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Effectiveness of water supply disinfection system in Um Al- Nasser village as a marginal rural community

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Dedication

To my Father and to my Mother, for her kindness

To my wife for her Support and Encouragement

To my Brothers and Sisters

To my Friends, Colleagues

To the Islamic University of Gaza

And to all those who believe in the richness of Learning

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Thanks to Allah the compassionate the merciful for giving me patience and strength to accomplish this research.

All thanks and appreciations go to Allah for His unlimited blessings and for giving me the strength to complete this study.

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The researcher

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Abstract

Water disinfection is one of the most important processes which protect public health. Chlorination is the best disinfectant which owns 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. Besides being cheap, chlorination is the most widely used disinfectant in centralized water distribution systems. This study is based on the water distribution network in Um Al Nasser village north Gaza governorate to ascertaining the factors, the effectiveness of chlorination process in the municipal water distribution network. The study aims to investigate the behavior of the water systems under the action of intermittent pumping a procedure of modeling the system as in reality system using (WaterCad Program). The outputs showed that the network is exposed to relatively high values of pressure and low value of velocity. The study relied mainly on the measurements of residual chlorine in the drinking water network of Um Al Nasser village in the period between January 2010 until August 2013, of fixed sampling point representing the whole area network. The study showed that some concentrations of residual chlorine in municipal water distribution network was infringement of the allowed values according to WHO guidelines by 51%. 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 network. The study was concerned about the impact of decreasing of residual chlorine in the network within waterborne. SPSS and Excel programs are used to analyze the data collected about residual chlorine and waterborne diseases such as Pin Worms, Ascariasis, Amoebiasis, Giardiasis and Diarrhoea. A strong negative correlation was found for Gaiardiasis and Diarrheal diseases with Average residual chlorine in drinking water networks in Um Al Nasser village whereas correlation with Pin Worms was the weakest. The results were discusses and appropriate recommendations were done in order to maintain the quality and safety of drinking water.

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ملخص البحث

تعتبر عملية تعقيم المياه واحدة من أهم الطرق للحفاظ على الصحة العامة للإنسان وتعتبر عملية الكلورة من أفضل نظم تطهير المياه حيث انها تملك خاصية البقاء – الكلور المتبقي – حتى بعد انتهاء عملية التعقيم والتي بدورها توفر الحماية المستمرة لمياه الشرب من المصدر حتى المستهلك بالإضافة لكونها الارخص بين انظمة التعقيم فهي الأكثر انتشارا في انظمة التوزيع المركزية. استندت هذه الأطروحة على دراسة شبكة مياه قرية ام النصر في محافظة شمال غزة وذلك للتحقق من عوامل فعالية عملية الكلورة في شبكة توزيع المياه.

لتحري سلوك شبكات المياه تحت تأثير الضخ المتقطع تم دراسة شبكة مياه قرية ام النصر كنموذج يمثل أنظمة الضخ المتقطع وتمثيلها بصورة مقاربة للواقع وذلك بحساب معاملات التشغيل وذلك باستخدام برنامج (WaterCad) حيث اشارت نتائج التحليل الى ان شبكة مياه قرية ام النصر تتعرض الى قيم عالية من الضغط وانخفاض قيمة السرعة. اعتمدت الدراسة بشكل رئيسي على قياس كمية الكلور المتبقي في شبكة مياه الشرب في قرية أم النصر في الفترة بين يناير 2010 وحتى أغسطس 2013 وذلك من نقاط فحص ثابتة تمثل شبكة المنطقة كلها. وأظهرت الدراسة أن تركيز الكلور المتبقي في شبكة توزيع مياه البلدية غير مطابق للقيم المسموح بها وفقا لمعايير منظمة الصحة العالمية بنسبة 51% . وكذلك أكدت الدراسة وجود علاقة عكسية بين كمية الكلور المتبقي في الشبكة والمسافة من المصدر بمعنى اضمحلال الكلور في الشبكة. كذلك ركزت الدراسة على الآثار المترتبة على انخفاض تركيز الكلور المتبقي في الشبكة وعلاقتها بالأمراض المنقولة بواسطة تلوث المياه. تم استخدام برنامج SPSS v.15 وبرنامج EXCEL 2007 لتحليل البيانات التي تم جمعها عن الكلور المتبقي و الأمراض التي تنقلها المياه مثل الديدان، الاسكارس، الأميبا ، الجيارديا و الإسهال. حيث أظهرت الدراسة وجود علاقة عكسية واضحة وقوية لأمراض الاسهال والجا رديا مع متوسط الكلور المتبقي في الشبكة مياه الشرب في قرية ام النصر حيث كان معامل الارتباط (r = -0.969) و (r= -0.912) على الترتيب لكل من الجارديا والإسهال ، في حين كانت العلاقة ضعيفة جدا بين الديدان وتركيز الكلور المتبقي. بعد ذلك كانت النتائج تابعة و أجريت التوصيات المناسبة من أجل الحفاظ على جودة و سلامة مياه الشرب في قرية ام النصر.

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List Of Abbreviations

CDC :Center for Disease Control
CT :Contact Time
CMWU :Coastal Municipalities Water Utility
DBP :Disinfection By-Product
EOSQ :Egyptian Organization for Standardization and Quality
GEWP :Gaza Emergency Water Project
JISM :Jordan Institution for Standards and Metrology
MCL :Maximum Contaminant Level
MCM : Million Cubic Meters
MOA : Ministry of Agriculture
MOH : Ministry of Health
NGOs :Non Governmental Organization
PCBS :Palestinian Central Bureau of Statistics
PHG :Palestinian Hydrologic Group
PWA : Palestinian Water Authority
PSI :Palestinian Standards Institution
SIP :Services Improvement Project
THMs :Trihalomethanes
UFW :Unaccounted For Water
UNICEF : United Nations Children's Fund
USEPA :United States Environmental Protection Agency
UV :Ultraviolet
WCC :World Chlorine Council
WHO :World Health Organization

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1. INTRODUCTION

1.1 Background

Water is essential to humans, animals and plants. Without water, life on earth would not exist. From the beginning of human civilization, people have settled close to water source, along rivers, beside lakes or near natural springs. Drinking water should be suitable for human consumption and for all usual domestic purposes including personal hygiene. "*The water required for each personal or domestic use must be safe, therefore free from micro-organisms, chemical substances and radiological hazards that constitute a threat to a person's health. Furthermore, water should be of an acceptable color, odor and taste for each personal or domestic use*." UN Committee on Economic, Social and Cultural Rights, General Comment 15: The right to water (2002).

The Gaza Strip is a part of the Palestinian coastal plain in the south west of Palestine, where it forms long and narrow rectangle on the Mediterranean Sea. It is located between longitudes 34° 2'' and 34° 25'' east and latitudes 31° 16'' and 31° 45'' north. It is bordered by Egypt from the south, Negev desert from east and the green line from the north. The Gaza Strip occupies an area of about 365 Km^2; about 45 Km long and 5 to 15 Km wide (Khalaf, 2005).

Groundwater from the coastal aquifer is the only source of water in Gaza Strip. The coastal aquifer consists primarily of Pleistocene age Kurkar Group deposits, including calcareous and silt sandstones, silts, clays, unconsolidated sands, and conglomerates. Near the coast, coastal clays extend about 2–5 km inland, and divide the aquifer into three or four sub aquifers. Towards the east, the clays pinch out the sub-aquifer is largely unconfined (PEPA 1994; Zeitoun *et al.*, 2009). Within Gaza Strip, the Kurkar Group is about 100 m thick at the shore in the south, increasing to about 200 m near Gaza City. At the eastern Gaza border, the saturated thickness is about 60–70 m in the north, and only a few meters in the south near Rafah. Local perched water conditions exist throughout Gaza Strip due to the presence of shallow clays (MEnA 2000). The groundwater aquifer of Gaza Strip is extremely susceptible to surface-derived contamination because of the high

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permeability of sands and gravels that compose the soil profile of Gaza (Zeitoun *et al.*, 2009).

Water quality in Gaza is affected by many different factors includng soil/water interaction in the unsaturated zone due to recharge and return flows, mobilization of deep brines, sea water intrusion or upcoming, and disposal of domestic and industrial wastes into the aquifer. Moreover, according to CMWU (2012), 65 % of wells were found contaminated with nitrate, 57 % with chloride, and some recorded high fluoride concentrations as well. Shockingly, the spread of diarrhea – a condition that can be easily treated and avoided – is thought to account for at least 12 % of young deaths in Gaza. It has been repeatedly reported that some 90–95 % of Gaza's groundwater is no longer fit for drinking purposes. However, this problem is being caused by several factors, rather than just over abstraction rates. The most hazardous of these include the unregulated disposal of untreated or partially treated wastewater into open lagoons, the penetration of fertilizers and cesspit effluents, and finally Israel's physical impediments to surface and subsurface recharge waters, which prevent any revival to the highly deteriorated Coastal Aquifer (WASH MP, Water for life, 2011).

Microbiological water quality is the most important aspect of drinking water. The microbial quality of drinking water and its relation to human health traditionally has been assessed by determining the presence or absence of enteric microbial pathogens directly or more commonly indirectly by the use of Fecal indicator bacteria (Martine, 1984). Bacteria in water are, in general, not present individually, but located as clump or in association with particulate matter. Each clump or particle may have bacteria associated with it (Jamie and Richard, 1996). Gaza Strip region constitutes a characteristic case of highly polluted coastal aquifer. This situation has developed due to hydrological stress as well as poor environmental management (Goldenberg and Melloul, 1994). It has been reported that the principal determinants of microorganisms growth in water are temperature, availability of nutrients, and lack of residual disinfectant. Nutrients may derive from the water body and/or materials in contact with water (WHO, 2002). According to microbiological contamination level of water samples collected from water wells and networks

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distribution system during 1999 to 2003 at annual basis study in Gaza Strip. In wells the Total Coliform contamination varied between 8-12% throughout the five years of testing. For the Total Colifrom contamination of the water networks, the values slightly varied from 11 – 14% in the same period. These values exceeded that of the World Health Organization, WHO limit (5%). In water networks the level of contamination decreased from 10% to 5% in the year 1999 to 2000, and then account for 6% for each of the next three years. In general, the Total and Fecal Coliform contamination in water networks was higher than that in the wells in the Gaza Strip along the study period. The total coliform contamination percentages in the wells showed a decreasing trend started with 13% in the year 1999 and ended by 7% in the year 2003. In water networks the values of contamination accounted for 17, 14, 10, 12 and 13% for years 1999 to 2003, respectively (Abu Amer *et al.,* 2006). The major factors contributing to the coliform problem in Gaza Strip in general, and in Gaza Strip, may include: (1) sewage infiltration through incorrectly designed sewage systems or through cesspools and wastewater treatment facilities in Gaza Strip; (2) interruption of water supply that may cause inverse pumping of wastewater or other contaminants from the surrounding system. This may be due to breakage in the distribution system, thus promoting bacterial biofilm growth. Biofilms were reported to develop in water distribution systems. (3) Improper maintenance of the distribution system and inadequate or interrupted disinfection contamination of groundwater with pathogenic microorganisms is generally believed to be a result of migration or introduction of Fecal material, either from humans or animals, into the subsurface. Fecal contamination can reach groundwater from many concentrated pond sources such as landfills, filled septic systems, leaking sewer lines and cesspools.

Melad, 2002 analyzed water samples from 20 groundwater wells located in the surrounding of the wastewater treatment pond of Beith Lahia, Gaza Strip, over four seasons (April 2000 to March 2001). Total coliform was isolated from 18 wells in winter seasons, and the count ranged between (1-130 cfu/100ml), from 17 wells in summer season and the count ranged between (2-130 cfu/100ml), (2-120 cfu/100ml), from 15 wells during spring season and recorded (1-110cfu/100ml) from 13 well during autumn season. Fecal coliform recorded values ranged between (1-120

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cfu/100ml) during winter season that obtained from 12 wells, while 11 wells during summer season had a values ranged between (1-120 cfu/100ml), and 8 wells in both spring and autumn season recorded counts ranged between (1-110 cfu/100ml) and (1-90 cfu/100ml), respectively.

There is a strong relationship between water quality and human health, as has been reported in many studies around the world. Statistics from the Center for Disease Control and Prevention (CDC) reveal that there were more than 17,000 cases of water-related illnesses during the last two years in Gaza. However, since many symptoms are often confused with other sicknesses, some researchers feel as many as 25 outbreaks go unreported for every one reported, since many people are exposed to potentially harmful microbes and pesticides, through drinking tap water and taking showers. One reason for these increasing health problems is that it is difficult to treat chlorine effectively, after using it as a disinfectant. Researchers have seen a two-fold increase in the risk of cancer for people who drink an average of two and one half cups of chlorinated water daily for more than 30 years, compared to those who drink water disinfected by other processes. The most common contaminates in the Gaza water system are chlorine by-products, lead, microorganisms, and residual pesticides. In Gaza Strip, The mean nitrate concentration is high at 199 mg/l and is attributed due to intensified agriculture activities and excess use of fertilizer. About 86% of the examined samples exceed the maximum permissible concentration of 50 mg/l set by World Health Organization (WHO),(Al-Khatib M and Al-Najar. H, 2011).

1.2 Problem Definition:

Pollution is one of the most danger threats to water resources and this due to poor techniques used to protect the environment from the effects of agricultural, industrial and domestic pollution. Gaza Strip people suffer from high proportion of contaminants in the groundwater that used for drinking, industry and agriculture use. Epidemic guardianship associated with contaminated drinking water has been reported in different locations in the Gaza Strip. According to the environmental and public health department in MOH; Yassin *et al.*, 2006; Abu Amer and Yassin, 2008 there are incidence of varies waterborne diseases registered in Gaza Strip as the following:

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Table 1.1 , Waterborne diseases registered in Gaza Strip

Years	2005	2006	2007	2008	2009
Hepatitis A	1272	1228	841	847	678
Salmonella	35	11	20	9	2
Shegilla	5	-	-	3	2
Typhoid fever	1330	853	324	499	378
parasites	6224	3906	3618	3049	2581

Source: Environmental and Public Health department at Ministry of Health, 2013

As a result of enhancing community participation in advocating children's rights project in 2004 they are found that in Um Al –Nasser village, Scares is the highest parasite infection (33.3%), then Giardia within (21%) and the lowest is Strongyloides (1.2%). That's might be a result of ineffective disinfection water supply system or other sources of microbial pollution.

1.3 Hypothesis :

As a part of the Gaza Strip Um Al- Nasser village – North Gaza Governorate - suffer from waterborne diseases and bad disinfection of drinking water. Therefore, the current study will concentrate on the disinfection of water supply system in Um Al-Nasser village.

1.4 Research importance:

Water and sanitation sector is a very related sector to people life, and as mentioned previously Gaza Strip exposes to very difficult circumstances and the water and sanitation sector faces many problems, also there is a scarcity in studies that search in problems of the sector in particular after the siege on Gaza since 2006. Therefore:

- ❖ This research is very important where it will give a chance to study and evaluate the efficiency of water disinfection system in Um Al Nasser village to keep the running of the systems and save access to water services to people.

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- It is important for interested people to know the main problems that face the sector and to be interested in the relation between water quality and waterborne diseases to prepare themselves to act with and to set their strategies.
- It is also important for interested people to take the benefit from research results and recommendations to know how to deal with crises and emergencies that water and sanitation sector can exposed to in Gaza Strip since the studies in this field are few.

1.5 Objectives:

The main objective of this research is to study the efficiency of water supply disinfection system in order to improve the water quality offered by the municipality and to minimize the dangerous of waterborne diseases . This can be achieved by:

1. To review and evaluate the water distribution system adequacy from public health prospective.
2. To investigate the disinfection system in Um Al- Nasser community based on WHO and Palestinian standards .
3. To investigate the relationship between chlorine decay and variables such as distance from the injection point.
4. To propose possible improvements on disinfection process to improve the microbiological quality of drinking water.

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2. LITERATURE REVIEW

2.1 Introduction:

Some water sources contain disease-causing organisms which need to be removed or killed before the water offer to drink. Water disinfection means the removal or killing of pathogenic microorganisms. Microorganisms are destroyed or deactivated, resulting in termination of growth and reproduction. When microorganisms are not removed from drinking water, drinking water usage will cause people to fall ill (Lenntech, 1998-2009).

Disinfection through inactivation usually involves the use of disinfectants such as chlorine, ozone, chlorine dioxide, or a combination of chlorine and ammonia (chloramines) which can render many pathogenic organisms harmless. Other materials that can act as disinfectants include potassium permanganate, iodine, bromine, ferrate, silver, hydrogen peroxide, and ultraviolet (UV) light (Cohn *et al.*, 1999). Table 2.1 shows a comparison of some major disinfection technologies.

Table (2.1) a comparison of some major disinfection technologies.

Disinfectant	Advantages	Limitations
Chlorine Gas	► Highly effective against most pathogens. ► Provides "residual" Protection required for drinking water. ► Generally the most cost- effective option.	► Byproduct formation (THMs, HAAs1). ► Special operator training needed. ► Not effective against Cryptosporidium.
Sodium hypochlorite	► Same efficacy and residual protection as chlorine gas. ►Fewer training requirements than chlorine gas. ►Fewer regulations than chlorine gas.	► Limited shelf-life. ► Same byproducts as chlorine gas and chlorate. ► Higher chemical costs than chlorine gas. ►Corrosive; requires special handling.
Calcium hypochlorite	►Same effect and residual protection as gas. ► Much more stable than sodium hypochlorite, allowing long-term storage.	► Same byproducts as chlorine gas. ►Higher chemical costs than chlorine gas. ►Fire or explosive hazard if

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	▶ Fewer safety regulations.	handled improperly.
Ozone	▶ Produces no chlorinated THMs, Has Fewer safety regulations. ▶ Effective again Cryptosporidium. ▶ Provides better taste and odor control than chlorination.	▶ More complicated than Chlorine or UV systems. ▶ No residual protection for drinking water. ▶ Hazardous gas requires special handling. ▶ Generally higher cost than chlorine.
UV	▶ No chemical generation storage, or handling. ▶ Effective against Cryptosporidium. ▶ No known byproducts at levels of concern	▶ No residual protection for drinking water. ▶ Less effective in turbid water. ▶ No taste and odor control. ▶ Generally higher cost than chlorine.
Boiling	▶ Readily available. ▶ Well suited for emergency & temporary disinfectant. ▶ Extremely effective disinfectant that will kill Guardia.	▶ Requires a great deal of heat. ▶ Time to bring water to boil & cool before use. ▶ Can give water stale taste. ▶ Required separate storage of treated water.

Source: (ACC,2010)

The inactivation of microbial pathogens through use of disinfectants is essential to protect public health. All disinfectants are by necessity reactive substances and produce by-products. Little is known about the nature and toxicity of the by-products of ozone, chlorine dioxide, or chloramines. A semi-quantitative presentation of risks associated with disinfection was first attempted by Morris (1978) and is given in the figure below. Figures 2.1 shows that, as the level of chlorination is increased, the risk continues to drop slightly but never quite reaches zero, the risk of waterborne infectious disease is very high when no chlorination is used and drops very sharply to a low value when even minimal levels of chlorination are maintained. For no system is perfect. At very high levels of chlorine the microbial risk increases, because taste and odor may cause use of unsafe supplies. The chemical risk does not start at zero, for there may be some hazard connected with the organic matter before chlorination. Because of by-product formation, the chemical risk increases with increasing levels of chlorination. Intuitively, Morris depicted the chemical risk from chlorination as being considerably lower than the microbial risk from a non disinfected supply.

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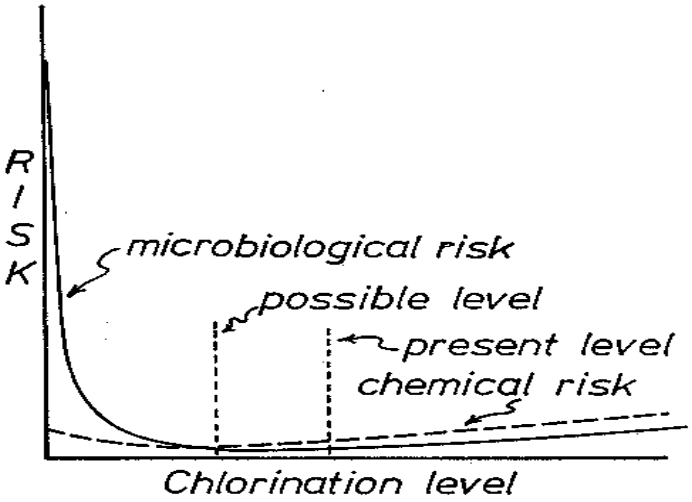

Figure 2.1 Risks and benefits of water chlorination (Morris 1978)

2.2 Considerations for selecting disinfection methods:

There are many consideration for selecting disinfection methods which are:

- ✓ Efficacy against pathogens/ controlling microbial contamination must always be given primary importance. While chlorine is effective against most pathogens, additional treatment steps may be needed where resistant organisms such as Cryptosporidium or Guardia are a concern.
- ✓ Laws and regulations/ Treatment processes and final drinking water quality must meet local standards.
- ✓ Source water quality/ the characteristics of local source water, such as turbidity and organic load, will impact disinfection requirements.
- ✓ Residual protection /only chlorine-based products provide a “residual” level of disinfectant that remains in water to prevent microbial re-growth and help protect treated water during distribution and storage. Therefore, no other disinfection method by itself can protect water all the way to the tap.
- ✓ Local capacity/ sufficient resources, supplies and training must be available to maintain service after treatment technologies are adopted.
- ✓ Safety/all disinfection chemicals require proper storage and handling practices. Safety guidelines are available from national and regional chlorine associations.

