



Research Journal of  
**Environmental  
Sciences**

ISSN 1819-3412



Academic  
Journals Inc.

[www.academicjournals.com](http://www.academicjournals.com)

## **Disinfection Process of Water Supply System in the Gaza Strip Between Real Practice and WHO Limitations**

<sup>1</sup>Mohammed Al-Safady and <sup>2</sup>Husam Al-Najar

<sup>1</sup>Institute of Water and Environment, Al-Azhar University, P.O. Box 1277, Gaza, Gaza Strip

<sup>2</sup>The Islamic University of Gaza, P.O. Box 108, Al-Rimal, Gaza Strip

*Corresponding Author: Husam Al-Najar, The Islamic University of Gaza, P.O. Box 108, Gaza Strip, Gaza*

### **ABSTRACT**

The main objective of the current research is to evaluate the disinfection process of water supply system in highly populated area in the Gaza Strip based on world health organization limitations for residual chlorine to ensure the microbiological safety of drinking water. The study relied mainly on the measurements of residual chlorine in the drinking water network of Jabalia city in the period between February 2009 until April 2010 of fixed sampling points representing the whole area network. Digital colorimeter is used to measure free chlorine and/or total chlorine residual at the monitoring points. A DPD-1 (free chlorine) or DPD-3 (total chlorine) tablet is added to a vial of sample water that causes a color change to pink. The vial is inserted into a meter that reads the intensity of the color change by emitting a wavelength of light and automatically determining and displaying the color intensity (the free or total chlorine residual) digitally. The study showed that some concentrations of residual chlorine in municipal water distribution network was infringement of the allowed values according to WHO standards by 41.4%, moreover a high rate of residual chlorine in some monitoring points up than value of the chlorine injected into the source for Jabalia. The study confirmed the existence of inverse correlation between the amount of residual chlorine and the distance from the source of chlorination in water supply networks. The results were discusses and appropriate recommendations were done in order to maintain the quality and safety of drinking water.

**Key words:** Chlorination, public health, distribution network, water quality, residual chlorine

### **INTRODUCTION**

Increasing the demand for fresh water in Gaza Strip due to the population increase leads to decline in levels of groundwater and finally to sea water intrusion and chemical pollution (Nassar *et al.*, 2009; Qahman *et al.*, 2009; Hamdan *et al.*, 2009; Al-Najar, 2007; Al-Najar and Adelay, 2005). Researchers in water science and environmental studies care about the main pollutants that are exposed water by anthropogenic, especially the agricultural and industrial ones (Craum *et al.*, 2001). The most important challenges in water treatment was to get rid of drinking water from hazards pollution as a result of adequate micro-organisms and chemical pollutants, that water does not constitute a threat to public health after treatment (WHO, 1996).

Microbiological quality is the most important aspect of drinking water in relation to waterborne diseases as most of the risk of chemical pollution due to the sea intrusion is intensively discussed neglecting other quality parameters such as microbiological safety of drinking water in Gaza Strip.

Water-related diseases are a growing human tragedy, killing more than 5 million people each year-10 times the number of people killed in wars. About 2.3 billion people suffer from diseases linked to dirty water. Some 60% of all infant mortality worldwide is linked to infections and parasitic diseases most of them water-related (Okpara *et al.*, 2011). Infiltration of wastewater from already overloaded sewerage system to the water distribution system is witnessed in some areas in Gaza as a result of eroded pipes and fittings. From major factors contributing to the coliform problem in Gaza Strip in general, improper maintenance of the distribution system and inadequate or interrupted disinfection process. In addition to factors cross-contamination of pipeline systems may contribute to higher levels of total and fecal coliform contamination registered for water networks. Detection of bacterial indicators in drinking water means the presence of pathogenic organisms that are the source of waterborne diseases. Such diseases could be fatal. Epidemic giardiasis associated with contaminated drinking water has been reported in different locations in Gaza Strip, Intestinal parasites are prevalent in Gaza Strip (Shomar, 2010; Abu Amr and Yassin, 2008; Yassin *et al.*, 2006). Water disinfection is one of the most important processes which protect public health. The three commonly used methods for disinfection are: chlorination, ozonation and ultraviolet (UV). Chlorination is the best disinfectants which own the properties to remain until after the disinfecting process as it provides certain and continuous protection of drinking water from water sources leading to the final consumer (Khleifat *et al.*, 2006). Besides being cheap, Chlorination is the most widely used disinfectant, both in centralized water distribution systems and for point-of use treatment in individual households. It is effectiveness against a wide spectrum of disease causing organisms. Only chlorine-based disinfectants leave a beneficial residual level that remains in treated water, helping to protect it during distribution and storage (WCC, 2008). Hence, it is important to study a residual chlorine levels in drinking water distribution network to ensure the integrity of the process of chlorination (Diana *et al.*, 2008). Therefore, the current research discusses the chlorination process principle and reveals the residual chlorine within a drinking water distribution system in Jabalia comparing the results with WHO limitations. Additionally, the depletion of residual chlorine at different distances from the chlorination unit's source is also studied to ensure adequate residual chlorine at the end of the distribution system.

