recorded in the North governorate. The Gaza, Middle and Rafah governorates' average concentration values were 116mg/L, 100mg/L and 194 respectively.

The highest average nitrate concentration in Khanyounis enhances the relationship between the wastewater network coverage in Khanyounis governorate and the contamination with NO_3^- (221mg/L), where the wastewater coverage in Khanyounis has reached 40%. In Rafah it was 70% and the NO_3^- contamination was very high at 194 mg/L.

Al-Yacubi A. (2006) reported that most municipal drinking wells in Gaza show nitrate levels in excess of the WHO drinking water standard of 50 mg/L. He also indicated that in urban centers nitrate concentrations are increasing at rates up to 10 mg/L per year. He attributed the main sources to domestic sewage effluent and fertilizers. He added: "In contrast to salinity, groundwater flowing from the east has relatively low nitrate levels". Shomar et al. (2008) has revealed that manure and septic effluents are the main sources of NO_3^- in the groundwater of Gaza followed by sludge and synthetic fertilizers.

Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium ($CaCl_2$). Chlorides are leached from various rocks into soil and water by weathering. The chloride ion is highly mobile and is transported to closed basins or oceans. Chloride in surface and groundwater comes from both natural and anthropogenic sources, such as run-off containing road de-icing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas (WHO, 2003)

In the Gaza Strip the chloride concentration in the municipal drinking water wells were ranging from 50 to 9040mg/L in 193 wells; the highest Cl^- concentration was recorded in Gaza governorate (9040mg/L).

The average concentration of Cl^- in the desalination plants' inlet water was 661mg/L. The highest average concentration was found in Khanyounis governorate (932mg/L), followed by the Middle governorate (896mg/L), while the lowest concentration was reported in Gaza governorate (489mg/L). The average concentrations were 509mg/L and 673mg/L in the North and Rafah governorate respectively.

Chloride and TDS were used in many groundwater studies as an indicator of salinity contamination of groundwater. Many researchers have reported that there are high Cl^- concentrations in the groundwater of the Gaza Strip especially in the Southern governorate (Khanyounis). Hudhud (1996) pointed out that the water situation in Gaza's groundwater is unacceptable for drinking purposes due to high concentrations of chloride, in some cases from 6 to 10 times the levels recommended by WHO. He concluded, through the collection and analysis of samples from a range of wells, that groundwater quality in the Gaza Strip is getting worse. According to data from Water Resources and the planning directorate (PWA, 2003) only 31% of the wells found conform to both Chloride and Nitrate PWA limits while only 12% of these wells conform to WHO limits.

According to Al-Agha M, et al (2004), in most parts of the Gaza Strip, the chloride and nitrate content of domestic water exceeds the WHO guidelines; he also reported chloride concentration ranges from 250 mg/L to 1500 mg/L. Baalousha H. (2005) stated that as pumping of the groundwater increases, the aquifer becomes more deteriorated and more brackish, and saline water encroaches the aquifer. Concentrations of chloride for instance have recently reached more than 1000mg/L at many locations because of over-pumping. He also indicated that high chloride concentrations have been detected in Gaza city and the southern area. In Khanyounis city, seawater intrusion has been detected that leads to high chloride concentration. El-Madhoun (2005) discussed the quality of drinking water wells that supply the residents of the Gaza Strip chloride during the period from 1990 to 2002. The author concluded that during the mentioned period, the average Cl^- concentration was 397.1mg/L, higher than the WHO recommendation (250mg/L). The average Cl^- concentration in Khanyounis governorate (777.8mg/L) was found significantly the highest among all the governorates of Gaza Strip.

Aish A. (2010) recorded that the chloride concentration of 30% of the inlet water samples is below the WHO recommendation standard (250mg/L) and 70% of the water samples have chloride concentrations higher than the WHO standard.