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✓ Consumer expectations/ educational efforts may help local communities understand the need for water disinfection , and ensure acceptance of treatment methods.

✓ Affordability / water service and home treatment products must be affordable to consumers (Drinking Water Chlorination, World Chlorine Council position paper 2008).

2.3 Factors that influence water disinfection:

✓ Contact time (CT): Contact time between disinfectant and microorganism and the concentration of disinfectant. When a particular disinfectant is added to water, it does not only react with pathogenic microorganisms, but also with other impurities such as soluble metals, particles of organic matter.

✓ The type of microorganism: Disinfectant can effectively kill pathogenic microorganism (bacteria, viruses & parasites). Some microorganisms can be resistant. E. coli bacteria are more resistant to the disinfectant than other bacteria. Several viruses are even more resistant than E. coli.

✓ The age of the microorganisms: The affectivity of a particular disinfectant also depends on the age of the microorganisms. Young bacteria are easier to kill than older bacteria. When bacteria growth older, they develop a polysaccharide shell over their cell wall, which makes them more resistant to the disinfectant.

✓ Water that requires treatment: the nature of the water that required treating has its influenced on the disinfectant. Turbidity of the water also reduces the affectivity of disinfectant.

✓ Temperature: Increasing the temperature usually increase the speed of reactions of disinfections. Increasing temperature can also decrease disinfection, because the disinfectant falls apart or is volatized.

2.4 Disinfection in Gaza Strip:

In (1996) with launching of (Water and Wastewater Services Improvement Project) (SIP) for Gaza strip financed by the World Bank, the World Bank representative proposed to allocate a budget from the S.I.P. to cover the cost of water disinfection and monitoring the microbiological contamination in the drinking water.

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Accordingly, the operator of the S.I.P, LEKA, started the process of procurement of all chlorination needs which included supply of Sodium hypochlorite, dosing pumps, testing kits and all other accessories and in the same time, a monitoring program for testing points was established with (150) points all over Gaza Strip. Due to the rapid increase in water production with the increase in the population of Gaza, the monitoring program was upgraded and amended, and the monitoring points were increased with produced maps showing the location of the testing points and started the chemical component testing of the municipal wells. In (2005) with the launching of Gaza Emergency Water Project, (GEWP) and with the establishment of the Costal Municipalities Water Utility, (CMWU) the operator (Inframan) modified the residual chlorine monitoring program and produced maps with the GIS showing all monitoring points on the network which were increased to (520) testing points and across matching program was proposed and conducted with the Ministry of health (MOH) to check for residual chlorine and microbiological contamination of the water supply. The amount of delivered chlorine in (2010) reached to(900) tons, bearing in mind that dosing rate designated by (PWA) manages from (0.1-0.2mg/l). The CMWU in Gaza used the Sodium hypochlorite solution to disinfect the water well over all Gaza strip (CMWU, 2012).

2.5 Chlorination:

Chlorination is the best disinfectant which own the properties to remain until after the disinfecting process as it provide certain and continuous protection of drinking water from water source leading to the final consumer (Khalefat *et al.*, 2011). Only chlorine-based disinfectant leaves a beneficial residual level that remains in treated water, helping to protect it during distribution and storage (WCC, 2008). When chlorine is added to water, some of the chlorine reacts first with organic materials and metals in the water and is not available for disinfection (this is called the chlorine demand of the water). The remaining chlorine concentration after the chlorine demand is accounted for is called total chlorine. Total chlorine is further divided into: 1- the amount of chlorine that has reacted with nitrates and is unavailable for disinfection which is called combined chlorine and, 2- the free

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chlorine, which is the chlorine available to inactivate disease-causing organisms, and thus a measure to determine the pot ability of water.

To know the disinfection efficiency and the simplicity of measuring, it is important to understand what happen to chlorine when added into water in relation to other existing chemicals in water. Chlorine gas rapidly hydrolyzes to hypochlorous acid according to:

$Cl2 + H_2O \rightarrow HOCl + H^{+} + Cl^{-}$

Aqueous solutions of sodium or calcium hypochlorite hydrolyze too:

$Ca(OCl)2 + 2H_2O \rightarrow Ca2^{+} + 2HOCl + 2OH^{-}$

$NaOCl + H_2O \rightarrow Na^{+} + HOCl + OH^{-}$

Hypochlorous acid is a weak acid and will disassociate according to:

$HOCl \Leftrightarrow H^{+} + OCl^{-}$

Hypochlorous acid is the most reactive and stronger disinfectant because it is neutral. Hypochlorous acid is able to oxidize microorganisms in seconds while hypochlorite ion can take up to 30 mints for the same effect. The two chemical species formed by chlorine in water, hypochlorous acid (HOCl) and hypochlorite ion (OCl^{-}), are commonly referred to as “free” or “available” chlorine. As free available chlorine residual increases, the previously produced chloramines are oxidized. This results in the creation of oxidized nitrogen compounds such as nitrous oxide, nitrogen and nitrogen trichloride, which in turn reduce the chlorine residuals to the breakpoint.

$2NH3+3Cl2 \rightarrow N2+6HCl$

When all chloramines are oxidized, additional chlorine added creates an unequal residual known as the breakpoint (that limit beyond which all residual is free available chlorine) (Alia, 2007).

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2.6 Break point Chlorination:

Breakpoint chlorination is the name of the process of adding chlorine to water until the chlorine demand has been satisfied. Chlorine demand equals the amount of chlorine used up before free available chlorine residual is produced. Further additions of chlorine will result in chlorine residual that is directly proportional to the amount of chlorine added beyond the breakpoint. Public water supplies normally chlorinate past the breakpoint. When chlorine is initially added to water, the following may happen:

1. If the water contains some iron, manganese, organic matter, and ammonia, the chlorine reacts with these materials and no residual is formed, meaning that no disinfection has taken place, (Zone I).

2. If additional chlorine is added at this point, it will react with the organics and ammonia to form chloramines. The chloramines produce combined chlorine residual. As the chlorine is combined with other substances, it loses some of the disinfection strength. Combined residuals have poor disinfection power and may be the cause of taste and odor problems, (Zone II).

3. With a little more chlorine added, the chloramines and some of the chlororganics are destroyed, (Zone III).

4. With still more chlorine added, a free chlorine residual is formed, free in the sense that it can react quickly, (Zone IV).

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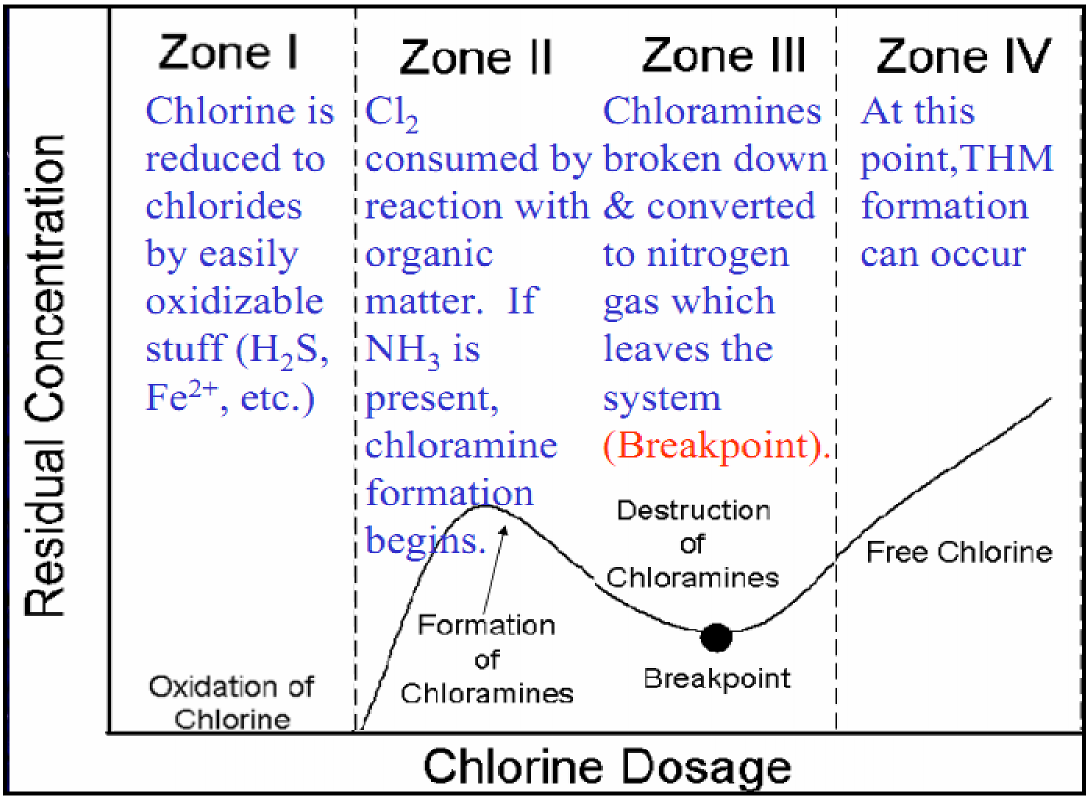

Figure 2.2, Breakpoint chlorination curve (Alia, 2007)

Free available chlorine is the best residual for disinfection. The free available residual forms at the breakpoint; therefore, the process is called breakpoint chlorination. A variety of reactions take place during chlorination. When chlorine is added to a water containing ammonia (NH_3), the ammonia reacts with hypochlorous acid (HOCL) to form monochloramine, dichloramine, and trichloramine. The formation of these chloramines depends on the pH of the water and the initial chlorine-ammonia ratio.

Ammonia + Hypochlorous acid → Chloramines + Water

NH3 + HOC1------------> NH2C1 + H$_2$0 Monochloramine

NH2C1 + HOC1------------ > NHC12 + H$_2$0 Dichloramine

NHC12 + HOC1------------ > NC13 + H$_2$0 Trichloramine

At the pH of most natural water (pH 6.5 to 7.5), monochloramine and dichloramine exist together. At pH levels below 5.5, dichloramine exists by itself. Below pH 4.0, trichloramine is the only compound found. The monochloramine and dichloramine forms have a definite disinfection power. Dichloramine is a more

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effective disinfecting agent than monochloramine. However, dichloramine is not recommended as a disinfectant due to the possibility of the formation of taste and odor compounds. Chlorine reacts with phenol and salicylic acid to form chlorophenol, which has an intense medicinal odor. This reaction is much slower in the presence of monochloramine. (Alia, 2007; Spon, R. 2008 ; Aaron Janzen *et al.*, 2009).

2.7 Chlorination Dosing Procedures:

Liquid chlorine is usually added to water after the initial stages of treatment. A pre-determined chlorine solution is mixed in a chemical storage tank. Chemical injection pumps figure (2.3) continuously pump the chlorine solution into the water through an in-line venture device to mix the pre-treated water. Sufficient contact time is required to allow the chlorine reactions to occur and to ensure that disinfection is achieved. Often small systems will incorporate a chlorine contact tank or possibly retention coils to achieve a desired chlorination contact time (often about 20 to 30 minutes depending on the design). The amount of liquid chlorine solution injected depends on the quantity and quality of water treated and the desired chlorine residual, after a suitable contact time, (K. Ryde, AAFC-PFRA, 2006).

Figure 2.3, Chemical injection pump

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2.8 Disinfection Dosage and Contact Time:

In order to work properly the chlorine must be allowed time to react with the water and the targeted disease-causing organisms. A chlorine dosage must be adequate to exceed the chlorine demand, and leave behind a chlorine residual. Disinfection occurs during the contact time of the chlorine and the targeted organisms. The longer the contact time the more effective the disinfection will be. A pre-determined chlorine concentration, C, is applied to the water for a specified length of contact time, T. The product is referred to as the CT value. The chlorine concentration C is the lowest continual chlorine residual in the treatment process, while the time T is the exposure time for that residual. Disinfection effectiveness is reduced at higher pH levels and lower water temperatures. Therefore, higher CT values are required with higher pH, and/or lower temperature. In other words, chlorination disinfection is more effective at a lower pH (<6) and high temperature (>20°C), (K. Ryde and AAFC-PFRA, 2006).

2.9 Disinfection By-Product (DBP)

Chemical disinfectants may be capable of producing by-products. In quantities that may present long-term health risks to the drinking water consumer. The concentrations of disinfection by-products (DBPs) produced are specific to the type of disinfectant, the chemical make-up of the naturally occurring organic precursors and their concentrations in water prior to chlorine (or other chemical disinfectant) addition, the concentration of the disinfectant in water, and the retention time in the drinking-water system before reaching the consumer’s tap. The DBPs are formed when the disinfectant reacts with natural organic matter (NOM) and/or inorganic substances present in water. More than 250 different types of DBPs have already been identified (Sadiq and Rodriguez, 2004).

In 1974, chloroform, a product of the reaction of chlorine and naturally occurring organic matter, was identified in disinfected drinking water (Bellar *et al.*, 1974; Rook 1974; Symons *et al.*, 1975, 1981; Sadiq and Rodriguez, 2004). Since that time, a number of other chlorinated DBPs have been identified, including trihalomethanes, halogenated acetic acids, halogenated acetonitriles, chloral hydrate, and the chlorinated phenols. Others include chlorinated furanone (MX), halopicrins,

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cyanogen halides, haloketones, and haloaldehydes. The halogenated DBPs identified account for,only a fraction of the total formed.

Another safety consideration for treated drinking water is disinfection byproducts (DBPs),chemical compounds formed unintentionally when chlorine and other disinfectants react with certain organic matter in water. All disinfectants form DBPs, although much more is known about chlorination byproducts than is known about the byproducts of other disinfectants. For example, toxicological studies suggest that some trihalomethanes (THMs) are carcinogenic to laboratory animals, but only at levels many thousands of times greater than those found in drinking water. Research has shown that chloroform (the main type of THM) is unlikely to cause cancer at extremely low levels found in drinking water. While the potential health risks from DBPs are small and uncertain, high levels of these chemicals are certainly undesirable. WHO, 2006 has established guideline values for several DBPs, including trihalomethanes as shown on table 2.2.

Table 2.2, Guideline values for chlorine and trihalomethanes, (WHO 2006)

WHO Guidelines for drinking water quality (2006)	
Chlorine	below 5 milligrams per liter (mg/L) *
Bromodichloromethane	below 0.06 mg/L
Bromoform	below 0.10 mg/L
Chloroform	below 0.20 mg/L
Dibromochloromethane	below 0.10 mg/L
* For effective disinfection, there should be a residual concentration of free chlorine of 0.5 mg/L	

DBP formation can be reduced through cost-effective methods, particularly by reducing the amount of natural organic material in water (through filtration or other means) prior to disinfection. Drinking Water Chlorination, World Chlorine Council position paper, 2008 supports adoption of these methods whenever possible. However, as WHO strongly cautions: *"The health risks from these byproducts at the*

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levels at which they occur in drinking water are extremely small in comparison with the risks associated with inadequate disinfection. Thus, it is important that disinfection not be compromised in attempting to control such byproducts."

It is difficult to accurately estimate population exposures to halogenated organic compounds in drinking water. Exposure to these compounds depends on a number of factors, including the concentration of chlorine, organic matter, pH, contact time, amount of water consumed, rate of volatilization, and inhalation exposures. Ingestion exposures may vary considerably if drinking water is heated before consumption (for tea, coffee, *etc*). For example, boiling water for five minutes eliminates 95% of the total volatile halogenated hydrocarbon fraction, whereas water heating at 70-90°C would eliminate 50-90% of the volatile halogenated compounds (IARC 199l).

2.9.1 Chlorine and its by-products

Chlorine is the most widely used drinking-water disinfectant. When added to water the following reaction occurs within a second or less:

$Cl2 + H2O = HOCl + H+ + Cl-$

The magnitude of the equilibrium hydrolysis constant is such that hydrolysis to hypochlorous acid, HOCl, is virtually complete in fresh water at pH > 4 and at chlorine doses up to 100 mg/litre (Morris, 1982). Hypochlorous acid is a weak acid that dissociates partially in water as follows:

$HOCl = H+ + OCl-$

The value of the acid ionization constant is about 3 x 10-8. As shown in figure 2.4, at 20C and pH 7.5, there is an equal distribution of HOCl and OCl-. At pH 8, about 30% of the free chlorine is present as HOCl, and at pH 6.5, 90% is present as HOCl (Morris, 1982). The term free chlorine refers to the sum of hypochlorous acid and hypochlorite ion. Since HOCl is a considerably more efficient disinfectant than OCl-, and free chlorine, even as hypochlorite, is more effective than combined chlorine, the Guidelines recommend that disinfection be carried out at pH less than 8 and at a free chlorine concentration > 0.5 mg/liter. Of all the disinfectants, the

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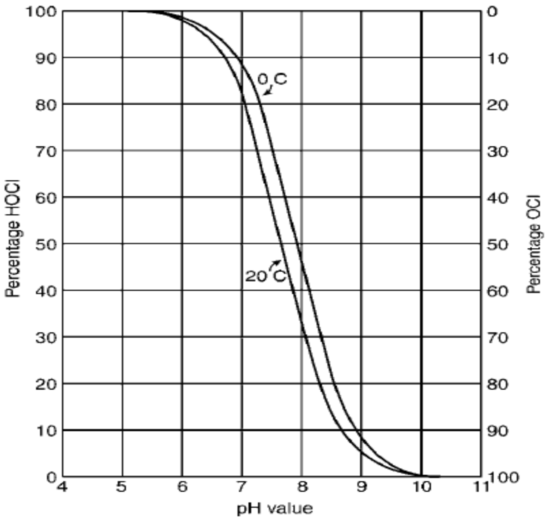
chemistry and toxicity of the reaction by-products of chlorine have been the most extensively studied, WHO1992 .



Figure, 2.4 : Distribution of hypochlorous acid and hypochlorite ion in water at different pH values and temperatures (Morris,1951)

The following chemicals resulting from chlorination of water supplies have been evaluated in the Guidelines:

- free chlorine (HOCl + OCl-)
- trihalomethanes
- chlorinated acetic acids
- halogenated acetonitriles
- chloral hydrate (trichloroacetaldehyde)
- chlorophenols
- MX (3-chloro-4-dichloromethyl-5-hydroxy-2(5H)-furanone).

2.9.2 Chlorine:

Free chlorine in drinking-water is not particularly toxic to humans. The major source of exposure to chlorine is drinking-water. Therefore, the health-based guideline value (GV) of residual chlorine (the sum of hypochlorous acid and hypochlorite ion) was established at 5 mg/l (WHO 1993b). Based on the taste and odor threshold of free chlorine, it is doubtful however that consumers would tolerate such a high level of chlorine. Most individuals are able to taste chlorine at

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concentrations below 5 mg/l, and some at levels as low as 0.3 mg/l. The health-based GV for chlorine should not be interpreted as a desirable level of chlorination.

2.9.3 Trihalomethanes:

Halomethanes are chemical compounds in which a number of hydrogen atoms of methane (CH_4) are replaced by halogen atoms (fluorine (F), chlorine (Cl), bromine (Br) or iodine (I)). Trihalomethanes (THMs) are trisubstituted halomethanes in which three of the four hydrogen atoms of CH_4 are replaced by halogen atoms. THMs are formed by the aqueous chlorination of humic substances, of soluble compounds secreted from algae and of naturally occurring nitrogenous compounds (Morris, 1982). THMs consist primarily of chloroform, bromodichloromethane, dibromochloromethane and bromoform.

Many trihalomethanes find uses in industry as solvents or refrigerants. THMs are also environmental pollutants, and many are considered carcinogenic. Trihalomethanes with all the same halogen atoms are called haloforms (Wikipedia, 2010).

The Palestinian standards for drinking water was published by Palestinian Standards Institution (PSI) in 2005. Table 2.3, shows the MCL of THM, which is much higher than that of the USEPA standards. In addition to table 2.4, shows the Palestinian standard of THM.

Table 2.3, Maximum contaminant level (MCL) of THM (USEPA1998c)

DBP	MCL
total trihalomethanes (TTHM) (measured as the sum concentration of chloroform ($CHCl_3$), bromoform ($CHBr_3$), bromodichloromethane ($CHBrCl_2$), and dibromochloromethane ($CHBr_2Cl$))	80 parts per billion (ppb)

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Table2.4, Palestinian standard of THM, (PSI, 2005)

DBP	MCL
THM	0.25 mg/L = 250 parts per billion (ppb)

Table 2.5, comparison of the PSI standards with United States Environmental Protection Agency (USEPA), World Health Organization(WHO), Jordan Institution for standards and Metrology(JISM), and Egyptian Organization for Standardization and Quality (EOSQ).

Table 2.5 Comparison of the PSI standards with USEPA, WHO, JISM & EOSQ.

	Regulation				
TTHM MCL (mg/L)	PSI, 2005	USEPA, 1998	WHO, 2006	JISM, 2008	EOSQ 1995
	0.25	0.08	<1	0.15	0.1

2.9.4 Factors affecting the formation of DBP in drinking water:

The type and amount of DBPs formed are a function of many factors including chlorine dose and residual concentration, concentration and characteristics of precursors, water temperature, water chemistry (including pH, bromide ion concentration, organic nitrogen concentration, and presence of other reducing agents such as iron and manganese), contact time, pipe material, and pipe age.