## **MATERIALS AND METHODS**

**Study area:** Water supply network is studied in a highly populated area within Jabalia city, the third main city in the Gaza Strip after Gaza and Khanyounis city. It characterized by its small size, the large population and the exclusiveness of a separate water distribution network and the network constitute of many zones. Two zones were selected for more research; old and new network (Fig. 1). The old and new networks aged 25 and 5 years, respectively. Jabalia lacks the presence of public water tanks where the water pumped from 11 groundwater wells each well provides water to specific zone and distributed by the network directly to consumers. The drinking water distribution system is relatively old and requires frequent maintenance. Chlorination is the recognized disinfection process for Jabalia city like most of the cities in the Gaza Strip, each individual well has chlorination unit continuously dosing soluble calcium hypochlorite  $\text{Ca(OCl)}_2$  to the pumped water. Due to the continuous interruption of the water supply the use of roof tanks is common in Jabalia for storage.

Water distribution network constitutes of 11 ground water well to provide water to the residents. To ensure the adequacy of the disinfection process, 26 monitoring points were distributed in the water network covering the zones of the network and the residential quarters of the city.

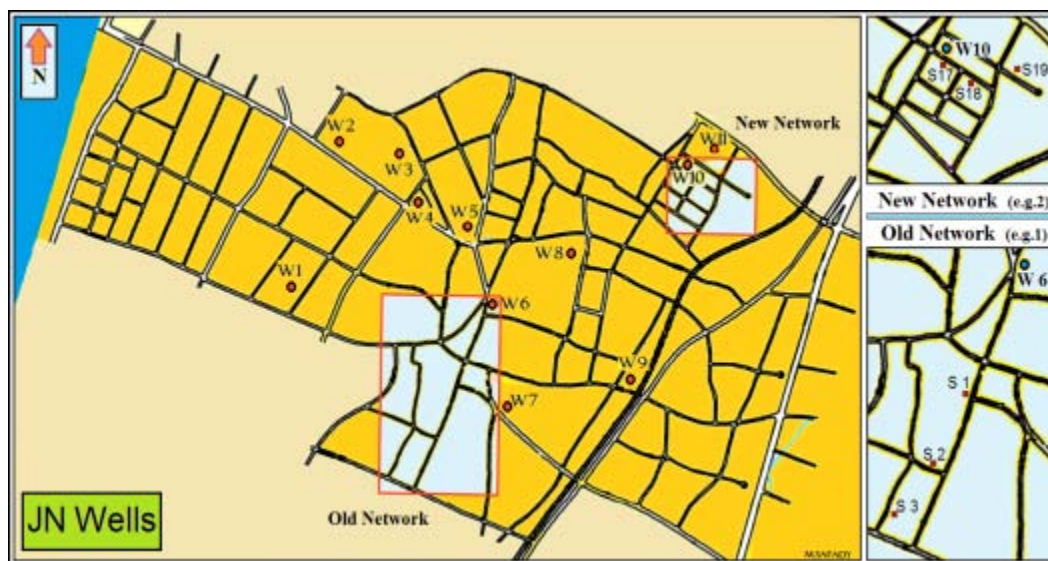


Fig. 1: Map of Jabalia, location of wells and two monitoring location, old and new networks

Samples were collected monthly from each water source (wells) and the monitoring points at the network and analyzed for free and total chlorine. The current research is part of long term monitoring project supervised by the Coastal Management Water Utility (CMWU) and the local municipalities. The researchers selected one of the highly populated cities for the study of nearly one year (February, 2009 till April 2010) to grantee all seasons of the year. Samples from proposed sampling points and the wells were collected and analyzed according to the methodology which followed also by the monitoring program.