Both calcium and magnesium are essential to human health. Inadequate intake of either nutrient can impair health. Recommended daily intakes of each element have been set at national and international levels. The concentrations of calcium and magnesium in drinking water vary markedly from one supply to another; mineral-rich drinking waters may provide substantial contributions to total intake of these nutrients in some populations or population subgroups. Water treatment processes can affect mineral concentrations and, hence, the total intake of calcium and magnesium for some individuals.

Calcium and magnesium are important nutrients in the development and maintenance of human health. These dietary components (as well as phosphorus) are most strongly associated with the development of strong bones and teeth and are essential to cardiovascular function. Approximately 99% of the body's calcium stores are found in bones and teeth, with small amounts in the tissues and body fluids necessary for muscle contraction, nerve transmission and glandular secretions. A smaller portion (50–60%) of the body's magnesium is found in the bone. Magnesium is a cofactor for over 350 enzyme reactions, many of which involve energy metabolism. It is also involved in protein and nucleic acid synthesis and is needed for normal vascular tone and insulin sensitivity. Both dietary calcium and dietary magnesium may play a role in the etiology of osteoporosis and cardiovascular disease (IOM 1997).

The MoH annual report of 2012 summarized the average concentrations of Ca^{+2} & Mg^{+2} in the municipal drinking wells of Gaza Strip. Ca^{+2} ranges from 18 mg/L to 764mg/L while Mg^{+2} ranges from 5mg/L to 538 mg/L. The highest concentrations were recorded in Gaza governorate followed by Khanyounis governorate.

The average concentration for Ca^{+2} in the desalination plants' inlet water in Gaza Strip was higher than the PSI standard (103mg/L). The highest average concentration of Ca^{+2} was found in the North governorate with a value of 133mg/L (not accepted by the PSI standards), followed by the Middle and Khanyounis governorates with values of 116mg/L and 114mg/L (not accepted by the PSI standards) respectively. In Gaza and Rafah governorates, the Ca^{+2} concentrations were meeting the PSI standards, at 90mg/L and 56mg/L respectively. However, for Mg^{+2}, the average concentration in Gaza Strip was below the PSI standards (74mg/L). Only the Middle governorate recorded an average concentration higher than the PSI standards, while Mg^{+2} concentrations were 72mg/L, 61mg/L, 77mg/L and 48mg/L for the North, Gaza, Khanyounis and Rafah governorate respectively.

Ca^{+2} & Mg^{+2} have been investigated in the groundwater and in the desalination plants' inlet water in Gaza Strip by some researchers. Al-Khatib et al. (2009) discussed the quality of the groundwater in Gaza Strip. He revealed that there was complete compliance (83 samples for Ca^{+2} and 79 samples for Mg^{+2}) with the PSI standards of (100mg/L) for both Ca^{+2} & Mg^{+2} concentrations.

Abu Mayla et al. (2009) summarized the concentrations of both Ca^{+2} & Mg^{+2} in the samples of the inlet water of the desalination plants in Gaza Strip. It was reported that the analytical data of inlet water samples show that 36.4% of the samples have calcium concentration less than the recommendations (100mg/l), while 45% of the samples have concentrations from 100mg/L to150mg/l. However the remaining samples (18.6%) need calcium decreasing.

Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for human health. It occurs widely in the environment, including all natural waters. It can also occur in drinking water as a consequence of the use of potassium permanganate as an oxidant in water treatment. In some countries, potassium chloride is being used in ion exchange for household water softening in place of, or mixed with, sodium chloride, so potassium ions would exchange with calcium and magnesium ions. Possible replacement or partial replacement of sodium salts with potassium salts for conditioning desalinated water has been suggested. The latter seems to be an unlikely development at this stage, in view of the cost difference. Currently, there is no evidence that potassium levels in municipally treated drinking water, even water treated with potassium permanganate, are likely to pose any risk for the health of consumers. It is not considered necessary to establish a health-based guideline value for potassium in drinking water. Although potassium may cause some health effects in susceptible individuals, potassium intake from drinking water is well below the level at which adverse health effects may occur (WHO, 2011). The WHO attributed the reasons why they didn't establish a guideline value for K^+ due to its occurring in drinking water at concentrations well below those at which toxic effects may occur.