1. Chlorine dose and residual concentration:

Halogenated byproducts are formed when free chlorine reacts with natural organic matter. In addition, brominated byproducts are formed when source water containing bromide is chlorinated. Chlorine reacts with natural organic matter in the water to form THMs. As the concentration of chlorine or chloramines increases, the

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production of DBPs increases. Formation reactions continue as long as precursors and disinfectant are present (Krasner, 1999).

2. Concentration and characteristics of precursors:

Total organic carbon (TOC), dissolved organic carbon (DOC) and UV absorption at 254 nm [UV254] are often used as surrogate parameters for monitoring precursor levels. In general, greater DBP levels are formed in waters with higher concentrations of precursors (EPA, 2006).

3. Temperature:

DBP concentrations tend to increase and to form more rapidly with increasing temperature (Clark *et. al.,* 2001). The disinfectant residuals deplete rapidly when the water temperature is high. Also, microbial activity within distribution systems is higher in warm than in cold waters (Sadiq and Rodriguez, 2004).

4. Water chemistry:

Aqueous bromine reactions with NOM are much faster than aqueous chlorine, so the speciation and concentrations of DBP formation in chlorination processes are mainly dominated by the ratio of bromide to reactive NOM as well as the ratio of bromide to chlorine concentrations (Westerhoff *et. al.,* 2004). The rate of THM formation increases with the pH (Stevens *et. al.,* 1976).

5. Time dependency of DBP formation:

The longer the contact times between disinfectant/oxidant and precursors, the greater the amount of DBPs that can be formed. High THM levels usually occur where the water age is the oldest.

6. Pipe material:

The occurrence of DBPs at consumers' taps may be influenced by pipe material; there is an interaction between residual disinfectant and the internal pipe material. One study found that the increased chlorine demand of unlined cast-iron results in lower levels of trihalomethanes than those dictated by testing the finished

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water alone (Brereton and Mavinic, 2002). In contrast, other studies have found that DBPs are increased in iron pipes.

2.10 Waterborne dieses :

Waterborne diseases cause many serious health problems to humans around the world. The problem has more significance to the developing and underdeveloped world, particularly in Africa, Asia and South America. Prevalence of waterborne diseases is related to generally poor and unhealthy sanitary conditions, as well as polluted environmental conditions. Many of the diseases caused by the human consumption of impure water are preventable if proper health and sanitation standards are enforced.

Waterborne diseases are caused by pathogenic microorganisms that most commonly are transmitted in contaminated fresh water. Infection commonly results during bathing, washing, drinking, in the preparation of food, or the consumption of food thus infected. Various forms of waterborne diarrheal disease probably are the most prominent examples, and affect mainly children in developing countries; according to the WHO, such disease account for an estimated 4.1% of the total dally global burden of disease, and cause about 1.8 million human deaths annually. The World Health Organization estimates that 88% of that burden is attributable to unsafe water supply.

Most intestinal (enteric) diseases are infectious and are transmitted through faecal waste. Pathogens – which include virus, bacteria, protozoa, and parasitic worms – are disease-producing agents found in the faces of infected persons. These diseases are more prevalent in areas with poor sanitary conditions. Some common waterborne diseases are:

- **Amebiasis:** caused by protozoa. Symptoms include fatigue, diarrhea, flatulence, abdominal discomfort and weight loss.
- **Campylobacteriosis:** caused by bacteria. Symptoms include diarrhea, abdominal pain and fever.
- **Cholera:** caused by bacteria. Symptoms include muscle cramps, vomiting and diarrhea.

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- **Cryptosporidiosis:** caused by protozoa. Symptoms include diarrhea and abdominal discomfort.
- **Giardiasis:** caused by protozoa. Symptoms include diarrhea and abdominal discomfort.
- **Hepatitis:** caused by a virus. Symptoms include fever, chills, jaundice, dark urine and abdominal discomfort.
- **Shigellosis**: caused by bacteria. Symptoms include bloody stool, diarrhea and fever.
- **Typhoid fever:** caused by bacteria. Symptoms include fever, headache, constipation, diarrhea, nausea, vomiting, loss of appetite and an abdominal rash.
- **Viral Gastroenteritis:** caused by a virus. Symptoms include gastrointestinal discomfort, diarrhea, vomiting, fever and headache. (http://www.who.int/water_sanitation_health/diseases/diseasefact/en/index.html).

2.10.1 Classification of water related diseases in Palestine:

Water borne diseases are diseases spread through contaminated water. Contamination of water may be direct (point source pollution), such as an aquifer recharging with poor quality wastewater effluent. Indirect point source contamination comes from wastewater reuse in agriculture or seepage from networks or open systems. Though many diseases are spread either directly through flies or fishes, all diseases that spread through water are termed as water born diseases. Most enteric diseases are infectious and get transmitted orally through water. We can divide the common water borne diseases in Gaza as follows, (Alfarra Amani and Lubad Sami 2006):

1- Acute diseases: These have effects which occur within hours or days of the time that a person consumes contaminated water. People can suffer acute health effects if they are exposed to extraordinarily high level, as in the case of a sewage spill. In drinking water parasites, bacteria and viruses are the greatest contaminates that cause acute health effects. Though acute contaminants do not have permanent effects, when high level occur, they can make people seriously ill and can be dangerous for persons whose immune system are already weak due to HIV/AIDS.

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2- Chronic diseases : These have a strong effect after people consume contaminated water at levels over safety standards for many years, mainly from disinfectant by-products, pesticides and solvents. Chemicals accumulation in human body can cause chronic diseases like cancer, liver closes, renal failure, kidney problems and reproductive difficulties. As a result of consuming bad quality water in Gaza Strip for several years, huge numbers of cancer cases are registered in hospitals. Additionally kidney problems, renal failure and reproductive problems have become more common.

3- Infectious diseases: Water borne infectious diseases are diseases caused by a number of different bacteria, viruses and protozoa, which spread through contaminated drinking water. These take the form of diarrheas, dysenteries, salmoellosis, hepatitis, guardian, and amoeba histolytic.

The most common symptoms in Gaza of these diseases include nausea, vomiting and bloody diarrhea with or without fever (Alfarra Amani and Lubad Sami 2006).

2.11 Hydraulic Simulation Software

2.11.1 Introduction:

Prior to computerization, time-consuming , distance from the well according to the flow direction manual calculations were required to solve networks for pressure and flow distribution. These calculations were carried out using the Hardy-Cross numerical method of analysis for determinate networks. Only simple pipelines systems consisting of a few loops were modeled and under limited conditions because of the laborious effort required to obtain a solution. The use of interactive on-screen graphics to enter and edit network data and to color code and display network maps, attributes, and analysis results has become commonplace in the water industry. This makes it much easier for the engineer to construct, calibrate, and manipulate the model and visualize what is happening in the network under various situations, such as noncompliance with system performance criteria,(AWWA, 2000). There is an abundance of network modeling software in the marketplace today. Some are free and others can be purchased at a nominal cost. Costs can vary significantly

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between models, depending on the range of features and capabilities provided; some of these programs are listed in Table (2.6).

Table 2.6 Names and Vendors of Hydraulic Simulation Software.

Software	Vendor	Country
AQUA	Computer Modeling, Inc.	USA
AVWATER	CEDRA	USA
BOSS EMS	BOSS International	USA
WATERCAD	Haestad Methods, Inc.	USA
EPANET	US EPA	USA
FAAST	Faast Software	USA
FLOW	Kelix Software Systems	USA
PICCOLO	SAFEGE Consulting Engineers.	FRANCE
RINCAD	CEDEGER	CANADA
SDP	Charles Howard & Assoc. Ltd.	CANADA
TDHNET	TDH Engineering	USA
WATNET	WRc	USA

Source: AWWA, (2000).

2.11.2 WaterCAD

Definition:

WaterCAD is powerful, easy to use program that helps civil engineers design and analyze water distribution. Water utility managers also use it as a tool for the efficient operation systems. WaterCAD provides intuitive access to the tools that is needed to model complex hydraulic situations, analyzes water quality, determines fire flow requirements, calibrate large distribution network. WaterCAD is a

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sophisticated tool that enables engineers and decision–makers to analyze and manage distribution network with unprecedented accuracy and efficiency.

Capabilities

- Perform steady –state, extended – period, and water quality simulation.
- Analyze multiple time – variable demands at any junction node.
- Model flow control valves, pressure reducing valves, pressure sustaining valves, pressure breaking valves, and throttle control valves.
- Model cylindrical and non- cylindrical tanks and constant hydraulic grade source nodes.
- Determine water source and age at any element in the system.
- Estimate construction costs.
- Simulate the operating of constant cycles of constant or variable speed pumps.

2.11.3 Conclusion:

The most available software in Gaza Strip is Epanet and WaterCAD, but WaterCAD was chosen because:

1. WaterCAD can do more than one scenario in one file and more than one alternative in the same scenario, while Epanet can do one scenario in one file.
2. WaterCAD has "undo" facility while Epanet don’t have this facility.

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3. STUDY AREA AND METHODOLOGY

3.1 Location of the study area

The village of Um Al-Nasser is located at the northern part of Gaza Strip bounded by Bit Lahia city from south and west and Bit hanoon from east and the Palestinian occupied land from north. The coordinates of Um Al Nasser village is 31°34 '50" north, 33 ° 31' 31" east and its rise about 38 m above mean sea level. The town is established in 1998 on a residential flat is about 800 dunums. The village established in the wake of the decision of the Palestinian Ministry of Housing building in Sheikh Zayed City, in the slaughterhouse north-south of Bit Lahiya. For the purpose of establishing the city on the ground which was inhabited by the families of Palestinian Bedouin, have been transferred from the area of residence, and housing near the water treatment plant sanitation (the village of Um Al-Nasser now). Figure 3.1 shows an aerial photo of Um Al Nasser village, Um Al Nasser municipality, 2013.

Figure 3.1, Aerial photo of Um Al Nasser village.

Source: Google earth,2010

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3.2 Population :

Gaza Strip is considered one of the most overpopulated areas all over the world. As it was stated, the area of Gaza Strip is about 365 km ^{2} with a population of 1,480,000 inhabitants (PCBS, 2007). The growth rate in Gaza strip is 3.37% according to Palestinian bureau of statistics (PCBS, 2013) council which means that the Gaza Strip population in 2011 reached 1,590,000 inhabitants. According to PCBS 2013, the population of Um Al Nasser village from 2007 to 2016 is shown in figure 3.2 bellow.

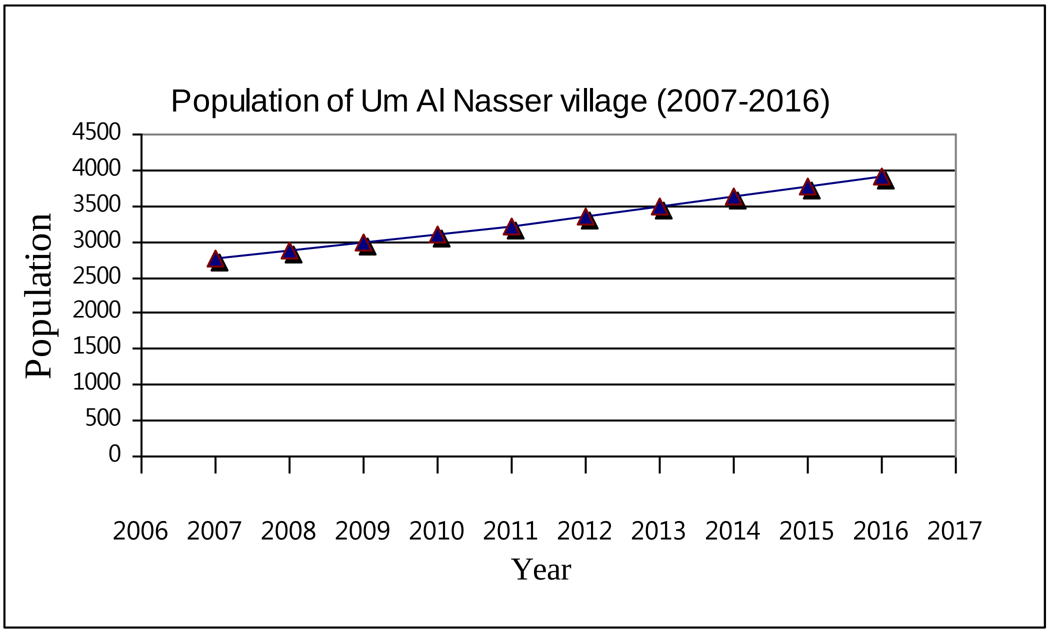

Figure 3.2, Population of Um Al Nasser village PCBS, 2013.

3.3 Climate and Rainfall:

Gaza Strip is located in the transitional zone between the arid desert climate of the Sinai Peninsula and the temperate and the semi-humid Mediterranean climate along the coast. The average daily mean temperature range from 25º C in summer to 13º C in winter. The annual average wind speed is 19 knots with highest wind speed is in winter that reaches 60 knots. The prevailing wind is from the southwest (MOPIC-1997). The average annual rainfall varies from 450 mm/year in the north to 200 mm/year in the south. Most of the rainfall occurs in the period from October to March, the rest of the year being dry (PHG, 2002). Um Al-Nasser village has average

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yearly rainfall more than 350 mm, where the rainfall intensity decrease from the north to the south of Gaza Strip. Therefore, Um Al-Nasser village is relatively receiving more rainwater than other location within the entire area of Gaza Strip.

3.4 Land use :

Um al-Nasser area was divided into a variety of geographic areas and adopted these divisions according to the structural plan which located in the municipality with total area of 800 dunums as shown on figure 3.3 below.

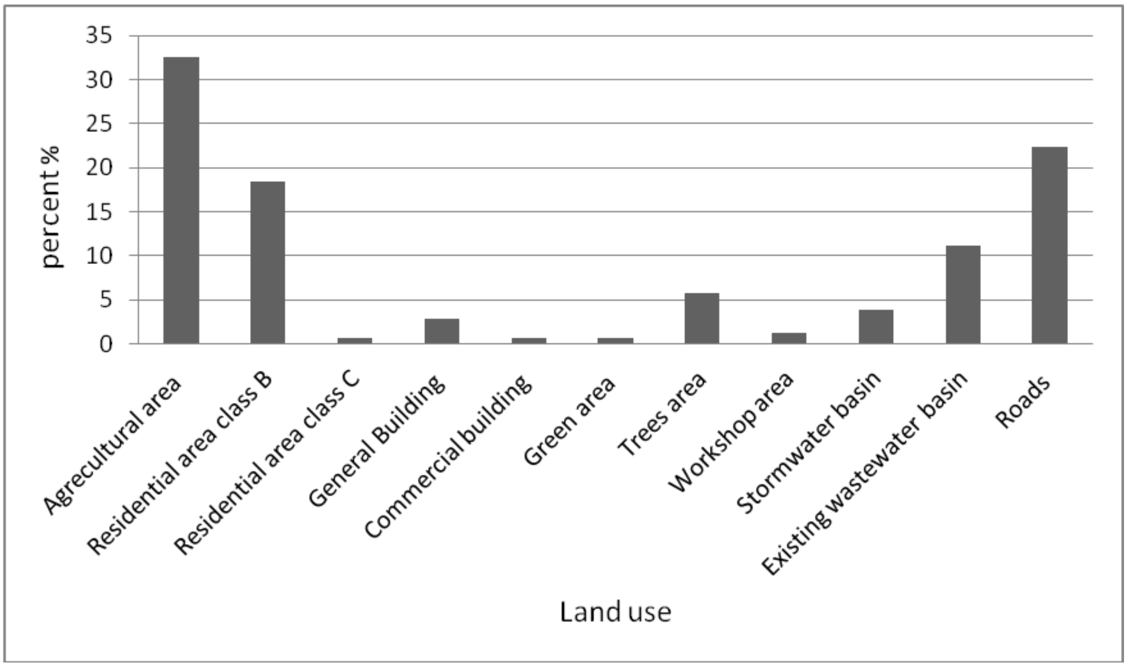

Figure 3.3 Um Al Nasser village land use, Um Al Nasser municipality, 2013.

3.5 Economic and social conditions in the village :

The village of Um Al-Nasser (the Bedouin village) has poor living conditions, as a result of its location close to the water treatment plant, increasing the suffering of the inhabitants of the degradation, Economic and social conditions, and the deterioration of the security situation. It is worth mentioning that most of the population of Bedouin village livelihoods depend on herding, collecting firewood and timber from forest areas adjacent to the village. The villagers cannot dispense with the practice of the profession to collect firewood and timber from areas adjacent to their village, where they use in their homes for cooking, heating water and heating. It also put the population of the village to the many of the confiscation of means of

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subsistence and livelihood a flock of sheep, as well as the exposure of its population to the deprivation of freedom mobility and movement because of the shelling and firing in the direction of the village, especially during the periods of the night. The village of Um Al-Nasser suffer from the dire economic situation, due to lack of employment opportunities, where the unemployment spread between the men of the village, since a long time, as a result of the closure imposed by the continuing Israeli occupation authorities on the Gaza Strip. This reflected a negative impact on the economic situation of residents of the village, where more than 80% of the workforce employed in Israel to work. Because of the continued closure, the worker have lost their jobs there, and moved to the Gaza unemployed. As a result of lack of income for the majority of village residents who are unable to work, due to high unemployment in their ranks, exposure of its population to serious problems. It has become the villagers suffer from in order to get their daily bread, and living expenses daily necessities such as educational, health and otherwise, Abu Luli and Ashour, 2001 .

3.6 Infrastructure Condition:

Um Al Nasser village suffering from poorly presence of many infrastructure projects, especially rehabilitation of the drinking water network and desalination plant. In addition the village suffering from the poor conditions of roads leading to it or the internal roads, where it is un paved and dirt. Also the village suffer from the lacks of many institutions work which offer the necessary service like schools, kindergartens, rehabilitation centers and voluntary organizations. According to Um Al Nasser municipality, the village has a wastewater network with length 4.44 Km and cover 80% from the village area . In addition the water network covers 90% from the village area with total length 10.24 km.

3.7 Wastewater treatment plant in Bait Lahiya.

The existing Beit Lahia wastewater treatment plant is located some 1.5 km east of the town of Beit Lahia in the northern part of Gaza. It was constructed in stages, commencing in 1976 during the Israeli occupation, and modifications were made in 1996 as a result of increased sewage inflow. The plant serves the town of Jabalia, as well as nearby refugee camps and the municipalities of Beit Lahia and

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Beit Hanun. The area's total population amounts of 250,000 people. The plant has no pre-treatment facilitates and has a designed peak flow capacity of 5,000 m3 per day. At present, about 12,000 m3 per day passes through the plant (UNICEF, 2007). The major aim of the plant was to produce effluent of a quality suitable for direct use in irrigation. However, as a result of the poor quality of the treated wastewater, which is far below the World Health Organization guidelines for use in agriculture, plans for transporting treated wastewater to agricultural areas were never completed. The plant is located in a closed depression without a natural outlet to the sea, although the distance to the sea is only 4.5km. The original design of the wastewater treatment plant included 4 original effluent ponds that would recharge the aquifer or evaporate. However as time passed and the volume of effluent increased, the effluent overflow has formed a lake covering 40 hectares, which has become a significant pollutant of the aquifer and a major environmental health problem for the population surrounding the lake. Given the seriousness of the border area prone to the bombing of the Israeli population and the refusal of Um Al Nasser people to locate the basin in the lower area, north of the village. As a result the basin built on the high area, north- east of the Bedouin village . As a result, 14 groundwater wells are no longer being used. The water level in this lake continues to rise and is threatening to overflow the whole sewerage system and its neighboring communities at Northern Gaza governorate. Flooding has already occurred on 2 occasions in 1989 and 1992, when sand barriers collapsed under the pressure of the foul water (UNICEF, 2007).

3.8 Methodology:

To achieve the desired objectives, the following methodology has been conducted:

3.8.1 Data collection phase :

The necessary information required by the research have been collected from the relevant institutions such as Um Al Nasser municipality, MOH, CMWU, PCBS and El Machharawy office for surveying or have been carried out by the researcher to make the modeling of the system, the following data have been needed:

1. Maps with layout of the existing distribution system.
2. Contour maps to determine the elevations of the consumption nodes.

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3. Sources of water and available quantities of potable water and it's elevation.
4. Demand patterns for domestic consumption.
5. Commercial, industrial, public consumption.
6. Population figures to estimate the consumption at the nodes.
7. Pump definition and pump curve.

3.8.2 Measurements :

The current research is a part of long term monitoring project supervised by CMWU and the local municipalities. The researcher selected a marginal area for his study of nearly 6 month during 2010,2011,2012 and 2013 to grantee the two important season of the year. Figure 3.4 showed the water distribution network of Um Al Nasser municipality. The distribution network consists of about 16.29 km of water pipes ranging in diameter from 2" to 6" covering 90% of the village. There are 9 testing point on the network from CT1 to CT9 to measure the residual or total chlorine which are distributed along the network. Residual or total chlorine was measured one time per month at each testing point so there are 9 value of the residual chlorine measured on Um Al Nasser water supply distribution network each month. As a general guide of WHO,2004 recommends that one sample per 1000 persons served should be examined each month for supplies serving up to 100000 persons. According to this recommendation, the number of sample of residual chlorine are sufficient, representative points throughout the network and taken at regular intervals throughout the month. Digital colorimeters are the most accurate methods to measure free chlorine and/or total chlorine residual in the field. The colorimeters 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 determine and display the color intensity (the free or total chlorine) digitally .