Digital colorimeters are the most accurate method to measure free chlorine and/or total chlorine residual in the field. The colorimeter is used as the following procedure:

- A DPD-1 (free chlorine) or DPD-3 (total chlorine) tablet or powder is added to a vial of sample water that causes a color change to pink
- The vial is inserted into a meter that reads the intensity of the color change by emitting a wavelength of light and automatically determining and displaying the color intensity (the free or total chlorine residual) digitally. The range of the meters is generally 0-4 mg L<sup>-1</sup>

The study relied on transactions descriptive statistics such as average, standard deviation, correlation coefficient by using the statistical program SPSS v.15, Excel 2007 in the analysis. Satellite images are also used to determine the distances between some monitoring points and wells.

## RESULTS

**Residual chlorine in water network of Jabalia:** The study begins by checking the value of free chlorine during period from February 2009 to April 2010 for all wells and monitoring points of the municipal drinking water network in Jabalia. As shown in Table 1, the selective residual chlorine samples were collected from fixed sampling points in the network representing the whole entire area of Jabalia. The highest average residual chlorine was 0.34 mg L<sup>-1</sup> in February 2010 and the lowest average was 0.21 mg L<sup>-1</sup> in April 2010, while Feb 2010 has a great variance 0.21 and a

Table 1: Sampling from the whole Jabalia network monitoring points and water source, showing the min., max and mean residual chlorine concentration

Sampling date	No. of sampling points	Concentration (mg L <sup>-1</sup> )				
		Min.	Max.	Mean	Std. Deviation	Variance
Feb. 2009	35	0.01	0.65	0.24	0.21	0.04
Apr. 2009	35	0.02	1.03	0.30	0.22	0.05
July 2009	37	0.05	1.18	0.31	0.24	0.06
Oct. 2009	37	0.08	1.84	0.26	0.29	0.08
Feb. 2010	37	0.09	3.00	0.34	0.46	0.22
April 2010	37	0.05	0.69	0.21	0.14	0.02

Table 2: The number and rates of non-standard recording for the total sample in Jabalia network

Sampling date	No. of sampling points (N)	N < 0.2 mg L <sup>-1</sup>	N > 1.2 mg L <sup>-1</sup>	Not approved	Approved
Feb. 2009	35	10	0	10	25
Apr. 2009	35	23	0	23	12
July 2009	37	13	0	14	23
Oct. 2009	37	19	0	20	17
Feb. 2010	37	15	0	15	22
April 2010	37	10	0	10	27
Total	222	90	2	92 (41.4%)	126 (55.6%)

standard deviation was 0.46 due to the higher dose of chlorine 3 mg L<sup>-1</sup> which was pumped during the same month in Well number 3 (W3) exceeding the allowable limits in WHO standards. The minimum concentration detected at the monitoring points mostly lower than WHO limitations ranging from 0.01 to 0.09 mg L<sup>-1</sup>.

The variation in averages is high in various months from February 2009 to April 2010 in all sampling location of Jabalia water distribution network. It is noticeable that, the residual chlorine are considerable high in 3 months, April 2009, July 2009 and Feb. 2010. It is noticed that the average amount of residual chlorine in February 2010 was 0.34 mg L<sup>-1</sup> that was larger than the average of February 2009 (0.25 mg L<sup>-1</sup>). The average amount of residual chlorine in April 2010 was 0.21 mg L<sup>-1</sup> that was less than the average of the same month in the year 2009 as it was 0.31 mg L<sup>-1</sup>. This violates the principle of the amount of residual chlorine at the same point during the a period of time.