In the Gaza Strip, according to the MoH recent report (2012) about the drinking water in the Gaza Strip, the K^+ concentrations were ranging from 1.5mg/L to 105mg/L in 193 municipal drinking water wells. The report revealed that the number of wells which have K^+ more than 10mg/L was 30 (15.5%).

For the desalination plants' inlet water in Gaza Strip, the K^+ concentrations were found to be within the PSI standards of 10mg/L. The average concentration of the K^+ in the Gaza Strip was 7mg/L. All the governorates' desalination plants' inlet water has concentrations of K^+ below the PSI standards at 5mg/L, 9mg/L, 8mg/L, 5mg/L and 4mg/L in the North, Gaza, the Middle, Khanyounis and Rafah governorates respectively.

Studies concerning potassium in the desalination plants' inlet water were very few in the Gaza Strip. However some studies were published and others were not. Al-Khatib I. et al. (2009) found that 295 samples of groundwater were having K^+ concentrations less than 10mg/L (100%). Aish A. (2010) studied the chemical parameters of the inlet water of 20 desalination plants in Gaza Strip. He mentioned that the maximum concentration of K^+ in the inlet water was 7.5mg/L and the minimum was 2.3mg/L while the average was 4.2mg/L. Shomar B. et al. (2010) stated that most wells in the Gaza Strip had an average value of K+ that was less than 5 mg/L; however, few wells showed levels of K+ more than 15mg/L.

The major source of sodium found in groundwater is derived from the natural erosion of salt deposits and sodium-bearing rock minerals and the infiltration of surface waters or storm waters contaminated by road salt; additional sources may include irrigation and precipitation waters leaching through soils high in sodium, groundwater pollution by sewage effluent, and infiltration of leachates from landfills and/or industrial sites.

The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution. At room temperature, the average taste threshold for Na^+ is about 200 mg/L. No health-based guideline value has been derived, as the contribution from drinking water to daily intake is small. No firm conclusions can be drawn concerning the possible association between sodium in drinking water and the occurrence of hypertension. Therefore, no health-based guideline value is proposed. However, concentrations in excess of 200 mg/L may give rise to unacceptable taste (WHO, 2011).

Sodium exists in the Gaza Strip aquifer with high concentrations. According to the MoH recent report of 2012, 126 out of 193 (65%) of the municipal drinking water wells had Na^+ concentrations higher than the WHO guideline of 200mg/L. The report revealed that the Na^+ concentrations in the groundwater wells were ranging from 34mg/L to 5000mg/L.

A few studies discussed the concentration of sodium in the groundwater and the drinking water. Shomar B. (2006) found that approximately 65 of the wells tested (>50% of the wells sampled) showed Na^+ levels higher than the WHO standard (200 mg/L). He concluded sodium had the same trend as Cl^- for all wells analyzed.

Al-Khatib I. et al. (2009) found that the percentage of non-compliant samples of groundwater (77 samples) with the WHO guideline in terms of Na^+ concentrations was 45.4%. Shomar B. et al. (2010) found that in 170 samples in 2008, sodium concentrations in the groundwater were ranging from less than 50mg/L in the North to higher than 1000mg/L in Khanyounis and Rafah. AlKhateeb M. (2010) found that the results of the analysis showed that the groundwater was chemically highly enriched with Na^+ and Cl^-, an indication of seawater intrusion into the aquifer; the concentrations of sodium and chloride vary respectively between 16 mg/l in the North governorate and 1400 mg/l in Gaza governorate and from 43 to 3119 mg/l, during 2009. He included that the highest concentration levels characterize the boreholes situated in the northern Gaza and Khanyounis governorates.

The sodium concentrations in the desalination plants' inlet water were detected in the current research. The average concentration of Na^+ was higher than the WHO guideline (442mg/L). All the governorates' Na^+ content exceeded the WHO level. The highest average concentration was found in Khanyounis at 669mg/L followed by the Middle which had an average concentration of 568mg/L. In the North, Gaza and Rafah governorates Na^+ concentrations were 224mg/L, 324mg/L and 485mg/L respectively.