The range of the meters is generally 0-4mg/L, which equivalent to 0-4 ppm. DPD tablets and powders are company specific, and that using one company’s test kit with another company’s DPD tablets is not recommended. In order to survey the

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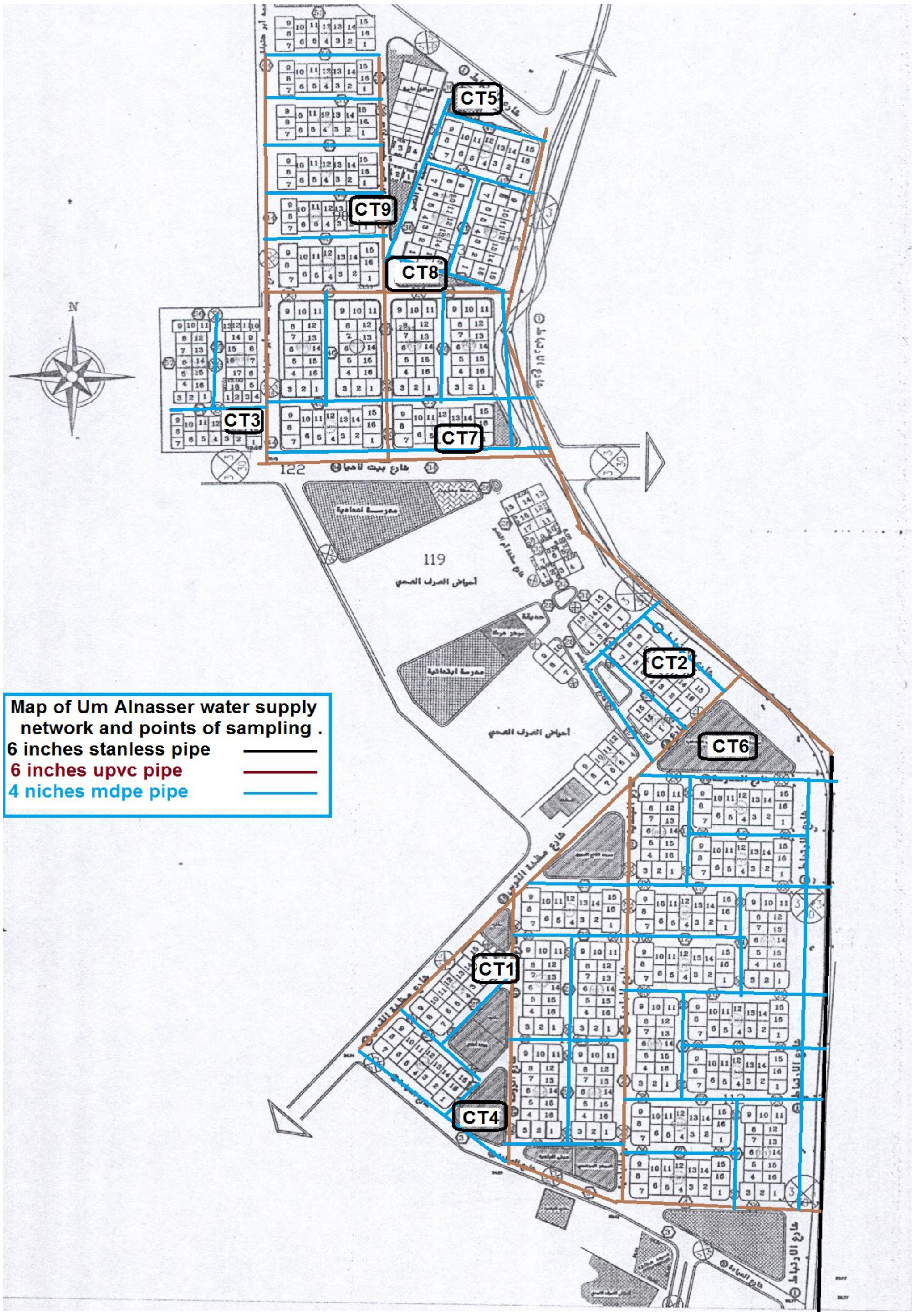
efficiency of water disinfection and quality of the delivery system 9 water sample from 9 sits of the water supply system of Um Al Nasser were analyzed for free chlorine.



Figure(3.4) Um Al Nasser Water Distribution system, Um Al Nasser municabilty,2013 .

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3.8.3 Modeling Um Al Nasser water supply distribution system .

The existing water supply network has been modeled using a computer program (WaterCad) as in reality (intermittent water system) depending on the existing situation of operating the different parts of the network.

3.8.4 Assumptions of the study

In modeling Um Al Nasser water supply system as intermittent supply system, the following assumptions have been taken into consideration:

1. The demand for each node of consumption was calculated as follows:

   Demand for each junction = number of residence X water consumption per capita per day.

2. Taking into account that, this amount of water is to be pumped in different periods of time for different zones – In Um Al Nasser municipality two zones. A study the way of operation, water reach each zone about four hours so when we want to convert from m^3 /day to m^3/ hr we divided by 4 only.

3. The demand of water for all uses was assumed to be (150L/c/d) as recommended by the water department at Um Al Nasser municipality.

4. The agriculture and commercial consumption of water can be neglected, since its very small value as recommended of the water department at Um Al Nasser municipality.

5. In this model, the pipes of diameters 2” and above were considered to limit the length of the network, and due to the difficulty for distinguishing small pipes and their demands .

6. The population figures, which have been adopted in this model, depend on calculating the density of population (person/ km) and the area for each joint, the area for each joint can be calculated be WaterCad and AutoCad programs as shown in table (1) in appendix I.

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7. When calculating the density of Um Al Nasser population, the area of sewage lagoons (which represent 25% from the total area) is neglected.

3.8.5 Data analysis

Data were computer analyzed using Microsoft Excel Program to show the relationship between months, distance, chlorine concentration and the percent of the sampling point which agree WHO. Some of data were statistically analyzed using the SPSS statistical software program to show a significance of effects of water borne diseases and residual chlorine.

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4. RESULT AND DISSCUSION

4.1 Introduction:

This chapter is aiming at describing the water distribution system in Um Al Nasser village area, model results, chlorination efficiency in summer and winter season, in addition to chlorination attenuation in water supply system. Furthermore, the relation between water born diseases and chlorine concentration in the network.

4.2 Um Al Nasser water distribution system

4.2.1 The Village Well (Um Al Nasser well no. A210):

Created the first water system in the village in the year 2000, where the village was supplied with potable water from water wells in particular is located in the north end of the village soon discovered that the well is contaminated with wastewater, since the well was located in the area of leakage of underground water aquifer where tests appear water well is contaminated, it was subsequently shutdown the well, and importing water from the town of Bait Lahiya. So the water sources of the village of Um Al-Nasser is one ground aquifer well (Um AL Nasser water well, well number A210), with elevation 63.15m above mean sea level. The safe yield of Um Al Nasser well is said to be approximately 115m^3/hr, with 87 m head. The pump in the pumping station of Um Al Nasser well is a vertical turbine closed impeller pump, figure (1) in appendix II, shows the pump catalogs and information. The chlorine is added directly into the system through a chemical injection pump continuously pump the chlorine solution into the water through an in-line venture device to mix the pre-treated water.

4.2.2 Water Supply Distribution System:

Water supply in Um Al Nasser village is based mainly on abstracted groundwater by water wells. The supply scheme in the area is considered intermittent supply scheme managed by complicated valve control system. In 2003, was completed second phase of the drinking water network, covering the whole village. A basic features of the network are transmission line, distribution mains, service lines, valves and house connections. The existing system consists of a variety of

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pipe types: UPV, Steel and High Density Polyethylene (HDPE) pipes, and there is a variety in pipe ages.

According to water department information, there are approximately 10 valves installed on the network, the diameters are between DN 110 mm up to DN 160 mm. Important valves are normally installed in manholes. About 50% of the valves are daily opened and closed. The average depth of valves in underground manholes is 0.8 to one meter. There are no pressure regulating devices in the distribution system, although the variation of altitude is large (between 65m.a.s.l and 32m.a.s.l).

4.2.3 Water network operation zones:

Water supply in Um Al Nasser Municipality is an intermittent water supply especially on summer and that due to insufficient water quantity, insufficient electricity fuel shortage and continues increasing of demand. The operation system is controlled manually by opining/closing valves in the transmission line, water distribution cycle is completed every 24 hour. Water network in Um Al Nasser is composed of two operation zone as the following: first Bedouin village and second Bedouin village, water reach each village about four hour per day.

4.2.4 Um Al Nasser water supply network model:

Table (4.1) shows the amount of water supply and water demand during several years. The total amount of water pumped to the water distribution system are 189300 m^3 in year 2010, 183910 m^3 in 2011, 184890 m^3 in 2012 and 195080 in years 2013 up to October. It's clear that each person share 155 L/C/day, which is nearly closed to the assumed value of demand of water at joints on the model. Water demand in the table (4.1) is a result of multiplied the water demand (L/C/day) by the number of population of each year, which is increasing each year due to the increasing of the population number. By analyzing data, we can get the efficiency of water network during 2013 only which is equal 72.3%, which is a good value comparing with other region and this can be explained as the pipes and other fittings are new and in a good state, in addition to their aren't enough agricultural area on Um Al Nasser village. The rate of unaccounted for water during 2013 is equal 27.7%, (

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Um Al Nasser municablity,2013). The modeling of Um Al Nasser water distribution system as an intermittent supply systems depends on some facts about the actual behavior of the Um Al Nasser water supply system under these conditions of providing water for consumers, taking into consideration some theoretical assumptions about the intermittent water systems. The modeling of the system as an intermittent system shows a normal service values of pressure up to 4 bar.

Table (4.1), Water supply & water demand, for Um Al Nasser village.

Year	**Water Supply (m^3/year)**	**Water Demand (m^3/year)**
2010	189300	167400
2011	183910	175500
2012	184890	183600
2013	195080	189000
2014	-	194400
2015	-	202500
2016	-	210600
2017	-	216540
2018	-	224100
2019	-	232200
2020	-	240300

Source: Water department, Um Al Nasser Municipality, 2013.

The highest value of pressure was recorded at the node (J155) with a value of 4.18 bar as shown in table (2) in appendix I. This point of demand located below Um Al Nasser water source, with a high difference of level up to (30 m). On the other hand, the smallest value of pressure was record at node (J64) with value of 1.45 bar, which agree with the existing situation where the people don't use a small pump to rising water to their tanks. When an evaluation between the pressure values at the nodes, it is noticeable that the decreasing of pressure at the nodes far away from the source of supplying water is more obvious than for those nodes nearest to the

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sources, also the range of difference between the maximum and minimum values of pressures at the nodes far away from the sources is not too large. Also the range of difference between the maximum and minimum values of pressure at nodes nearest to the sources is small in comparison to the difference for the farthest nodes.

The change setting valves in the distribution system to provide the needed amounts of water to the consumers affects the values of pressure in the system, and the closing valves cause increasing the pressure in the system. For the parts of the system that are located far away from the sources, it is clearly obvious that they are suffering from low-pressure values. This emphasizes the hypothesis, which state that there is a wide range of variations in pressure values in the intermittent system. The normal pressure values in residential areas ranges between 1.5 - 3.0 bars. This means that approximately all pressure value in all joints are normal pressure. The negative sign of discharges as shown in tables (3) in appendix I is an indication to the wrong in assuming direction of flow through pipes in the distribution system. The intermittent model shows low values of velocities, the largest registered velocity is 2.59 m/s at pipe (P-87). About 18.5% of the velocity on the pipe satisfy the normal velocity values in residential areas ranges between 0.6 – 2 m/s, that have to be avoided in order to avoid stagnation and water quality problems in the water and to prevent erosion on pipes. As a result of modeling Um Al Nasser water distribution system, table (4.2) shows each testing point with amount of flow and velocity in the pipe that the testing point closed to it. It's noticed that as we go away from water source the amount of flow increasing depending on the amount of demand. CT6 and CT7, have a large amount of flow where they are laying onto 4" diameter pipe which make it as a distributer to the smallest pipe diameter.

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Table (4.2) Testing point with distance, flow and velocity.

Testing Point	Distance from source (m)	Velocity (m/sec)	Flow (m^3/hr)	Pipe diameter (inch)
CT 4	1290	0.10	0.58	2"
CT 1	1400	0.13	0.72	2"
CT 6	1440	0.54	15.86	4"
CT2	1560	0.01	0.90	2"
CT 7	1840	0.50	14.57	4"
CT3	2100	0.01	0.19	4"
CT 8	2110	0.04	0.25	2"
CT 9	2180	0.04	0.25	2"
CT 5	2250	0.08	2.44	2"

4.3 The relationship between the decreasing of residual chlorine and months during winter and summer.

The study have some records of Um Al Nasser chlorine residuals and total chlorine for four years ago from January, 2010 to August, 2013 in water supply system in the village. The study concentrate on the two main seasons summer and winter as show in the tables (4.3&4.4).

Table (4.3) residual chlorine during winter seasons from 2010 to 2013.

Year	2010			2011			2012			2013		Average	Std. deviation
Month	Dec	Jan	Feb	Dec	Jan	Feb	Dec	Jan	Feb	Jan	Feb		
CT .1	0.14	0.09	0.10	0.22	0.12	0.15	0.29	0.20	0.12	0.22	0.18	0.17	0.06
CT .2	0.16	0.12	0.10	0.13	0.14	0.09	0.28	0.20	0.22	0.25	0.14	0.17	0.06
CT .3	0.14	0.18	0.13	0.16	0.19	0.13	0.25	0.18	0.18	0.32	0.11	0.18	0.06
CT .4	0.16	0.08	0.11	0.22	0.18	0.13	0.32	0.15	0.21	0.23	0.11	0.17	0.07
CT .5	0.16	0.11	0.10	0.16	0.17	0.12	0.2	0.20	0.16	0.29	0.13	0.16	0.05
CT .6	0.14	0.14	0.15	0.18	0.14	0.09	0.25	0.24	0.20	0.28	0.10	0.17	0.06
CT .7	0.17	0.11	0.13	0.19	0.11	0.16	0.25	0.23	0.20	0.27	0.11	0.18	0.06
CT .8	0.16	0.14	0.08	0.17	0.19	0.11	0.35	0.17	0.13	0.27	0.13	0.17	0.08
CT .9	0.17	0.09	0.11	0.17	0.18	0.16	0.3	0.22	0.21	0.30	0.12	0.18	0.07

Source: Um Al Nasser municipality, 2013

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Table (4.4), Residual chlorine during Summer seasons from 2010 to 2013.

Year	2010			2011			2012			2013			Average	Std deviation
Month	Jun	July	Aug	Jun	July	Aug	Jun	July	Aug	Jun	July	Aug		
CT .1	0.22	0.16	0.17	0.20	0.18	0.10	0.13	0.6	0.33	0.24	0.22	0.26	0.23	0.13
CT .2	0.21	0.25	0.29	0.20	0.2	0.23	0.31	0.57	0.44	0.21	0.19	0.17	0.27	0.12
CT .3	0.25	0.20	0.12	0.13	0.18	0.13	0.26	0.51	0.27	0.28	0.24	0.18	0.23	0.11
CT .4	0.19	0.17	0.15	0.15	0.18	0.09	0.33	0.45	0.4	0.32	0.28	0.25	0.25	0.11
CT .5	0.18	0.18	0.16	0.16	0.20	0.12	0.28	0.63	0.25	0.23	0.2	0.17	0.23	0.13
CT .6	0.20	0.21	0.17	0.15	0.16	0.22	0.23	0.58	0.37	0.35	0.31	0.35	0.28	0.12
CT .7	0.13	0.22	0.13	0.23	0.20	0.12	0.21	0.5	0.32	0.28	0.26	0.32	0.24	0.11
CT .8	0.21	0.20	0.09	0.14	0.18	0.22	0.32	0.43	0.43	0.29	0.31	0.28	0.26	0.11
CT .9	0.16	0.21	0.18	0.18	0.14	0.20	0.23	0.64	0.3	0.32	0.3	0.29	0.26	0.13

Source: Um Al Nasser municipality, 2013

Tables showing the chlorine test for 9 points in Um Al Nasser village area during the main month of summer and winter on the studying period, Figures below (4.1, 4.2, 4.3 and 4.4) showing the monthly average during the studying period. Figures (2 to 17) in appendix II, shows the regionally average during summer and winter season.

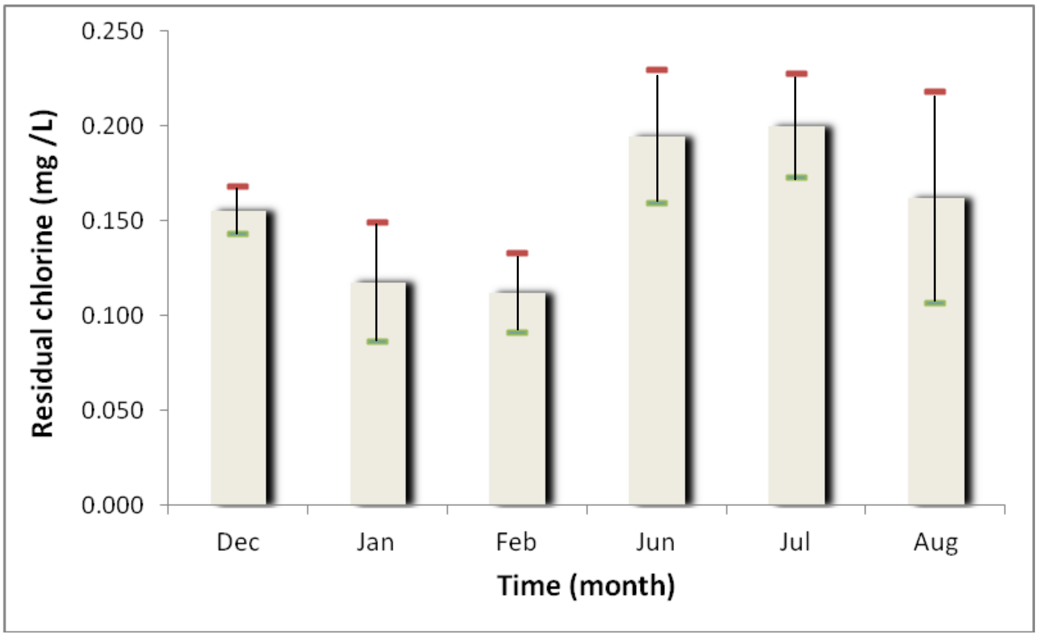

Figure (4.1) Monthly average for residual chlorine in winter & summer seasons during 2010.

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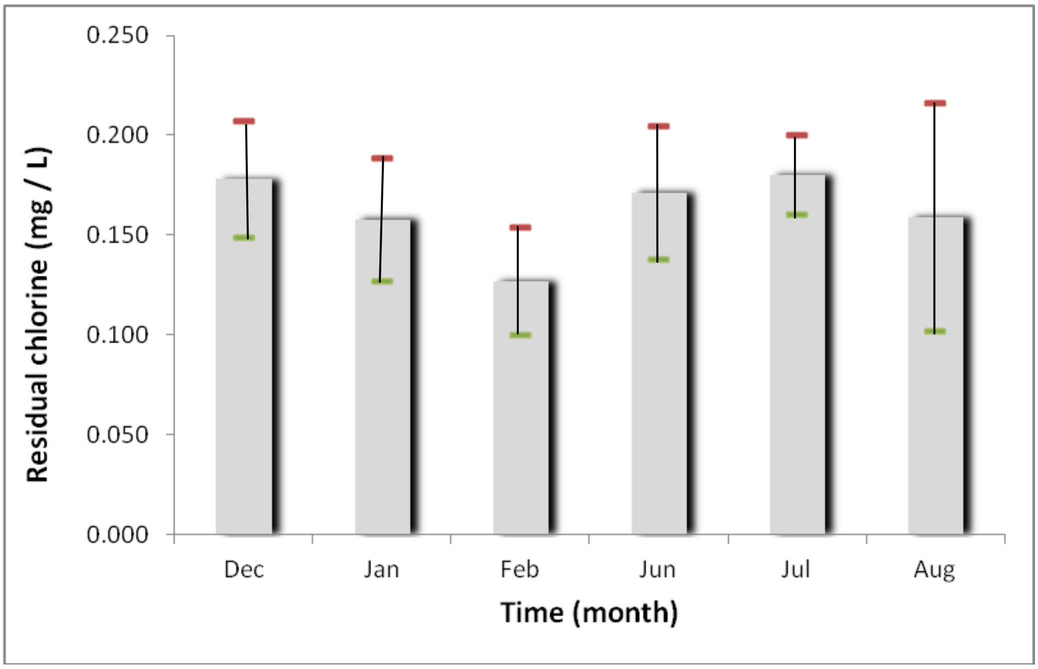

Figure (4.2) Monthly average for residual chlorine in winter & summer seasons during 2011.