On the other hand, the study identified that the number of recordings which increased over the maximum allowable in accordance with standards adopted by the WHO (N>1.2 mg L<sup>-1</sup>) are two samples only. While, the number of samples which are below the minimum standards (N<0.2 mg L<sup>-1</sup>) are 90. This means that the proportion of non-standard recordings was 41.4% of the total recordings as shown in Table 2.

**Residual chlorine at the source:** Jabalia was provided with water from 11 ground water wells as a source of water. Chlorination process starts at the wells. As shown in Table 3 the lowest average residual chlorine in well number 6 (W6) which was 0.19 mg L<sup>-1</sup>. The highest average was in well (W3) which accounts for 1.01 mg L<sup>-1</sup>. The highest average of residual chlorine considering the season was in Feb 2010 (3.0 mg L<sup>-1</sup>) and the lowest was in April 2010 (0.28 mg L<sup>-1</sup>). The doses for well (W3) accounts for 1.84 mg L<sup>-1</sup> and 3 mg L<sup>-1</sup> in Oct 2009 and Feb 2010, respectively. These values are higher than the recommended values by WHO (2004).

Table 3: The average residual chlorine at the water source for the period (2/2009-4/2010)

Well No.	Feb. 2009	April 2009	July 2009	Oct. 2009	Feb. 2010	April 2010	Average
W1	0.56	0.58	1.18	0.41	0.21	0.13	0.51
W2	0.55	0.48	0.50	0.60	0.44	0.43	0.50
W3	0.30	0.29	0.51	1.84	3.0	0.13	1.01
W4	-	-	0.32	0.26	0.19	0.07	0.21
W5	0.36	0.33	0.07	0.28	0.39	0.38	0.30
W6	0.25	0.29	0.12	0.14	0.16	0.2	0.19
W7	-	-	0.64	0.18	0.38	0.34	0.39
W8	0.57	0.31	0.24	0.43	0.13	0.27	0.33
W9	0.50	0.32	0.53	0.20	0.24	0.32	0.35
W10	0.62	1.03	0.13	0.23	0.55	0.08	0.44
W11	0.50	0.78	0.16	0.45	0.32	0.69	0.48

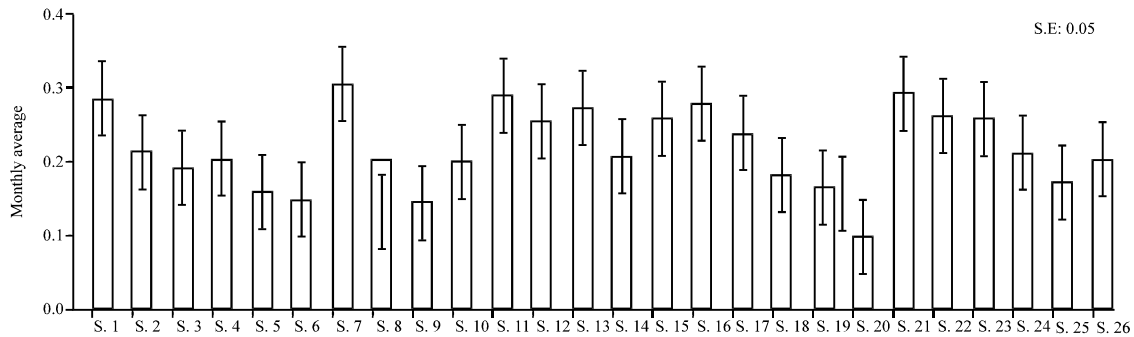


Fig. 2: Average residual chlorine variations between monitoring points of the Jabalia water network

High variation in chlorination process was seen in water source for Jabalia network. Well number 3 (W3) got high dosages, while wells number 4 and 6 (W4 and W6) are the lowest. Even though, the residual chlorine at the source is with the WCC (2008) limits (more than or equal 0.2 and less than 1.2 mg L<sup>-1</sup>).