Abu Mayla Y. et al. (2009) agreed with Aish (2010) when they found similar results in the inlet water of the desalination plants in Gaza Strip. They found 50% of the samples containing sodium concentrations below the WHO guideline (200 mg/L). They also reported that the other 50% of the samples need to have their sodium concentration decreased.

The results of the outlet water of the desalination plants in the Gaza Strip revealed that the average Na^+ concentrations were less than the WHO guideline. All the average concentrations were less than 35mg/L. In the Gaza Strip, the average concentration was found to be 22.6mg/L. Average Na^+ concentration in Khanyounis was the highest at 34.9mg/L, followed by Rafah which had an average concentration of 29.7mg/L. The North, Gaza and the Middle governorates also recorded very low content of Na^+. The average concentrations were 15.4mg/L, 19.5mg/L and 22.3mg/L respectively.

The low concentrations of sodium in the outlet water of the desalination plants were recorded in some studies about desalinated water. The low concentrations were recorded in the study by Abu Mayla Y. et al. (2009), who found that 100% of the samples accepted by the WHO and the outlet samples were containing sodium levels less than 30 mg/L. Al-Khatib I. et al. (2009) analyzed the data of 122 samples of desalinated water. They $indicated that the percentage of the compliant samples with the WHO guideline in terms of Na^+ content was 100%.

6.0 Conclusions

- Water quality in the Strip is deteriorating. Groundwater from the coastal aquifer is currently the main source of water, and its depletion and increasing salinity are becoming urgent problems.
- The average concentrations of chemical parameters in the desalination plants' inlet water (groundwater) were higher than the WHO standards in almost all the inlet water samples.
- In some plants the inlet water average concentrations of chemical parameters were accepted by the WHO guidelines and the inlet water didn't need a desalination process.
- All the desalination plants show a high performance in the removal of the chemical parameters from the inlet water which in turn affected the pH value in the outlet water.
- All the chemical parameters' average concentrations in the outlet water of all the desalination plants were accepted by the WHO guidelines for drinking water, except some pH values in some plants.
- The high desalination efficiency led to very high removal of essential elements that are essential to human health such as calcium, magnesium and potassium.

7.0 Recommendations

- A monitoring program for the desalination plants includes chemical and microbiological analysis which should be enhanced, developed and intensified for the evaluation of the product and distributed water.
- A strategy should be adopted to control the location of the small scale desalination plants' construction according to the groundwater quality to manage salinity problems in the Gaza Strip.
- Dependence on desalinated water should increase, which means that the desalination capacity of the current plants should be boosted or new plants should be built. This will reduce the water withdrawal rate from the coastal aquifer and allow it to rehabilitate itself and reduce its salinity. Moreover, this will guarantee a high quality water supply in the Gaza Strip. Distribution of desalinated water, then, should be totally done through the water network.
- Large seawater desalination plants should be established in order to decrease pumping water in the Gaza Strip aquifer.
- Frequent maintenance and upgrading of water and wastewater networks should occur, and open over-ground dumping of wastewater should cease.
- The desalination plants must be professionally operated according to global standards to protect the quality of desalinated water. This includes implementing necessary pre- and post-treatment of water, as needed, and maintenance of the desalination units.
- The disinfection processes in the desalination plants should be enhanced.
- The desalinated water tanks and distribution cars should be cleaned and disinfected carefully and regularly.
- Awareness campaign targeting the plants owners to increase their awareness about the water problem in Gaza Strip and how could they share in solving it, how could they mange there investment not only for commercial reasons, but also to be part of the water problem solution in Gaza Strip.
- Awareness campaigns should be targeting the consumers to increase their awareness about the drinking water recommendations and healthy water quality.
- More studies about the relation between consuming desalinated water regularly and its health effects should be done.

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