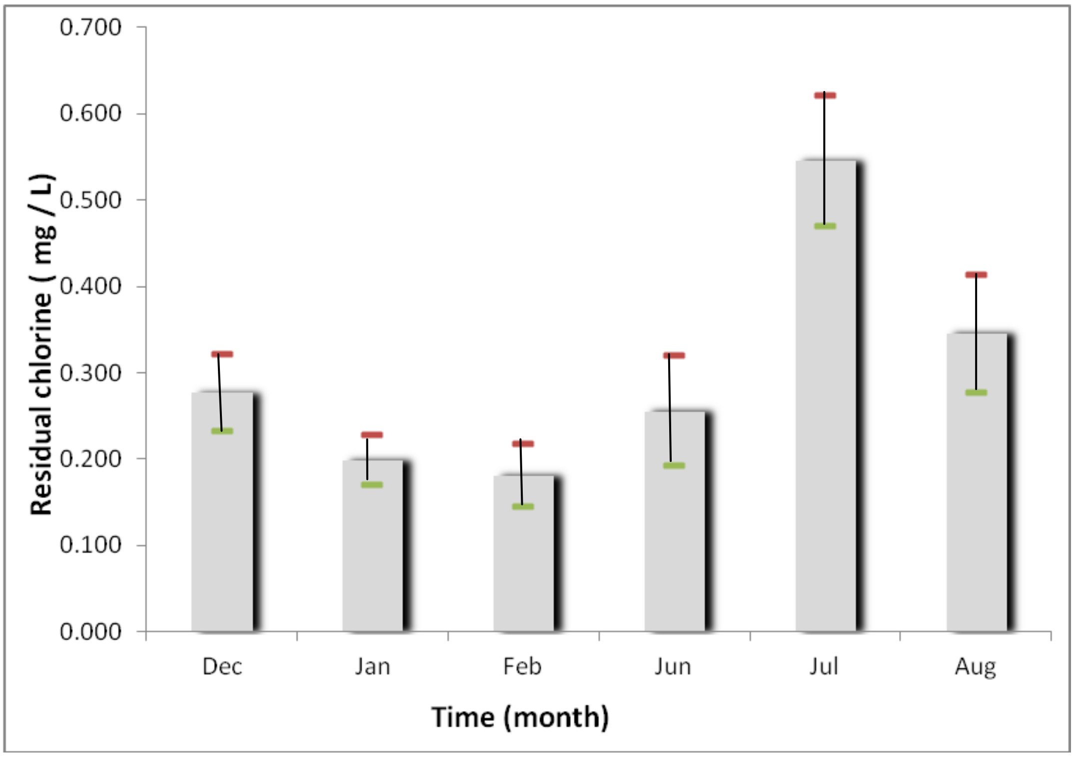

Figure (4.3) Monthly average for residual chlorine in winter & summer seasons during 2012.

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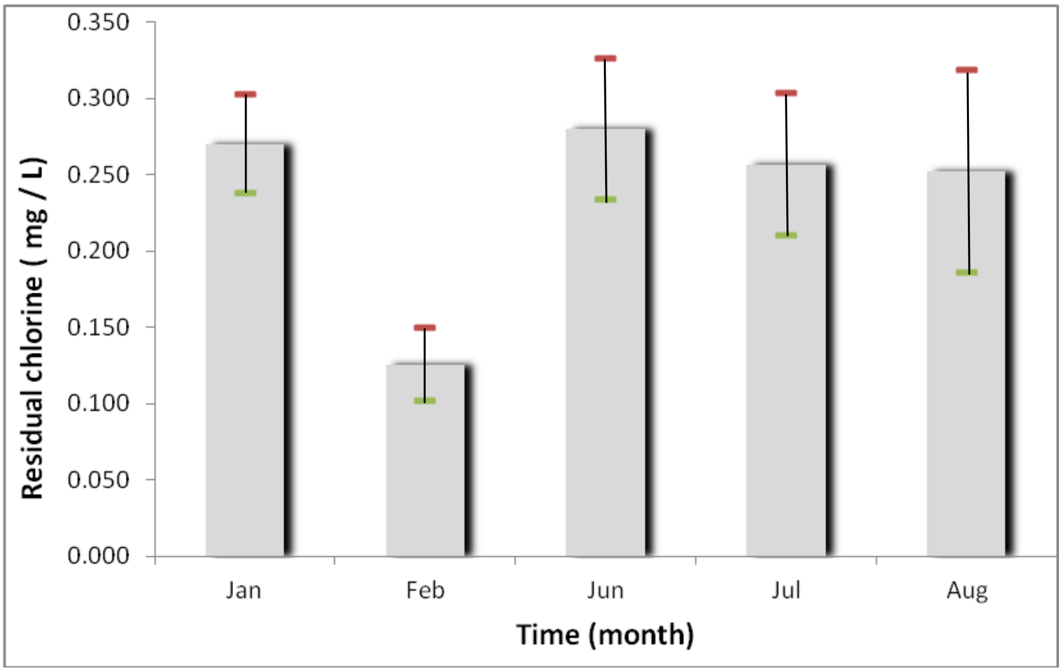

Figure (4.4) Monthly average for residual chlorine in winter & summer seasons during 2013.

As shown in the above tables and figures, the selective residual chlorine samples were collected from fixed sampling points in the network representing the whole entire area of Um Al Nasser. The highest monthly average residual chlorine was 0.55 mg/L in July 2012 and the lowest monthly average was 0.11 mg/L in February 2010, while July 2012 has a great Variance 0.006 and a standard deviation was 0.076 due to the highest dose of chlorine which was pumped during the same month in the well. The variation in average is high in various months from Jan 2010 to Aug 2013 in all sampling location of Um Al Nasser water distribution network. It's noticeable that, the residual chlorine are considerable high in two month, July 2012 and Aug 2012. It is noticed that the average amount of residual chlorine in July 2012 was 0.546 mg/ L that was the larger than July 2010 (0.20 mg / L), July 2011(0.18 mg/ L) and July 2013 (0.26 mg / L). The average amount of residual chlorine in Feb 2010 (0.112 mg/L) was less than the average amount of the same month in the year 2011 as it was (0.127 mg / L), 2012 as it was (0.181 mg / L) and 2013 as it was (0.126 mg / L). This violates the principles of the amount of residual chlorine at the same point during a period of time. It's shown that from the monthly average residual chlorine during 2012 figure, high amount of residual chlorine in July month, this is may be due to the non operation of the non returned valve of the

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chlorine tank without knowing the well operation, and the chlorine enter the network by suction properties due to the high different elevation level. The average value of regionally residual chlorine recording of 9 points monitoring points of Um Al Nasser drinking water network during the summer and winter 2010 to 2013 was calculated. As shown in figures (2 to 17) in appendix II, the highest regionally average residual chlorine was calculated for point (CT2) and accounts for 0.44 mg/L in summer 2012, while CT9 has the highest value of 0.24 mg/L in winter 2012. The lowest regionally average value was found at monitoring point (CT4) and accounts for 0.14 mg/L in summer 2010, while CT 1 has the lowest value 0.11 mg/ L in winter 2010. The location of point (CT2) is nearly 1560 m from the well and CT1 is nearly 1400m from the well connected to the network. In general the residual chlorine in the monitoring point 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 0.4 mg/L, while the other percentage fall below 0.2 mg/L.

The study find that the best value of the correlation coefficient (r) = -0.836 and this indicates the strange inverse relationship, as the value of sig = 0.005 which is less than the level of significant α = 0.05, at which the mean difference is significant.

4.4 The relationship between the residual chlorine and the distance between well and sampling points in the water network.

The study was concerned about the impact of the well (source) and the specific points located at different distance from the well within the municipal water system. The distances were measured according to the flow direction on the water supply network which was taken from the model. The decrease in chlorine can be represented during the Um AL Nasser water network scatter panel showing in the direction of the relationship and regression equation shown in figures below (4.5 to 4.12):

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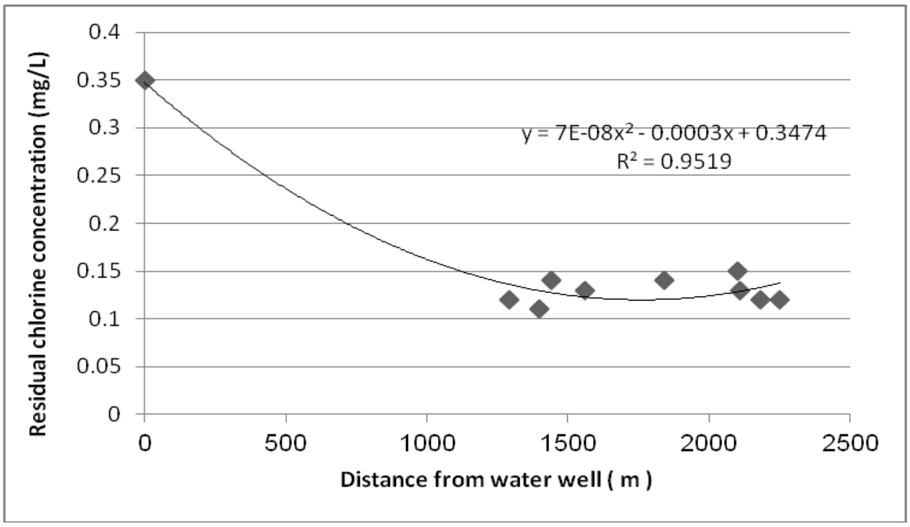

Figure(4.5), Relationship between residual chlorine and distance from the source in winter season during 2010.

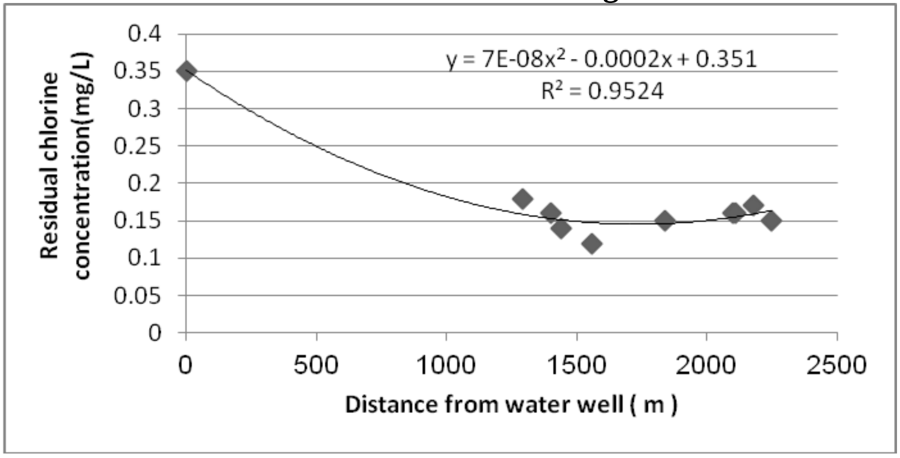

Figure (4.6), Relationship between residual chlorine and distance from the source in winter season during 2011.

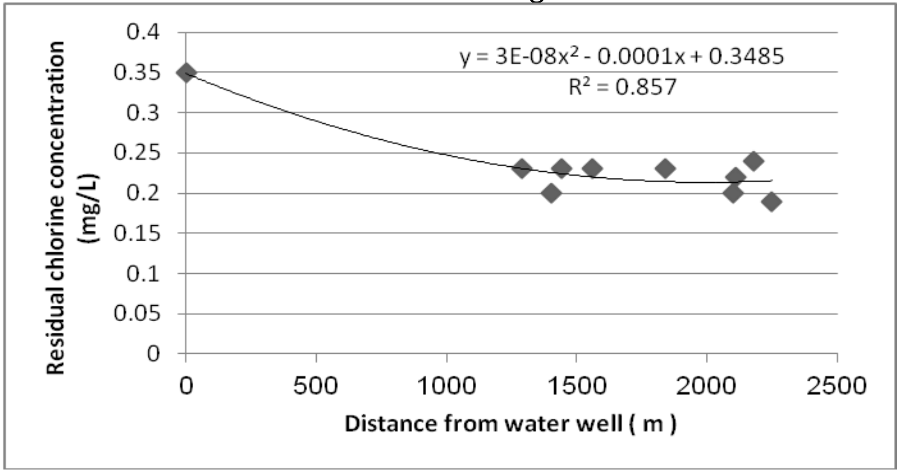

Figure (4.7) , Relationship between residual chlorine and distance from the source in winter season during 2012.

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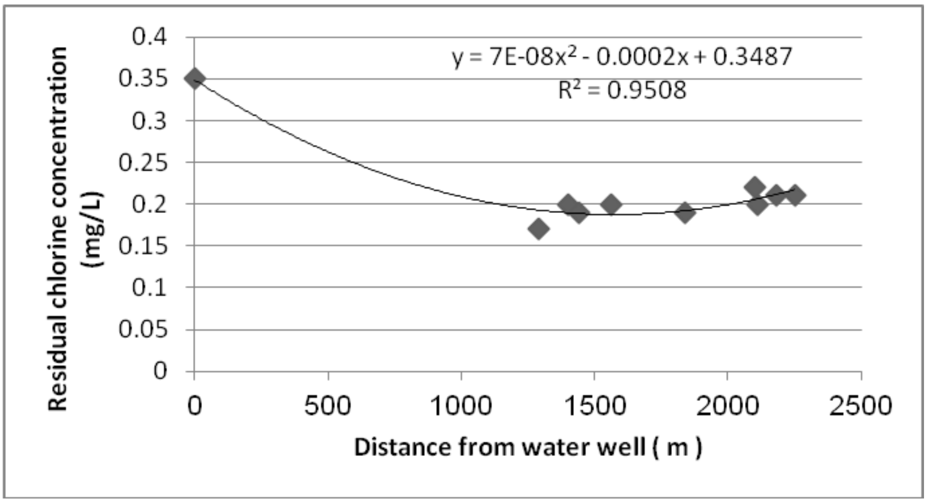

Figure (4.8) , Relationship between residual chlorine and distance from the source in winter season during 2013

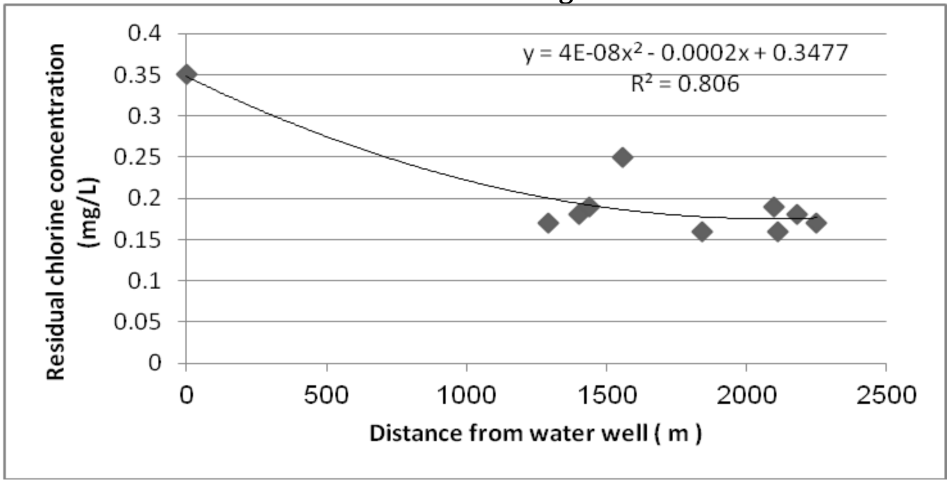

Figure (4.9), Relationship between residual chlorine and distance from the source in summer season during 2010.

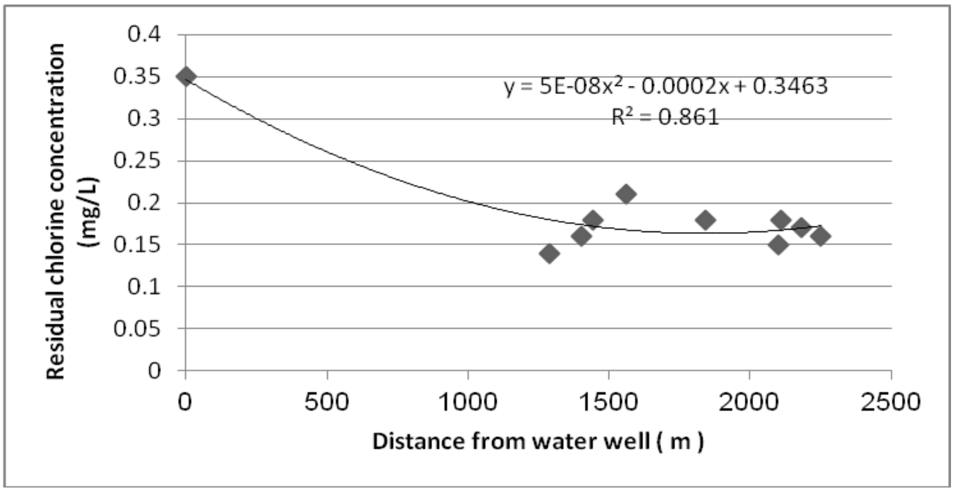

Figure (4.10), Relationship between residual chlorine and distance from the source in summer season during 2011.

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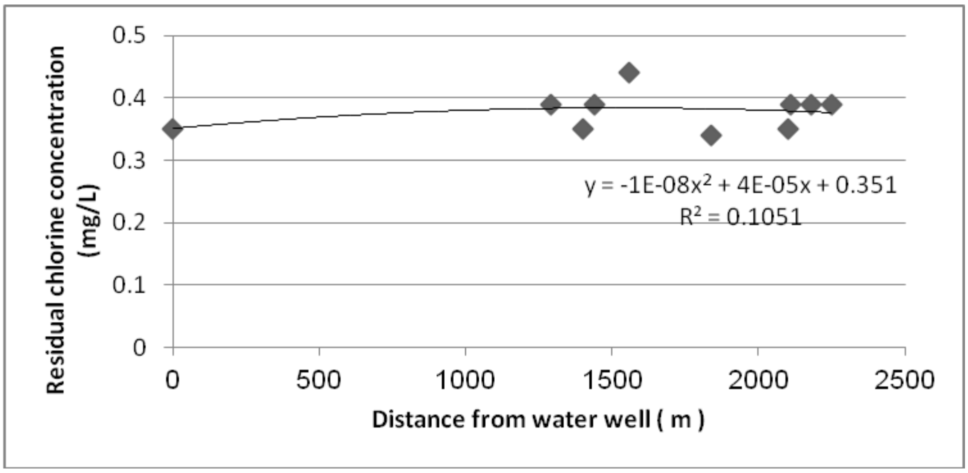

Figure (4.11), Relationship between residual chlorine and distance from the source in summer season during 2012.

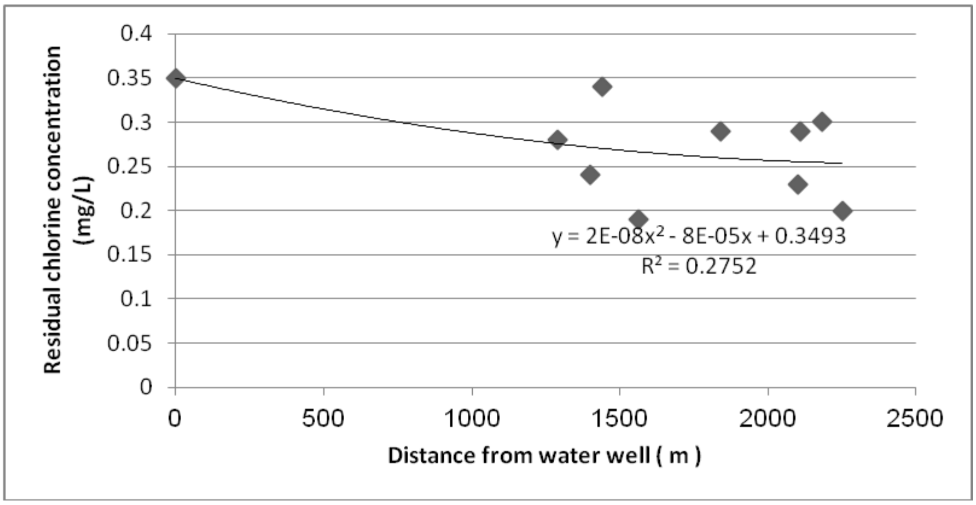

Figure (4.12) , Relationship between residual chlorine and distance from the source in summer season during 2013

The figures above showing the relationship between residual chlorine and the distance from the well at nine testing points covering the water network of Um Al Nasser village area during the main month of summer and winter on the studying period. The variation in the correlation factor R^2 is high in various months from Jan 2010 to Aug 2013 in all sampling location of Um Al Nasser water distribution network. It is noticed that the R^2 in winter 2011 was 0.952 has the largest value due to the studding period on the other hand the value of R^2 in summer 2012 (0.105) was the smallest value due to the studding period. As we know the closer value of R^2 to 1, the stronger relationship between the variables and visa versa, this means that winter period during 2011 have the most significant relationship between the distance from the well and residual chlorine concentration and summer period during

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2012 don’t have significant relationship between the variables. It's notice that only summer season during 2012, the curve has concave up this means that as the distance increase the residual chlorine concentration on the net work increase and the other seasons have a negative slop (r has a negative singe). If we refer to the monthly average for residual chlorine in winter & summer seasons figure during 2012, we notice that the summer month have the largest value of residual chlorine especially July 2012 and this is may be due to the non operation of the non returned valve of the chlorine tank without knowing the well operation as we explained before.