**Residual chlorine at the monitoring points:** The average value of monthly residual chlorine recording of 26 monitoring points of Jabalia drinking water network during the months Feb. 2009 to April 2010 was calculated. As shown in Fig. 2, the highest average residual chlorine was calculated for the point (S.7) and accounts for 0.31 mg L<sup>-1</sup>. The lowest average value was found at monitoring point (S.20) and accounts for 0.09 mg L<sup>-1</sup>. The location of S.20 is nearly 250 m from the nearest well connected to the network. In general the residual chlorine in the monitoring points in the network located at the minimum range of WHO limitations. Around 50% of the monitoring points located with the range of 0.2 to 0.3 mg L<sup>-1</sup>, while the other percentage fall below 0.2 mg L<sup>-1</sup>.

**Residual chlorine at the monitoring point related to the distance from the source:** Two different zones from the network were selected to study the relation between residual chlorine concentration at the monitoring points and the distance from the source of chlorination (mostly the closest well).

The first zone represent old network consist from well no. 6 (W6) provides water directly to 3 monitoring points (S.1, S.2 and S.3) at different distances, 844, 1130 and 1480 m, respectively. As shown in Table 4, The dose of chlorine pumped to well W6 less than the amount of chlorine remaining in the monitoring points that come out of it. The relation between the average residual chlorine from well W6 and its monitoring points are shown in Fig. 3 and Table 4. The coefficient of Pearson correlation between the average residual chlorine of well W6 and the distance of the three monitoring points is shown in (Fig. 4).

The value of the correlation coefficient ( $r$ ) = (-0.158) indicating a correlation weak reverse and estimated the value of  $\text{sig} = 0.842$  leading to a significant correlation between the two variables at the level of significance  $\alpha = 0.05$ . The decrease in chlorine can be represented during this part of the Jabalia water distribution network scatter panel showing the line direction of the relationship and the trend equation Fig. 4.

The second zone consist of new piping system provided by water from well (W10) and three different monitoring points (S.17, S.18 and S.19) has a distance of 320, 430 and 540 m from the chlorination source, respectively as shown in Table 5.

Figure 5 and Table 5 show the relationship between the average residual chlorine of well W10 and its monitoring points with different distances from the source.

A coefficient of Pearson correlation between the residual chlorine average remaining well W10 points in accordance with following distance for a well source is represented in the Fig. 6, the

Table 4: Average residual chlorine of well W6 and the three monitoring points

Sample location	Distance (m)	Feb. 2009	April 2009	July 2009	Oct. 2009	Feb. 2010	April 2010
Well 6	1	0.25	0.29	0.12	0.14	0.16	0.2
S.1	844	0.15	0.36	0.40	0.27	0.28	0.25
S.2	1130	0.26	0.35	0.24	0.11	0.20	0.12
S.3	1480	0.05	0.33	0.17	0.10	0.17	0.33

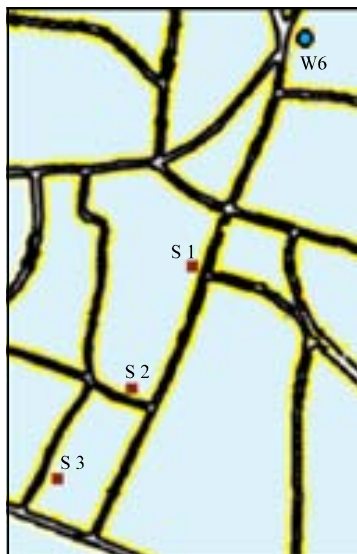


Fig. 3: The selected zone



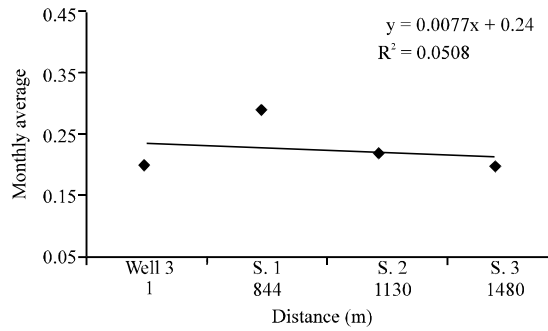


Fig. 4: The decreasing of RC monitoring points with distance changing

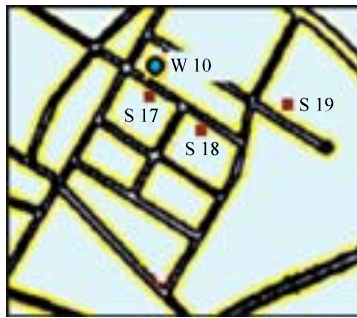


Fig. 5: W10 monitoring area

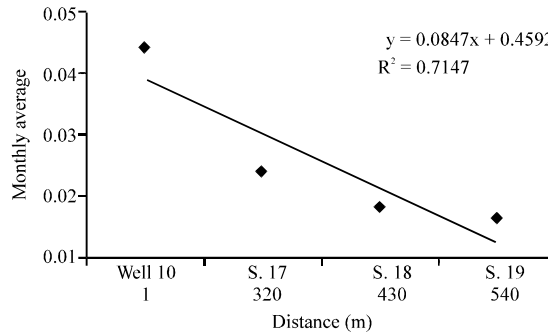


Fig. 6: The relation of residual chlorine at the monitoring points with distance from the source

Table 5: The average residual chlorine of Well W10 and the three monitoring points

Sample location	Distance (m)	Feb. 2009	April 2009	July 2009	Oct. 2009	Feb. 2010	April 2010
Well 10	1	0.62	1.03	0.13	0.23	0.55	0.08
S.17	320	0.42	0.05	0.26	0.14	0.47	0.09
S.18	430	0.01	0.06	0.30	0.26	0.40	0.06
S.19	540	0.16	0.21	0.08	0.17	0.20	0.17

correlation coefficient (r) = -0.876 and this indicates the strong inverse relationship, as the value of sig. = 0.124 indicate a significant correlation between the two variables at the level of significance  $\alpha = 0.05$ .



The decrease in chlorine can be represented during this part of the Jabalia water network scatter panel showing the line direction of the relationship and the regression (trend) is obviously shown in Fig. 6.

## DISCUSSION

For many years chlorination has been the standard method of water disinfection in the Gaza Strip. Chlorine is used in most water treatment facilities to kill harmful microorganisms in drinking water that cause serious diseases. While this certainly works, the chlorine itself causes many health problems such as asthma, cancer, fertility problems, heart diseases, eczema and birth defect (Oparaku *et al.*, 2011) in case it is not in the range of WHO limitations. This condition represents 41% of most the sampling points in the network of Jabalia. Therefore the chlorination process should be monitored and fixed values of chlorine dosage should be added to the system according to WHO limitations and standards. Comparing any month of the 2009 with the same month of 2010, the disparity is noticed, this indicates the existence an error in the amount of total pumped chlorine in the water sources before they enter the network, according to the used chlorine (Calcium Hypochlorid) has a fixed concentration (10-12%), this may be the result of dosing system at the source. The incorrect dosages of chlorine in water distribution system leads to failure in the disinfection process and as a sequence some waterborne diseases are detected among the children in the Gaza Strip. These results in agreement with (Yassin *et al.*, 2006) and (Abu Amr and Yassin, 2008) who explained the breakthrough of parasites in Gaza dense areas through water distribution system.

The percentage of doses less than the minimum allowable (non-standard) was 41% of recordings of the amount of residual chlorine and this prevents the hazardous materials to form in the water but did not provide adequate disinfection leading to rapid growth of microorganisms within the water network. In high chlorine dosage to the water distribution network cause high risk to the health. Studies have shown going to hazardous substances resulting from imbalances chlorination or non-compliance with standard doses be dangerous to public health, such as Trichloroacetic which causes cancer and disorders ability fertility (Alia, 2007). Residual chlorine more than WHO limitation ( $1.2 \text{ mg L}^{-1}$ ) is also indicated in the water network specially at the close sampling points to the chlorination source. Because of the amount of chlorine injected less than allowed in some sources, the presence of damaged parts and consumers in the network branches, the rapid consumption of water in the more populated areas and sometimes neglect some of the workers in the follow-up disinfection operations. The infiltration of wastewater to the water distribution system is a common phenomena specially in winter time, where sewerage system is overloaded (Hamdan *et al.*, 2009), this fact explain the low concentration of residual chlorine in the study area in winter time due to the high consumption of total chlorine in the network due to the existence of ammonia and microorganisms.