The study identified that there aren’t any sample of recording which increased over the maximum allowable in accordance with standards adopted by the WHO 2004 (No.>1.2 mg /L) or the Palestinian standards (No.>0.8 mg/L). While the number of samples which are below the minimum standards (No.<0.2 mg/L) are 68. This means that during winter season the proportion of non-standard recording was 69% of the total recording as shown in Table (4.5). On the other hand about 34% of the reading during summer season along the study period of chlorination in Um AL Nasser village were without limit by the WHO shown in tables (4.6).

Table (4.5), The number and rates of standard & non standard chlorine sample of Um Al Nasser network during winter season.

Test point	NO.	NO.<0.2 mg/L	NO.>1.2 mg/L OR NO.>0.8 mg/L	No. standard sample	No. non standard sample
CT1	11	7	0	4	7
CT2	11	7	0	4	7
CT3	11	9	0	2	9
CT4	11	7	0	4	7
CT5	11	8	0	3	8
CT6	11	7	0	4	7
CT7	11	7	0	4	7
CT8	11	9	0	2	9
CT9	11	7	0	4	7
Total	99	68	0	31(31.5%)	68(68.5%)

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Table (4.6)The number and rates of standard & non standard chlorine sample of Um Al Nasser network during summer season .

Test point	NO.	NO.<0.2 mg/L	NO.>1.2 mg/L OR NO.>0.8 mg/L	No. standard sample	No. non standard sample
CT1	12	5	0	7	5
CT2	12	2	0	10	2
CT3	12	5	0	7	5
CT4	12	6	0	6	6
CT5	12	6	0	6	6
CT6	12	3	0	9	3
CT7	12	3	0	9	3
CT8	12	3	0	9	3
CT9	12	4	0	8	4
Total	108	37	0	71 (66 %)	37 (34%)

For many years chlorination has been the standard method of water disinfection in Gaza Strip. Chlorine is used in most water treatment facilities to kill harmful microorganisms in drinking water that cause serious diseases. While this certainly work, 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 limitation. This condition represent 51% of most the sampling points in Um Al Nasser village. Therefore the chlorination process should be monitored and fixed values of chlorine dosage should be added to the system according to WHO limitation and standards. Comparing any month of 2010 with the same month of 2011 or 2012 or 2013, the disparity is noticed, this indicates the existing an error in the amount of total pumped chlorine in the water source before they enter the network . The incorrect dosage 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 Gaza Strip. These results in agreement with (Yassin *et al.*, 2006) and (Abu Amer and Yassin, 2008)

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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 51% of the 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 substance resulting from imbalances chlorination or non-compliance with standard dosage 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 mg) is also indicated in the water network specially at the close sampling point to the chlorination source. Because of the amount of chlorine injected less than allowed in the 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 operation. The infiltration of wastewater to the water distribution system is a common phenomena specially in winter time, where sewage system is overload (Hamdane *et al*., 2009), this fact explained the low concentration of residual chlorine in the study area in winter time due to high consumption of total chlorine in the network.

The household water treatment and safe storage as an option of particular potential with high health improvements (Okara *et al*., 2011). This approach is completely true for Um Al Nasser village where the residential store the water for more than two days due to the continues interruption of water supply. The residual chlorine in the household storage tanks is nearly zero, therefore water tanks could be suitable environment for biological contamination.

4.5 Waterborne Diseases

Without access to safe water, adequate sanitation and proper hygiene, children are particularly vulnerable to sickness caused by water borne disease. In Gaza, diarrhea, an easily preventable disease, is behind 12 percent of young deaths,

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(UN Humanitarian Country Team and AIDA, 2009). Furthermore lack of safe water is an immediate cause of undernutrition for millions more children, which can have lasting impact on a child's cognitive and physical development. Waterborne diseases are common in the Gaza Strip.

The Department of Health of the UN Relief and Works Agency (UNRWA) reports that: "*Watery diarrhea ... as well as acute bloody diarrhea and viral hepatitis remain the major causes of morbidity among reportable infectious diseases in the refugee population of the Gaza Strip*''. (UNRWA Epidemiological Bulletin,2009). The study have some records of the most commune waterborne diseases such as Pin Worms, Ascariasis, Amoebiasis, Giardiasis and Diarrhoea of Um Al Nasser village for four years ago from January, 2010 to August, 2013. As we show before the study concentrate on the two main seasons summer and winter as show in the tables (4.7&4.8).

Table 4.7, Number of cases of waterborne diseases during winter season from 2010 to 2013

Year	**2010**			**2011**			**2012**			**2013**	
Diseases	Dec	Jan	Feb	Dec	Jan	Feb	Dec	Jan	Feb	Jan	Feb
Pin Worms	15	19	17	18	36	24	16	22	31	16	17
Ascariasis	3	5	3	1	0	1	1	1	2	2	2
Amoebiasis	13	16	14	11	15	16	19	7	15	10	20
Giardiasis	38	14	9	9	25	16	8	11	20	4	11
Diarrhoea	20	38	25	29	30	29	27	29	24	37	25

Source: Um Al Nasser clinic.

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Table 4.8, Number of cases of waterborne diseases during summer season from 2010 to 2013.

Year	2010			2011			2012			2013		
Diseases	Jun	July	Aug	Jun	July	Aug	Jun	July	Aug	Jun	July	Aug
Pin Worms	40	21	16	12	42	9	30	15	22	45	26	20
Ascariasis	3	4	1	2	5	4	5	4	2	1	0	2
Amoebiasis	51	27	25	30	29	17	18	53	47	32	55	23
Giardiasis	47	51	37	22	13	18	19	47	56	31	25	21
Diarrhoea	66	73	65	124	57	75	47	53	42	63	76	43

Source: Um Al Nasser clinic.

Tables showing the waterborne diseases in Um Al Nasser village area during the main month of summer and winter on the studying period. Figures (18 to 32) in appendix II showing the average diseases reading during summer and winter through studying period and the correlation factors between summer and winter for each year. As shown in the above tables and figures, the selective diseases were collected from Um Al Nasser health clinic report, which affiliated to the Union of Palestinian Medical Relief Committees. The highest yearly diseases reading was 767 inhabitant during 2010 and the lowest reading was 700 during 2013, while 2012 have value of 718 inhabitant which is very closed to 2010. The variation in the number of disease type in various years from 2010 to 2013 is very small - Pin Worms (529 inh), Amoebiasis (542 inh), Giardiasis (542 inh) - except two diseases, Ascariasis (54 inh) and Diarrhoea (1097 inh), which can be considered high variation. The study find that the best value of the correlation coefficient (r) = 0.978 and this indicates the strange direct relationship, as the value of sig = 0.004 which is less than the level of significant $\alpha = 0.05$, at which the mean difference is significant.

4.6 The relationship between residual chlorine and waterborne disease.

The study was concerned about the impact of decreasing of residual chlorine in the network within waterborne. SPSS and Excel program are used to

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analyze the data collected about residual chlorine and water borne diseases such as Pin Worms, Ascariasis, Amoebiasis, Giardiasis and Diarrhoea. Descriptive Statistics and correlation between waterborne diseases and residual chlorine are studied for each diseases during summer and winter along studying period as shown in figures below(4.13 to 4.22).

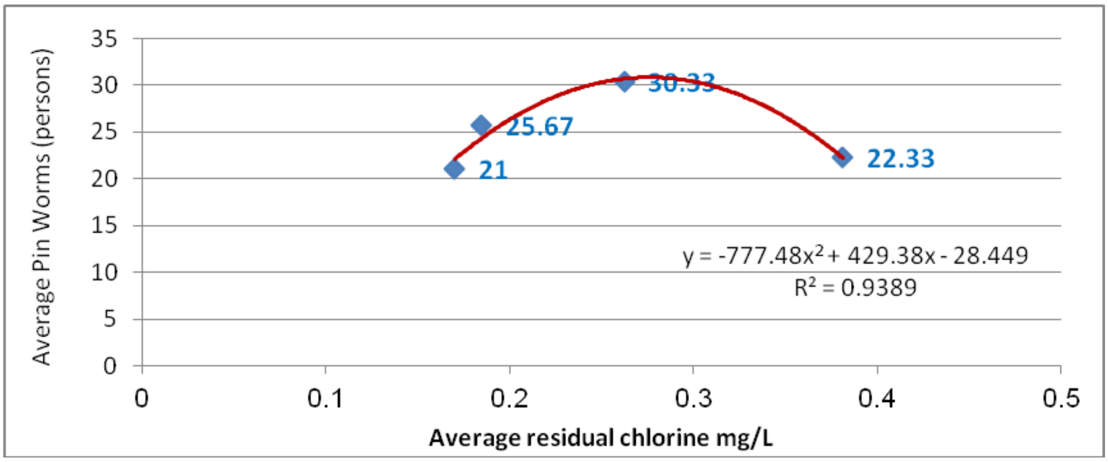

Figure (4.13), Correlation factor between average residual chlorine & Pin Worms diseases during summer season.

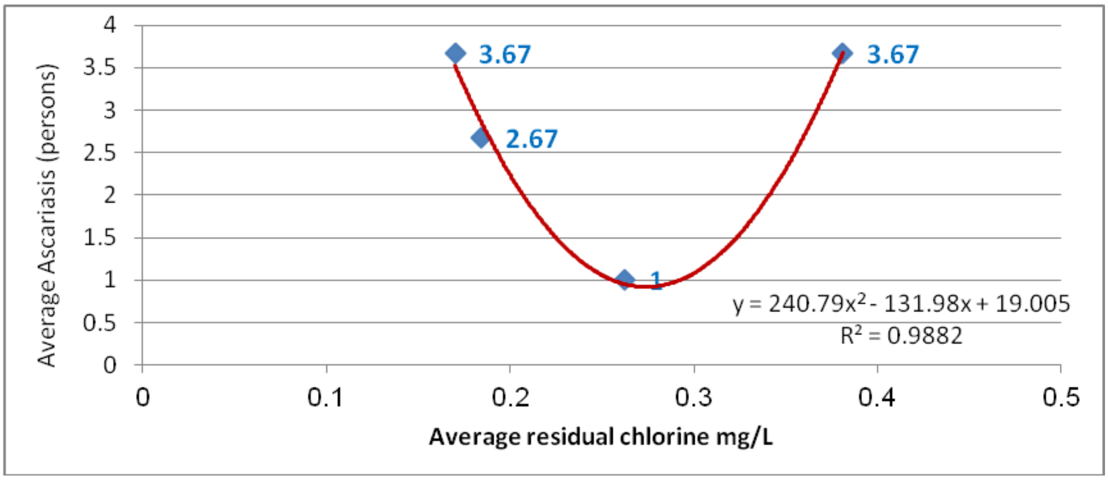

Figure (4.14), Correlation factor between average residual chlorine & Ascariasis diseases during summer season .

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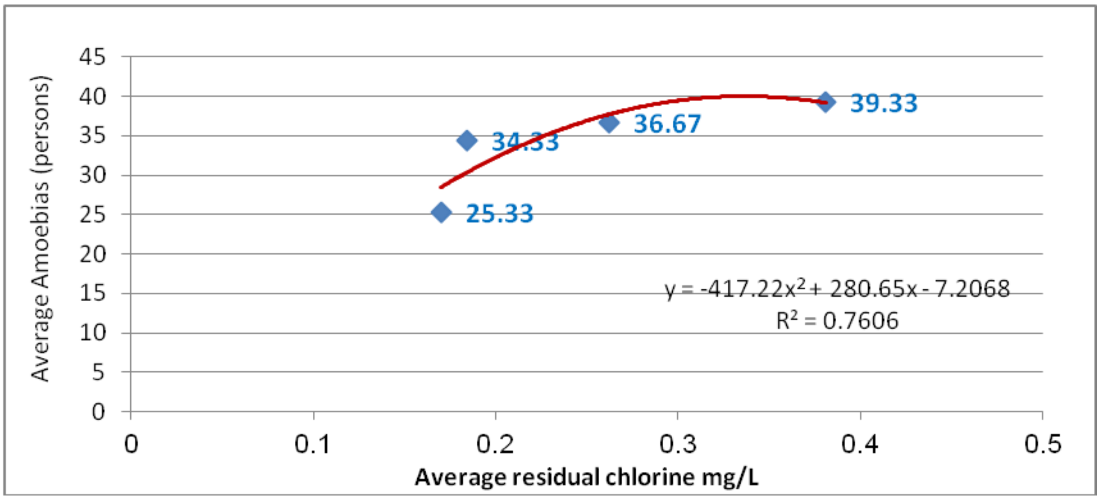

Figure (4.15), Correlation factor between average residual chlorine & Amobias diseases during summer season .

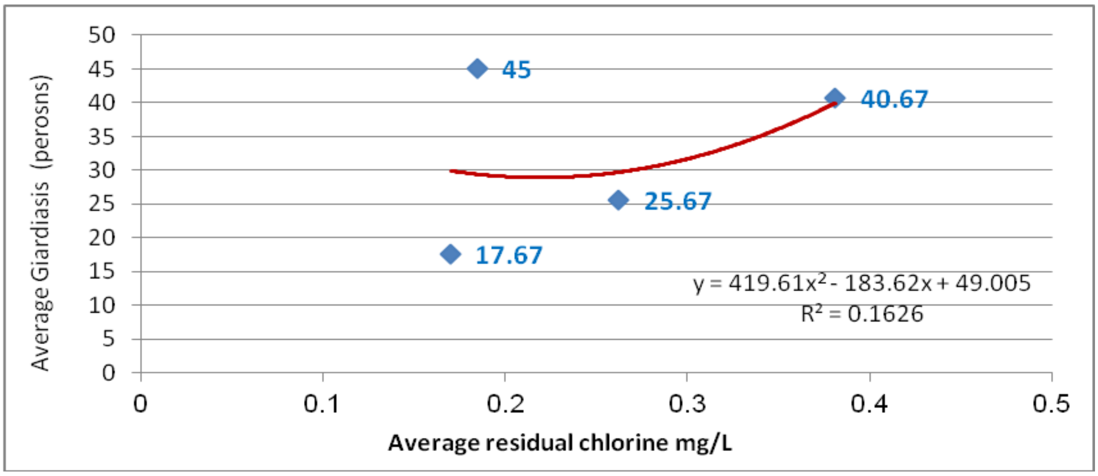

Figure (4.16), Correlation factor between average residual chlorine & Giardiasis diseases during summer season.

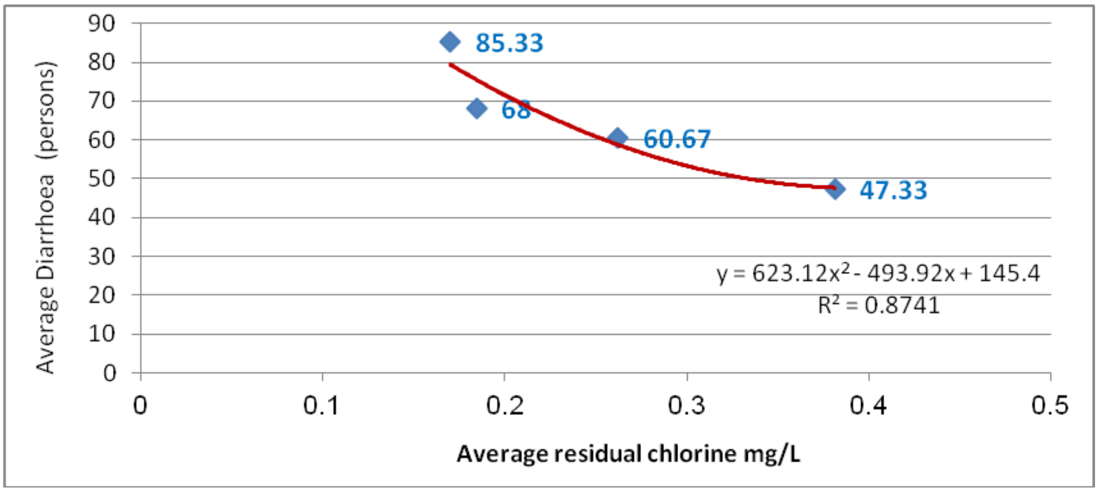

Figure (4.17), Correlation factor between average residual chlorine & Diarrhoea diseases during summer season .

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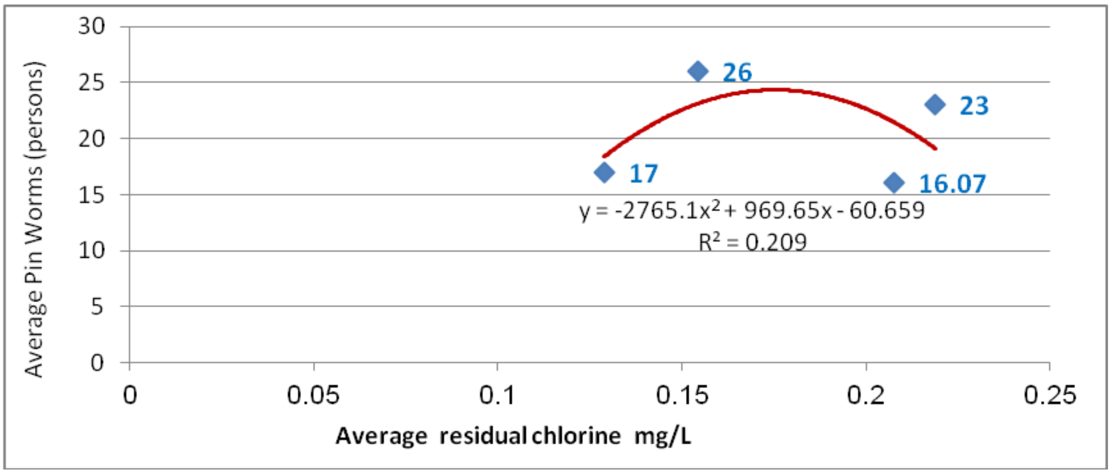

Figure (4.18) Correlation factor between average residual chlorine & Pin Worms diseases during winter season.

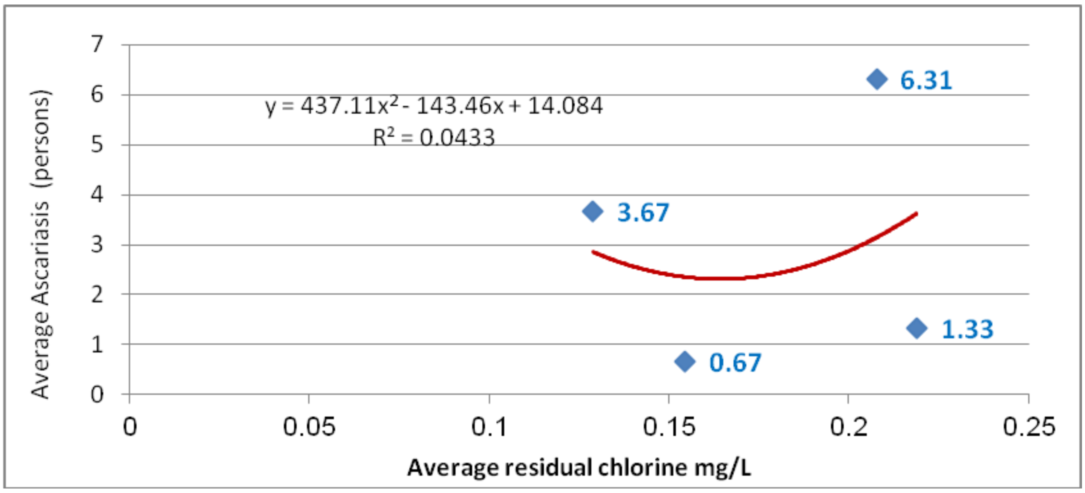

Figure (4.19), Correlation factor between average residual chlorine & Ascariasis diseases during winter season .

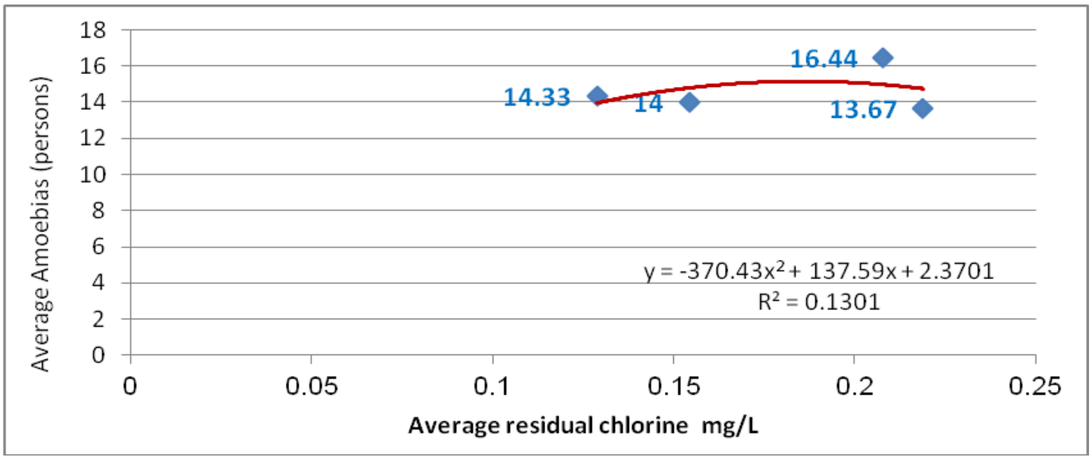

Figure (4.20), Correlation factor between average residual chlorine & Amoebias diseases during winter season.

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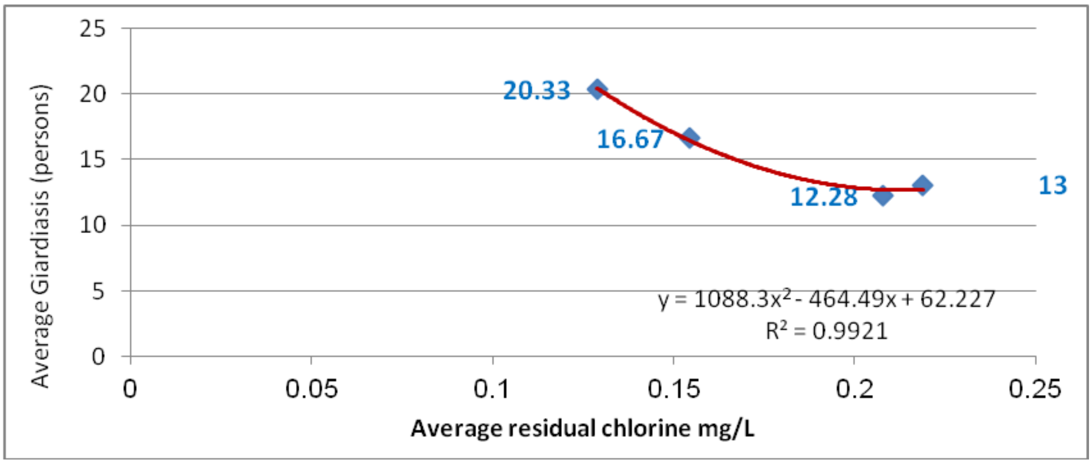

Figure (4.21), Correlation factor between average residual chlorine & Giardiasis diseases during winter season .

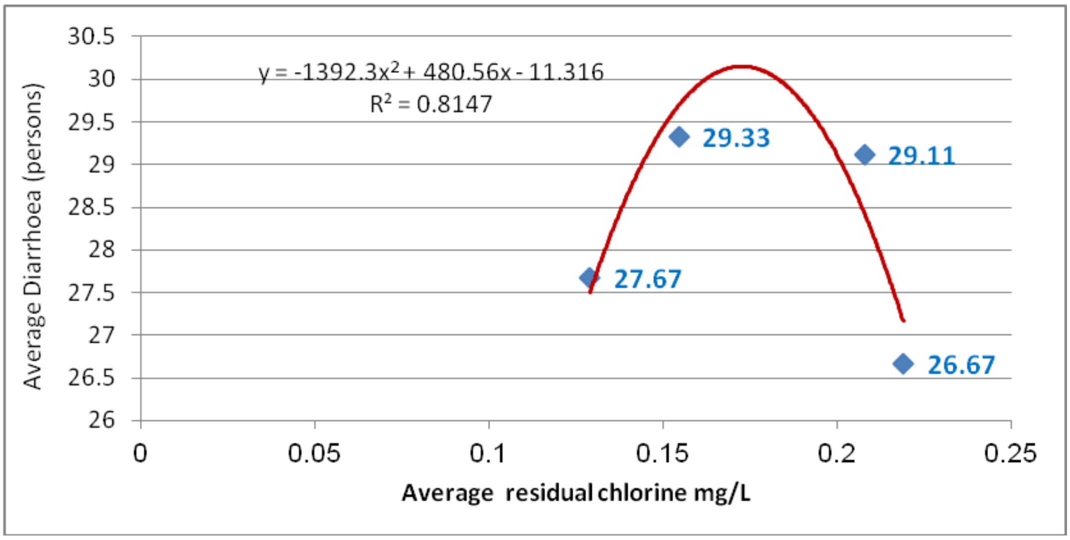

Figure (4.22), Correlation factor between average residual chlorine & Diarrhoea diseases during winter season .

Figures above showing the relationship between the residual chlorine on the network and waterborne diseases of Um Al Nasser village area during the main month of summer and winter on the studying period, results of descriptive statistics and correlation (See appendix III) is obtained. From the figures and descriptive statistics we notice the following:

- The relationship between average residual chlorine and pin Worms and Amoebias diseases construct a parabolic curve 2nd degree, concave up during summer period. According to statistics analysis, the value of the correlation coefficient (r) = -0.008 for Pin Worms indicating weak relationship,(r) = 0.796 for

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Amoebias indicating strong relationship and estimated the value of sig = 0.992, 0.204 respectively leading to significant correlation between the two variables at the level of significance α = 0.05. Also during summer period the relationship between average residual chlorine Ascariasis, Diarrhoea and Giardiasis disease construct a parabolic curve 2nd degree concave down. The value of the correlation coefficient (r) = 0.085, -0.912 and 0.366 respectively indicating weak relationship for Ascariasis, strong relationship for Diarrhoea and moderate relationship for Giardiasis. Estimated the value of sig = 0.915,0.088 and 0.634 respectively leading to significant correlation between the two variables at the level of significance α = 0.05.

- On the other hand, during winter seasons the relationship between the average residual chlorine and Pin Worms, Amoebias and Diarrhoea disease construct a parabolic curve 2nd degree concaveup. The value of the correlation coefficient (r) = 0.021, 0.275 and -0.223 respectively indicating a weak relationship. Estimated the value of sig = 0.979, 0.725 and 0.777 respectively leading to significant correlation between the two variables at the level of significance α = 0.05. In addition, the coefficient of Pearson correlation between average residual chlorine and Giardiasis and Ascariasis diseases (r) = -0.969 & 0.159 respectively , and this indicates a very strong inverse relationship for Giardiasis and a weak relationship for Ascariasis , as the value of sig = 0.031 for Giardiasis which is less than the level of 0.05 at which the mean difference is significant and 0.841 for Diarrhoea indicates a significant correlation between the two variables at the level of significance α = 0.05.

Water played a significant role in the transmission of human disease. Bacteria, viruses and protozoa that cause disease are known as pathogens. Fecal Coliform in water indicates that the water may contain one or more of these organisms that can cause human diseases. Moreover, an increase in the concentration of the indicator measure should increase the risk of illness (Timothy, 2003). Giardiasis, Entamabiasis, Ascariasis, Diarrheal diseases Hepatites A, Salmonilasis and Shegellosis are some of waterborne diseases registered in Gaza Strip. Also, these diseases can be transmitted to human by food. In Gaza Strip as a whole, a strong positive correlation was found for Giardiasis and diarrhea diseases with Fecal Coliform contamination in water networks whereas correlation with hepatitis A was

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relatively weak. Diarrhea was strongly associated with source of drinking water In Gaza Strip (Abu Mourad, 2004). Hepatitis A. Diarrheal diseases were the most frequently self-reported disease among interviewees in Gaza city. Such diseases were more prevalent among people using municipal water than people using desalinated water and water filtered at home for drinking (Yassin *et al.*, 2006). Without access to safe water, adequate sanitation and proper hygiene, children are particularly vulnerable to sickness caused by water borne disease. In Gaza, diarrhoea, an easily preventable disease, is behind 12 percent of young deaths, UN Humanitarian Country Team and AIDA Association of International Development Agencies, *The impact of the blockade on Gaza's basic needs,* 9 November 2009.

As a part of Gaza Strip, Um Al Nasser village suffering from waterborne diseases, The Water-related diseases are most prevalent in the village of Um Al-Nasser, including the disease meningitis, inflammation of the liver Epidemiological, pneumonia, Alascrias, bedwetting, Gardia and widespread diarrhea among children under the age of three Years, Source:unrwa, 2008.

As notice from the correlation figures between residual chlorine and waterborne diseases, Diarrhoea increasing in summer season for many reasons, one of them is the rapidly destroy of food because of high temperature and growth of microorganisms, Frequent out the children's out of the house for playing , in addition people visiting to each other increasing in the summer, also there are some of Diarrhoea cases may be Amoebias or Giardiasis but it is records as Diarrhoea because there aren't stool anlysis at the clinic. Drinking water supplied in the Gaza Strip is insufficient and intermittent system, with interruptions of supplies sometimes lasting for several days. The shortage in water resources and the increased water demand by a fast-growing population in the Gaza Strip has forced the PWA and CMWU to interrupt the supply. With inadequate disinfection, such practice could lead to suitable conditions for biofilm bacterial regrowth, thus increasing the possibility of water Contamination. One of the most problem in Gaza Strip is the lack of spare parts and professional to repair and maintain water distribution system. Leakage form nodes and joints, interruption of water supply for many hours a day increase the possibilities of wastewater seepage to water network. In addition, the problems of networks contamination will exacerbated due to the destruction of the

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infrastructure including water and wastewater networks by the Israeli militant activities. WHO, 1996 reported that deterioration of the bacteriological quality of water during distribution can occur and there where are a number of places contamination can be introduced. In addition many wells have damage chlorination units. Chlorination chemical compounds in many cases are not in the market due to the Israeli restriction and closure.

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5. Conclusion and Recommendation

5.1 Conclusion

- The study achieved the main objectives that were set in the beginning, which were:
    - ✓ To review and evaluate the water distribution system adequacy from public health prospective.
    - ✓ To investigate the disinfection system in Um Al- Nasser community based on WHO and Palestinian regulations.
    - ✓ To investigate the relationship between chlorine decay and variables such as chlorine dosage in the well and distance from the injection point.
    - ✓ To propose possible improvements on disinfection process to improve the microbiological quality of drinking water.

- From the analysis of Um Al Nasser water source, chlorination system and water supply network and, its new and in a good condition, but it needs a good management, a periodicity maintenance and get more importance and monitoring. It haven't enough periodical biological tests.

- Um Al Nasser municipality has one water source (A210 well) with capacity 115 m^3/ hr operating 8 hours per day, serviced approximately 3500 inhabitant in 2013. Increasing the number of customers per years due to natural population growth rate forced Um Al Nasser municipality to find another source of water or to increasing operation hours.

- After presentation of information in the study it's clear that each person share of water that is pumped to the water network reached 155 L/C/day, which is nearly closed to the assumed value of demand of water at joints on the model and the efficiency of the water network during 2013 only which is equal 72.3%. This means that the rate of unaccounted for water during 2013 is equal 27.7%, which is

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very small value compared to the rate in developing countries in Asia which is equal to 42% in the maximum rate of losses .

- The existing mode of water supply system of Um Al Nasser village is not suitable; since it depends on direct pumping into the network so it must be changed using storage tanks which will feed the whole area to achieve the contact time between the disinfectant and microorganisms in addition to solve hydraulic problems.
- The intermittent supply affects the hydraulic performance of the network and exposes it to high values of pressure, it's found that the velocity in most pipes have values under the design criteria limits, some of these pipes are existed in the city with large diameter and others have the smallest diameter ,but the velocity still low since they are located in low demand regions. About 18.5% of the velocity on the pipe satisfy the normal velocity values in residential areas ranges between 0.6 – 2 m/s.
- The intermittent service is the procedure of providing water that is followed in operating most of the water distribution systems in Palestine.
- There is adverse affect of the intermittent systems on the readings of the customer water meters due to the pushed and sucked air in the network
- The imbalance in the performance of the chlorination process during the studied period is the main characteristics of Um Al Nasser water supply system. This can be clearly in the amount of residual chlorine in the water system during the period of study, the average amount in summer season 0.25 mg L^{-1} while it was 0.177 mg L^{-1} in winter season.
- There is inverse relationship between the amount of residual chlorine and the distance from the source to be severe in all parts of the network.
- 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.

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- The study hasn’t any records for free chlorine, so we didn’t have clear chart for chlorine consumption in the network.
- About 34% in summer season and 68.5% in winter season of the residual chlorine readings were without the limit of WHO (0.2 -1.2 mg L^{-1}).
- The risk of waterborne infectious disease is very high when no chlorination is used and drops very sharply to a low value when even minimal levels of chlorination are maintained. As the level of chlorination is increased, the risk continues to drop slightly but never quite reaches zero, for no system is perfect. At very high levels of chlorine the microbial risk increases, because taste and odor may cause use of unsafe supplies.
- A strong negative correlation was found for Gaiardiasis and Diarrheal diseases with Average residual chlorine in drinking water networks in Um Al Nasser village (r = -0.969 and -0.912, respectively) whereas correlation with Pin Worms was the weakest (r =-.008).

5.2 Recommendations

1. Frequent maintenance of water and wastewater networks is needed to reduce breakage of pipelines and wastewater flooding events. Interruption of water supply should be minimized. Frequent cleaning of water roof tanks and proper implementation of water disinfection are recommended.

2. Re-training of human resources in chlorination sector according to scientific criteria and define the responsibilities of each of the observer, the examiner, the operator and official disinfectant through a system of integrated management and effective.

3. Raising the quality of water and improve the specifications and purified as reflected in the public health and to reduce the economic cost resulting from the optimal use in the process of chlorination.

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4. Make a special study to identify the characteristics and types of micro-organisms and other pollutants in the water, and the redefinition of doses used or the use of chlorine disinfectant in the last drinking water system.

5. Establishment of data base program in the hospital and clinics for documentation of waterborne diseases incidence in addition to analysis of the local data and water pollution to limit the spread of such cases to residents.
6. Specialized software should be developed to model the behavior of the intermittent systems in our region.

7. It is very necessary to monitor continuously the value of TTHM in the water system and ensure not to exceed the MCL value.
8. Old steel pipes need to be replaced.
9. Chlorine dose and residual need to be more closely monitored.
10. A public awareness campaign should be conducted relating to the importance of clean drinking water and hygiene. This should include information to private water departments regarding chlorination and hygienic transport as well as individuals on the importance of safe water storage at the household level. Safe water should be provided to infants to ensure that they do not suffer the adverse affects of water contamination.

5.3 Recommendations for further research

It is recommended to:

- Studying the feasibility of declining Cl2 as disinfectant and using other alternatives.
- Studying the effects of water quality parameters on the formation of TTHM.

- Studying the needs for water contamination and its relation to human health.

- Connect the water network and chlorination system with GIS.

- Studying the effect of pipe materials and pipe ages on the chlorination system and the formation of TTHM.

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Appendix I

Table (1) , Current consumption, and Nodes of Um Al Nasser Water System

Node No	Elevation (m)	Area (m^2)	Population	Q (l/d)
J-1	35	9672.15	54	8125
J-2	35.8	5779.57	32	4855
J-3	36	5774.57	32	4851
J-4	36	1462.41	8	1228
J-5	34.8	699.08	3.4	587
J-6	36	971.2	6	816
J-7	37	479.85	5	403
J-8	35.5	473.07	5	397
J-9	35.6	281.17	5	236
J-10	35.8	947	5	795
J-11	35.5	588.39	5	494
J-12	36	782.01	4	657
J-13	35	2513.16	14	2111
J-14	33	1152.53	7	968
J-15	33.25	1401.73	8	1177
J-16	32	14769.6	83	12406
J-21	37.2	453.39	5	381
J-22	36.7	838.89	5	705
J-23	36.7	1888.9	11	1587
J-25	37	639.08	4	537
J-26	36	2553.07	14	2145
J-27	36	1223.81	7	1028

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Node No	Elevation (m)	Area (m^2)	Population	Q (l/d)
J-28	36	2318.28	13	1947
J-29	36	1994.42	11	1675
J-30	36	2138.16	12	1796
J-31	36	1426.93	8	1199
J-32	36	1772.02	10	1488
J-33	36	3004.43	17	2524
J-34	35.8	1276.2	8	1072
J-35	35.5	561.56	5	472
J-36	36	672.94	4	565
J-37	34.5	1508.47	9	1267
J-38	35.5	2373.82	13	1994
J-39	35.5	2801.61	16	2353
J-40	35	556.11	4	467
J-41	35.5	1707.95	9.10	1435
J-42	36	744.11	4	625
J-43	36	2117.09	12	1778
J-46	35.5	500.02	2	420
J-47	35	103.02	5	87
J-48	33	95.04	7	80
J-49	32.5	18407.78	103	15463
J-52	32.8	17863.6	100	15005
J-53	35	2997.7	17	2518
J-54	33	2121.94	12	1782
J-55	33.3	840.63	5	706

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Node No	Elevation (m)	Area (m²)	Population	Q (l/d)
J-56	35	1392.28	8	1170
J-57	35	1494.99	9	1256
J-60	33.3	990.67	6	832
J-61	34.3	3509.13	20	2948
J-62	35.6	2318.91	13	1948
J-63	35.8	1581.93	9	1329
J-64	40.5	1730.89	10	1454
J-65	66	36015.58	202	30253
J-66	40.5	96.14	11	81
J-67	33	3030.63	17	2546
J-68	31.5	971.47	6	816
J-69	31.5	11324.28	63	9512
J-70	32.5	29168.35	164	24501
J-71	34.5	28205.67	158	23693
J-72	36.5	342386.9	1918	287605
J-73	36.5	21558.92	103	18109
J-74	36.8	2896	17	2433
J-75	37.5	1448	8	1216
J-76	37.8	1448	8	1216
J-77	36.5	1456.93	8	1224
J-78	35.3	1266.87	7	1064
J-79	34.5	640.48	4	538
J-80	33.5	1088.58	7	914
J-81	34	14721.6	83	12366

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Node No	Elevation (m)	Area (m^2)	Population	Q (l/d)
J-82	34	6392	36	5369
J-83	33.3	3184.89	18	2675
J-84	34.2	2782.01	16	2337
J-85	35.2	3589.29	20	3015
J-86	34.7	1411.09	8	1185
J-87	34.3	1039.58	6	873
J-88	34.7	1227.93	7	1031
J-89	35.7	1365.54	8	1147
J-90	33.8	2537.69	15	2132
J-91	34.5	954.7	6	802
J-92	35.3	1049.16	6	881
J-93	33.7	1649.37	10	1385
J-94	33.8	2161.95	13	1816
J-95	33.5	3510.37	20	2949
J-96	37.5	1751.6	11	1471
J-97	36.5	1827.6	11	1535
J-98	36.5	739.67	5	621
J-99	37.2	739.67	5	621
J-100	37.6	1792.82	10	1506
J-101	38.2	1818.8	10	1528
J-102	39.3	696.99	4	585
J-103	39.3	554.26	8	466
J-104	35.5	3992.02	23	3353
J-105	32.7	31914.65	178	26808

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Node No	Elevation (m)	Area (m²)	Population	Q (l/d)
J-106	32.8	2185.57	13	1836
J-107	34.5	2460.23	14	2067
J-108	34.4	2463.43	14	2069
J-109	34.5	2131.88	12	1791
J-110	35.3	889.7	5	747
J-111	36.5	2886.45	17	2425
J-112	36.8	2266.32	12	1904
J-113	33.5	1538.26	9	1292
J-114	36	1233.21	7	1036
J-115	35.8	2403.47	14	2019
J-116	36	1935.43	11	1626
J-117	36	718.85	4	604
J-118	34.8	2597.91	15	2182
J-119	36.8	2891.11	16	2429
J-120	36.5	2312.52	13	1943
J-121	36.5	1004.33	6	844
J-122	37	9776.63	55	8212
J-123	36.5	10132.22	57	8511
J-124	35	22721.6	127	19086
J-125	31.7	4288.17	24	3602
J-126	36.5	663.28	4	557
J-135	33	371.4	2	312
J-152	32.5	371.4	2.07984	312
J-153	33	350.3	2	294

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Table(2), Results of Consumptions and Pressures at Nodes.