There are spatial and temporal variations in the amount of residual chlorine between the different wells. This is due to the different doses of chlorine depending on the well location, the ability of the pump to release chlorine solution related to the amount of water being pumped. The chlorine pumps are fixedly adjusted to release constant dose regardless of the degree of well contamination. Microbiological test of groundwater in Gaza shows microbial pollution, therefore chlorination process in situ is a must. Sources of water contamination could form natural or anthropogenic sources. Private wells can become contaminated if they have been poorly constructed or improperly sited or if they have been infiltrated by contaminated surface water. In fact, the aquifer itself can even be the source of contamination. Surface water and unprotected groundwater

are susceptible to fecal contamination from humans, livestock, wild animals and even house pets (Okpara *et al.*, 2011).

The recent controversy about the safety of chlorine and its byproducts has renewed interest in other forms of disinfection. From the health point of view, achieving the water and sanitation target by simple technologies would lead to global average reduction of 10% of episodes of diarrhea. The burden of diseases associated with lack of access to safe water supply, adequate sanitation and lack of hygiene is concentrated on children under five in developing countries. Accordingly, emphasis should be placed on interventions likely to yield an accelerated, affordable and sustainable health gains. This review points to household water treatment and safe storage as an option of particular potential with high health improvements (Okpara *et al.*, 2011). This approach is completely true for Jabalia city where the residents store the water for more than three days due to the continuous interruption of water supply. The residual chlorine in the household storage tanks is nearly nil, therefore water tanks could be suitable environment for biological contamination.

The amount of residual chlorine in the network ( $0.10 - 0.31 \text{ mg L}^{-1}$ ) the most important reasons behind the high variation are the distance between monitoring point and the source; network properties and quality of the city's water, diameter pipelines, the life span of a network, the growth of microbes that work on the analysis of chlorine remaining before the arrival of the monitoring points due to cracks in the pipes in the water distribution system. Disorder in pumping chlorine to wells prior to entering the network, not to follow or not to inform some of the workers on imbalances of emergency, use the same bottle standard when examining different samples without cleaning it, causing confusion among the remnants of residual chlorine from the examination previously with residual chlorine from the new sample, giving results that are misleading.

The study shows that inverse correlation when distance increased between the monitoring points and water sources, the residual chlorine decreasing within the pipes of the network. The difference in the relationship on two studied zones. The average doses of residual chlorine of well Number 10 (W10) on south of Jabalia was ( $0.19 \text{ mg L}^{-1}$ ) compared to well number 3 (W3) on north, the average doses was ( $0.44 \text{ mg L}^{-1}$ ) in the same period. Differences in properties and quality of the water network is the main reason behind the variation, it is very old and multi branches on W3 zone, W10 zone is newer network and less branches. The correlation between the depletion of the residual chlorine and the distance from the chlorination source emphasizes the fact of microbial contamination along the distribution network, in this case chlorine is consumed in the network as an oxidant to the microorganism which is the mechanism of disinfection (Parsons and Jefferson, 2006).

## CONCLUSIONS

The imbalance in the performance of the chlorination process during the studied period is the main characteristics of Jabalia water supply system. This can be clearly shown in the amount of residual chlorine in the water system during the period of study, the average amount in April  $0.21 \text{ mg L}^{-1}$  while it was  $0.31 \text{ mg L}^{-1}$  in the year 2009 and 2010, respectively.

There is a logical decrease in the amount of chlorine to some sources of water during the study period. Also there is a marked imbalance is contrary to the specifications of the standard doses of chlorine to some wells as a result of biological conditions or human negligence.

There is inverse relationship between the amount of residual chlorine and the distance from the source to be severe in some parts of the network and limited in other parts. The trend equation (regression) can be derived in which we can expect the value of chlorine remaining in the other points from the same source. Further research is needed to identify the characteristics and types of microorganisms and other pollutants in the water and the redefinition of doses used.

## **ACKNOWLEDGMENT**

The authors would like to thank the environment and water engineers at the municipality of Jabalia for providing the necessary data and maps. Special thanks to Eng. Majed Ghannam from Coastal Management Water Utility (CMWU) for his constructive ideas and recommendations.

## **REFERENCES**

- Abu Amr, S.S. and M.M. Yassin, 2008. Microbial contamination of the drinking water distribution system and its impact on human health in Khan Yunis Governorate, Gaza Strip: Seven years of monitoring (2000-2006). *Public Health*, 122: 1275-1283.
- Al-Najar, H. and A.J. Adeloye, 2005. The effect of urban expansion on groundwater as a renewable resource in the Gaza Strip. *RICS Res.*, 5: 7-21.
- Al-Najar, H., 2007. Urban agriculture and eco-sanitation: The strategic potential toward poverty alleviation in the Gaza Strip. *RICS Res.*, 7: 9-22.
- Alia, T., 2007. A study of free chlorine residual in the drinking water distribution system: Al-ramil al-shimali quarter-lattakia city. *Tishreen Univ. J. Stud. Sci. Res. Eng. Sci. Series*.
- Craun, G., F.S. Hauchman and D.E. Robinson, 2001. *Microbial Pathogens and Disinfection Byproducts in Drinking Water: Health Effects and Management of Risks*. ILSI Press, Washington, D.C., pp: 533-545.
- Diana, R., J. Nicolae and R. Dan, 2008. Modelling chlorine decay in drinking water mains. *Environ. Eng. Manage. J.*, 7: 737-741.
- Hamdan, S.M., U. Troeger and A. Nassar, 2009. Stormwater availability in the Gaza Strip, Palestine. *Int. J. Environ. Health*, 1: 580-594.
- Khleifat, K., M. Abboud, W. Al-Shamayleh, A. Jiries and K.A. Tarawneh, 2006. Effect of chlorination treatment on gram negative bacterial composition of recycled wastewater. *Pak. J. Biol. Sci.*, 9: 1660-1668.
- Nassar, A., K. Tubail and S. Afifi, 2009. Attitudes of farmers toward sludge use in Gaza Strip. *Int. J. Environ. Technol. Manage.*, 10: 89-101.
- Okpara, C.G., N.F. Oparaku and C.N. Ibeto, 2011. An overview of water disinfection in developing countries and potentials of renewable energy. *J. Environ. Sci. Technol.*, 4: 18-30.
- Oparaku, N.F., B.O. Mgbenka and C.N. Ibeto, 2011. Waste water disinfection utilizing ultraviolet light. *J. Environ. Sci. Technol.*, 4: 73-78.
- Parsons, S.A. and B. Jefferson, 2006. *Introduction to Potable Water Treatment*. Blackwell Publishing Ltd., Ames, Iowa, ISBN-10: 1-4051-2796-1.
- Qahman, K., A. Larabi, D. Ouazar, A. Naji and A.H.D. Cheng, 2009. Optimal extraction of groundwater in gaza coastal aquifer. *J. Water Resour. Protect.*, 4: 249-259.
- Shomar, B., 2010. Groundwater contaminations and health perspectives in developing world case study: Gaza Strip. *Environ. Geochem. Health*.
- WCC, 2008. Drinking water chlorination position paper 2008. [http://worldchlorine.com/publications/pdf/WCC\\_Policy\\_Paper\\_Water\\_Chlorination.pdf](http://worldchlorine.com/publications/pdf/WCC_Policy_Paper_Water_Chlorination.pdf).
- WHO, 1996. *Guidelines for Drinking-Water Quality*. 2nd Edn., Vol. 2, World Health Organization, Geneva.
- WHO, 2004. *Guidelines for Drinking-Water Quality*. 3rd Edn., World Health Organization, Geneva, pp: 296-459.
- Yassin, M.M., S.S. Amr and H.M. Al-Najar, 2006. Assessment of microbiological water quality and its relation to human health in Gaza Governorate, Gaza Strip. *Public Health*, 120: 1177-1187.