Joint	Elevation (m)	Demand (m^3/h)	Hydraulic Grade (m)	Pressure (m H_2O)
J-1	35	2.02	54.16	19.1
J-2	35.8	1.22	54.04	18.2
J-3	36	1.22	53.9	17.9
J-4	36	0.32	53.88	17.8
J-5	34.8	0.14	53.88	19
J-6	36	0.22	53.88	17.8
J-7	37	0.11	53.86	16.8
J-8	35.5	0.11	53.84	18.3
J-9	35.6	0.07	53.84	18.2
J-10	35.8	0.22	53.81	18
J-11	35.5	0.11	53.84	18.3
J-12	36	0.18	53.76	17.7
J-13	35	0.54	53.85	18.8
J-14	33	0.25	53.85	20.8
J-15	33.25	0.29	53.85	20.6
J-16	32	3.1	53.85	21.8
J-21	37.2	0.11	53.37	16.1
J-22	36.7	0.18	53.38	16.6
J-23	36.7	0.4	53.36	16.6
J-25	37	0.14	53.4	16.4
J-26	36	0.54	53.46	17.4
J-27	36	0.25	53.46	17.4
J-28	36	0.5	53.47	17.4
J-29	36	0.43	53.48	17.4

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Joint	Elevation (m)	Demand (m³/h)	Hydraulic Grade (m)	Pressure (m H_2O)
J-30	36	0.43	53.53	17.5
J-31	36	0.29	53.52	17.5
J-32	36	0.36	53.6	17.6
J-33	36	0.65	53.48	17.4
J-34	35.8	0.25	53.48	17.6
J-35	35.5	0.11	53.76	18.2
J-36	36	0.14	53.85	17.8
J-37	34.5	0.32	53.84	19.3
J-38	35.5	0.5	53.76	18.2
J-39	35.5	0.58	53.76	18.2
J-40	35	0.11	53.78	18.7
J-41	35.5	0.36	53.75	18.2
J-42	36	0.14	53.75	17.7
J-43	36	0.43	53.75	17.7
J-46	35.5	0.11	53.77	18.2
J-47	35	0.04	53.77	18.7
J-48	33	0.04	53.82	20.8
J-49	32.5	3.85	53.86	21.3
J-52	32.8	3.74	51.61	18.8
J-53	35	0.61	52.63	17.6
J-54	33	0.43	52.6	19.6
J-55	33.3	0.18	53.73	20.4
J-56	35	0.29	53.73	18.7
J-57	35	0.32	53.74	18.7
J-60	33.3	0.22	53.74	20.4

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Joint	Elevation (m)	Demand (m^3/h)	Hydraulic Grade (m)	Pressure (m H2O)
J-61	34.3	0.72	53.55	19.2
J-62	35.6	0.5	53.6	18
J-63	35.8	0.32	53.59	17.7
J-64	40.5	0.36	55.05	14.5
J-65	63.15	7.56	96.36	33.1
J-66	40.5	0.04	55.09	14.6
J-67	33	0.65	54.79	21.8
J-68	31.5	0.22	54.72	23.2
J-69	31.5	2.38	54.72	23.2
J-70	32.5	6.12	54.23	21.7
J-71	34.5	5.94	54.16	19.6
J-72	36.5	71.89	54.16	17.6
J-73	36.5	4.54	54.27	17.7
J-74	36.8	0.61	57.19	20.4
J-75	37.5	0.29	58.84	21.3
J-76	37.8	0.29	59.17	21.3
J-77	36.5	0.29	54.34	17.8
J-78	35.3	0.25	54.89	19.5
J-79	34.5	0.14	54.81	20.3
J-80	33.5	0.22	54.18	20.6
J-81	34	3.1	50.51	16.5
J-82	34	1.33	52.3	18.3
J-83	33.3	0.68	52.22	18.9
J-84	34.2	0.58	54.22	20
J-85	35.2	0.76	54.27	19

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Joint	Elevation (m)	Demand (m^3/h)	Hydraulic Grade (m)	Pressure (m H2O)
J-86	34.7	0.29	54.27	19.5
J-87	34.3	0.22	54.27	19.9
J-88	34.7	0.25	54.27	19.5
J-89	35.7	0.29	54.27	18.5
J-90	33.8	0.54	54.38	20.5
J-91	34.5	0.22	54.79	20.3
J-92	35.3	0.22	54.79	19.4
J-93	33.7	0.36	54.29	20.5
J-94	33.8	0.47	54.27	20.4
J-95	33.5	0.72	54.22	20.7
J-96	37.5	0.36	56.73	19.2
J-97	36.5	0.4	56.27	19.7
J-98	36.5	0.14	56.21	19.7
J-99	37.2	0.14	56.32	19.1
J-100	37.6	0.36	55.28	17.6
J-101	38.2	0.4	54.99	16.8
J-102	39.3	0.14	55.04	15.7
J-103	39.3	0.11	55.05	15.7
J-104	35.5	0.83	55	19.5
J-105	32.7	6.7	54.19	21.4
J-106	32.8	0.47	54.18	21.3
J-107	34.5	0.5	55.27	20.7
J-108	34.4	0.5	55.77	21.3
J-109	34.5	0.43	55.4	20.9
J-110	35.3	0.18	54.92	19.6

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Joint	Elevation (m)	Demand (m^3/h)	Hydraulic Grade (m)	Pressure (m H_2O)
J-111	36.5	0.61	55.4	18.9
J-112	36.8	0.47	55.39	18.6
J-113	33.5	0.32	54.92	21.4
J-114	36	0.25	54.92	18.9
J-115	35.8	0.5	56.62	20.8
J-116	36	0.4	56.25	20.2
J-117	36	0.14	56.25	20.2
J-118	34.8	0.54	55.98	21.1
J-119	36.8	0.61	56.8	20
J-120	36.5	0.47	56.78	20.2
J-121	36.5	0.22	54.27	17.7
J-122	37	2.05	54.52	17.5
J-123	36.5	2.12	54.51	18
J-124	35	4.79	54.51	19.5
J-125	31.7	0.9	54.51	22.8
J-126	36.5	0.14	53.81	17.3
J-135	33	0.07	53.82	20.8
J-152	32.5	0.07	53.82	21.3
J-153	33	0.07	53.82	20.8
J-154	32.5	0.07	53.82	21.3
J-155	63.3	0	105.19	41.8

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Table (3) Pipes, Lengths, Discharges, and Velocities.

Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Flow (m^3/h)	Velocity (m/s)	Head loss Gradient (m/m)
P-1	62.84	101.6	PVC	150	12.58	0.43	0.002
P-2	84.89	101.6	PVC	150	11.35	0.39	0.002
P-3	44.66	101.6	PVC	150	5.57	0.19	0
P-4	31.54	101.6	PVC	150	2.8	0.1	0
P-5	23.74	101.6	PVC	150	0.22	0.01	0
P-6	244.39	101.6	PVC	150	2.44	0.08	0
P-7	166.63	101.6	PVC	150	2.19	0.07	0
P-8	30.25	101.6	PVC	150	2.08	0.07	0
P-9	8.44	45	HDPE	140	1.98	0.35	0.004
P-10	108.92	101.6	PVC	150	0.03	0	0
P-11	8.42	45	HDPE	140	3.2	0.56	0.009
P-12	31.96	101.6	PVC	150	-3.28	0.11	0
P-13	94.32	101.6	PVC	150	0.73	0.03	0
P-14	43.73	101.6	PVC	150	0.29	0.01	0
P-15	45.34	101.6	PVC	150	0.19	0.01	0
P-19	186.77	101.6	PVC	150	-4.56	0.16	0
P-21	100.75	45	HDPE	140	-0.11	0.02	0
P-22	66.96	45	HDPE	140	0.4	0.07	0
P-24	36.77	45	HDPE	140	-0.68	0.12	0.001
P-25	85.55	45	HDPE	140	-0.83	0.14	0.001
P-26	27.42	45	HDPE	140	0.25	0.04	0
P-27	134.2	45	HDPE	140	1.62	0.28	0.003
P-28	29.81	45	HDPE	140	-0.5	0.09	0

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Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Flow (m^3/h)	Velocity (m/s)	Head loss Gradient (m/m)
P-29	84.55	45	HDPE	140	-0.68	0.12	0.001
P-30	31.25	45	HDPE	140	0.29	0.05	0
P-31	37.93	45	HDPE	140	-1.4	0.25	0.002
P-32	84.61	45	HDPE	140	1.15	0.2	0.001
P-33	35.84	45	HDPE	140	0.25	0.04	0
P-34	41.85	45	HDPE	140	0.25	0.04	0
P-35	18.69	45	HDPE	140	-0.11	0.02	0
P-36	20.94	45	HDPE	140	2.92	0.51	0.008
P-37	130	45	HDPE	140	-0.14	0.03	0
P-38	7.23	45	HDPE	140	2.45	0.43	0.006
P-39	79.27	45	HDPE	140	0.97	0.17	0.001
P-40	87.46	45	HDPE	140	0.22	0.04	0
P-41	40.42	45	HDPE	140	-0.64	0.11	0
P-42	124.12	45	HDPE	140	0.4	0.07	0
P-43	21.93	45	HDPE	140	0.14	0.03	0
P-44	39.4	45	HDPE	140	-0.1	0.02	0
P-45	44.41	45	HDPE	140	-0.29	0.05	0
P-46	47.72	45	HDPE	140	1.15	0.2	0.001
P-47	128.32	45	HDPE	140	0.25	0.04	0
P-53	18.61	101.6	PVC	150	-0.11	0	0
P-54	75.1	101.6	PVC	150	-7.49	0.26	0.001
P-55	44.57	101.6	PVC	150	-7.81	0.27	0.001
P-61	82.75	45	HDPE	140	-3.74	0.65	0.012
P-62	123.52	45	HDPE	140	0.43	0.08	0

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Label	**Length (m)**	**Diameter (mm)**	**Material**	**Hazen-Williams C**	**Flow (m^3/h)**	**Velocity (m/s)**	**Head loss Gradient (m/m)**
P-63	68.62	45	HDPE	140	-0.18	0.03	0
P-64	1.36	45	HDPE	140	-5.26	0.92	0.023
P-65	57.25	45	HDPE	140	4.79	0.84	0.019
P-66	5.57	45	HDPE	140	2.09	0.36	0.004
P-69	68.46	45	HDPE	140	0.22	0.04	0
P-70	82.66	45	HDPE	140	-0.72	0.13	0.001
P-71	58.93	45	HDPE	140	-1.55	0.27	0.002
P-72	122.09	45	HDPE	140	-0.32	0.06	0
P-75	12.91	152.4	Ductile Iron	130	-39.38	0.6	0.003
P-78	45.7	101.6	PVC	150	11.27	0.39	0.002
P-79	3.44	101.6	PVC	150	12.82	0.44	0.002
P-80	130.82	101.6	PVC	150	17.82	0.61	0.004
P-81	337	101.6	PVC	150	3.79	0.13	0
P-82	103.74	101.6	PVC	150	0.43	0.01	0
P-83	3.85	101.6	PVC	150	-53.81	1.84	0.028
P-84	87.67	101.6	PVC	150	-58.56	2.01	0.033
P-85	43.99	101.6	PVC	150	-62.31	2.13	0.037
P-87	1,077.07	147.6	PVC	150	-159.44	2.59	0.035
P-88	7.53	101.6	PVC	150	-67.92	2.33	0.044
P-89	49.16	101.6	PVC	150	-17.65	0.6	0.004
P-90	129.03	101.6	PVC	150	-19.19	0.66	0.004
P-91	47.57	101.6	PVC	150	11.17	0.38	0.002
P-92	133.54	101.6	PVC	150	7.38	0.25	0.001
P-93	65.94	101.6	PVC	150	7.91	0.27	0.001

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Label	Length (m)	Diameter (mm)	Material	Hazen-Williams C	Flow (m^3/h)	Velocity (m/s)	Head loss Gradient (m/m)
P-94	163.6	101.6	PVC	150	2.58	0.09	0
P-95	207.21	45	HDPE	140	-3.1	0.54	0.009
P-96	159	45	HDPE	140	0.68	0.12	0.001
P-97	86.01	45	HDPE	140	5.11	0.89	0.022
P-98	121.46	45	HDPE	140	-0.58	0.1	0
P-99	45.94	45	HDPE	140	-1.25	0.22	0.002
P-100	85.32	45	HDPE	140	-0.08	0.01	0
P-101	26.68	45	HDPE	140	0.22	0.04	0
P-102	5.11	45	HDPE	140	-0.59	0.1	0
P-103	37.27	45	HDPE	140	0.29	0.05	0
P-104	85.64	45	HDPE	140	-1.13	0.2	0.001
P-105	43.93	45	HDPE	140	-3.22	0.56	0.009
P-106	1.77	45	HDPE	140	-3.65	0.64	0.012
P-107	70.39	45	HDPE	140	0.22	0.04	0
P-108	41.08	45	HDPE	140	1.55	0.27	0.002
P-109	58.77	45	HDPE	140	0.47	0.08	0
P-110	111.35	45	HDPE	140	0.72	0.13	0.001
P-111	89.48	45	HDPE	140	5.33	0.93	0.024
P-112	44.22	45	HDPE	140	3.4	0.59	0.01
P-113	44.36	45	HDPE	140	1.13	0.2	0.001
P-114	181.31	147.6	Ductile Iron	130	-57.38	0.93	0.007
P-115	178.11	147.6	Ductile Iron	130	-91.24	1.48	0.016
P-116	8.6	101.6	PVC	150	-33.71	1.16	0.012
P-117	90.49	45	HDPE	140	3.42	0.6	0.01

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Label	**Length (m)**	**Diameter (mm)**	**Material**	**Hazen-Williams C**	**Flow (m^3/h)**	**Velocity (m/s)**	**Head loss Gradient (m/m)**
P-118	45.54	45	HDPE	140	2.6	0.45	0.006
P-119	41.16	45	HDPE	140	-1.01	0.18	0.001
P-120	9.7	101.6	PVC	150	17.96	0.62	0.004
P-121	86.42	101.6	PVC	150	15.86	0.54	0.003
P-122	4	45	HDPE	140	-1.99	0.35	0.004
P-123	44.91	45	HDPE	140	0.83	0.14	0.001
P-124	86.09	45	HDPE	140	3.22	0.56	0.009
P-125	44.69	45	HDPE	140	-3.94	0.69	0.014
P-126	29.14	45	HDPE	140	0.47	0.08	0
P-127	43.18	45	HDPE	140	0.45	0.08	0
P-128	178.56	45	HDPE	140	1.76	0.31	0.003
P-129	42.76	101.6	PVC	150	31.29	1.07	0.01
P-130	44.06	101.6	PVC	150	27.89	0.96	0.008
P-131	44.96	101.6	PVC	150	31.36	1.07	0.01
P-132	3.92	101.6	PVC	150	30.61	1.05	0.01
P-133	47.79	45	HDPE	140	2.89	0.51	0.008
P-134	43.29	45	HDPE	140	1.81	0.32	0.003
P-135	61.94	45	HDPE	140	0.47	0.08	0
P-137	44.07	45	HDPE	140	1.56	0.27	0.002
P-138	42.76	45	HDPE	140	3.11	0.54	0.009
P-139	36.87	45	HDPE	140	0.14	0.03	0
P-140	44.27	45	HDPE	140	2.57	0.45	0.006
P-141	43.7	45	HDPE	140	3.91	0.68	0.013
P-142	87.12	45	HDPE	140	-1.87	0.33	0.003

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Label	**Length (m)**	**Diameter (mm)**	**Material**	**Hazen-Williams C**	**Flow (m^3/h)**	**Velocity (m/s)**	**Head loss Gradient (m/m)**
P-143	44.84	45	HDPE	140	-2.05	0.36	0.004
P-144	65.48	45	HDPE	140	0.47	0.08	0
P-145	44.38	45	HDPE	140	-3.13	0.55	0.009
P-146	80.21	45	HDPE	140	0.22	0.04	0
P-147	184.75	147.6	Ductile Iron	130	-29.16	0.47	0.002
P-148	160.79	147.6	Ductile Iron	130	-39.02	0.63	0.003
P-149	8.67	152.4	Ductile Iron	130	7.81	0.12	0
P-150	133.66	152.4	Ductile Iron	130	4.79	0.07	0
P-151	141.94	152.4	Ductile Iron	130	0.9	0.01	0
P-152	87.41	101.6	PVC	150	-2.9	0.1	0
P-153	119.12	101.6	PVC	150	-14.57	0.5	0.003
P-154	23.71	45	HDPE	140	0.14	0.03	0
P-196	4.8	152.4	Ductile Iron	130	0.14	0	0
P-197	206.58	152.4	Ductile Iron	130	0.2	0	0
P-198	40.71	152.4	Ductile Iron	130	0.13	0	0
P-199	2.17	152.4	Ductile Iron	130	0.14	0	0
P-200	208.38	152.4	Ductile Iron	130	0.2	0	0
P-201	41.46	152.4	Ductile Iron	130	0.13	0	0
P-204	1.87	152.4	Ductile Iron	100	167	2.54	2.941
P-205	81.57	152.4	Ductile Iron	130	-0.32	0	0
P-206	83.96	45	HDPE	140	0.25	0.04	0
P-211	2.34	152.4	Ductile Iron	130	167	2.54	0.042

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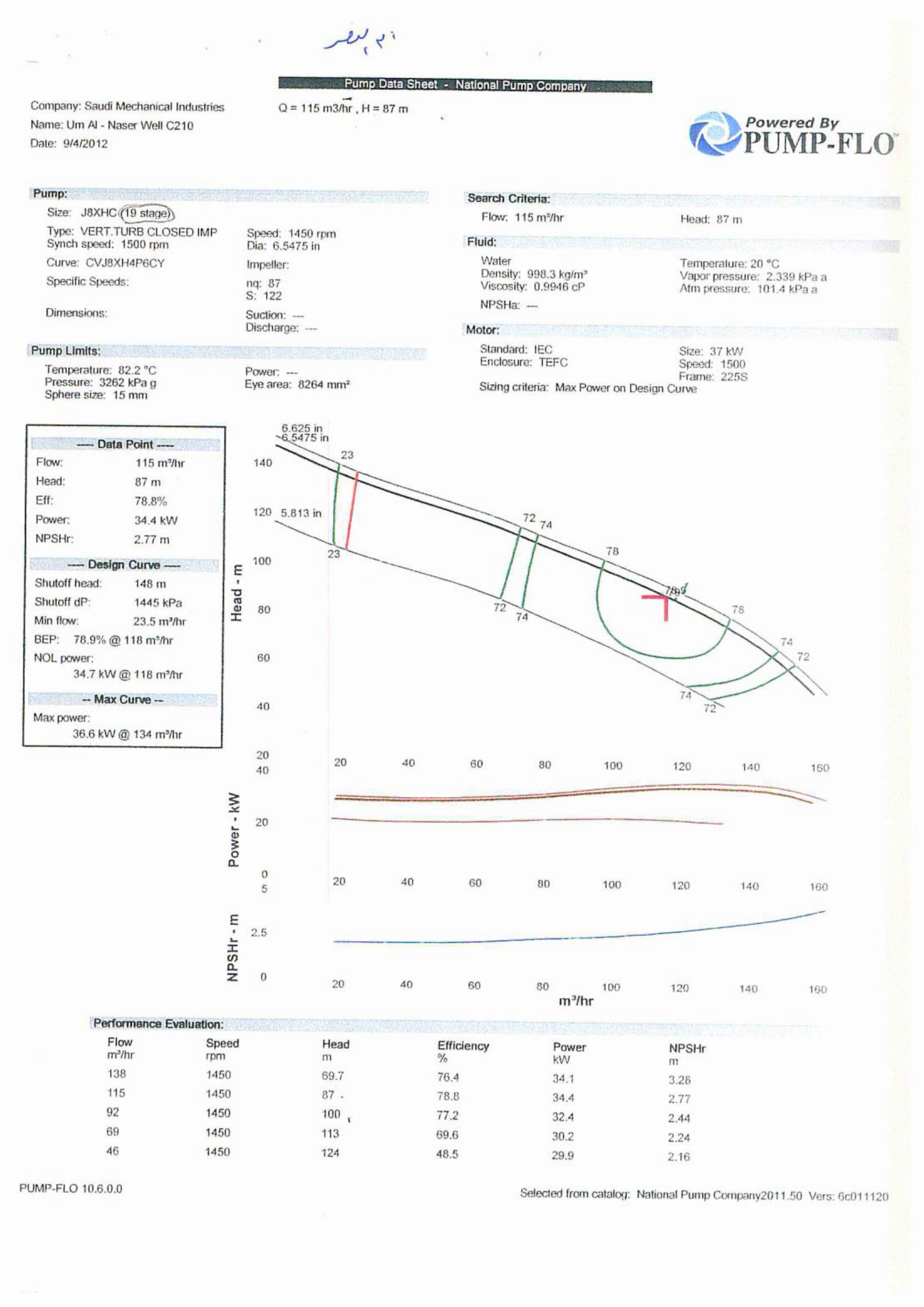
Appendix II



ام النصر

Pump Data Sheet - National Pump Company

Company: Saudi Mechanical Industries
Name: Um Al - Naser Well C210
Date: 9/4/2012

Q = 115 m3/hr , H = 87 m

Pump:

Size: J8XHC (19 stage)
Type: VERT.TURB CLOSED IMP
Synch speed: 1500 rpm
Curve: CVJ8XH4P6CY
Specific Speeds:
Dimensions:
Speed: 1450 rpm
Dia: 6.5475 in
Impeller:
nq: 87
S: 122
Suction: ---
Discharge: ---

Pump Limits:

Temperature: 82.2 °C
Pressure: 3262 kPa g
Sphere size: 15 mm
Power: ---
Eye area: 8264 mm²

Search Criteria:

Flow: 115 m³/hr
Head: 87 m

Fluid:

Water
Density: 998.3 kg/m³
Viscosity: 0.9946 cP
NPSHa: ---
Temperature: 20 °C
Vapor pressure: 2.339 kPa a
Atm pressure: 101.4 kPa a

Motor:

Standard: IEC
Enclosure: TEFC
Size: 37 kW
Speed: 1500
Frame: 225S
Sizing criteria: Max Power on Design Curve

---- Data Point ----

Flow: 115 m³/hr
Head: 87 m
Eff: 78.8%
Power: 34.4 kW
NPSHr: 2.77 m

---- Design Curve ----

Shutoff head: 148 m
Shutoff dP: 1445 kPa
Min flow: 23.5 m³/hr
BEP: 78.9% @ 118 m³/hr
NOL power:
34.7 kW @ 118 m³/hr

-- Max Curve --

Max power:
36.6 kW @ 134 m³/hr

Performance Evaluation:

Flow m³/hr	Speed rpm	Head m	Efficiency %	Power kW	NPSHr m
138	1450	69.7	76.4	34.1	3.28
115	1450	87	78.8	34.4	2.77
92	1450	100	77.2	32.4	2.44
69	1450	113	69.6	30.2	2.24
46	1450	124	48.5	29.9	2.16

PUMP-FLO 10.6.0.0

Selected from catalog: National Pump Company2011.50 Vers: 6c011120

Figure (1) Um Al Nasser pump catalogs and information.

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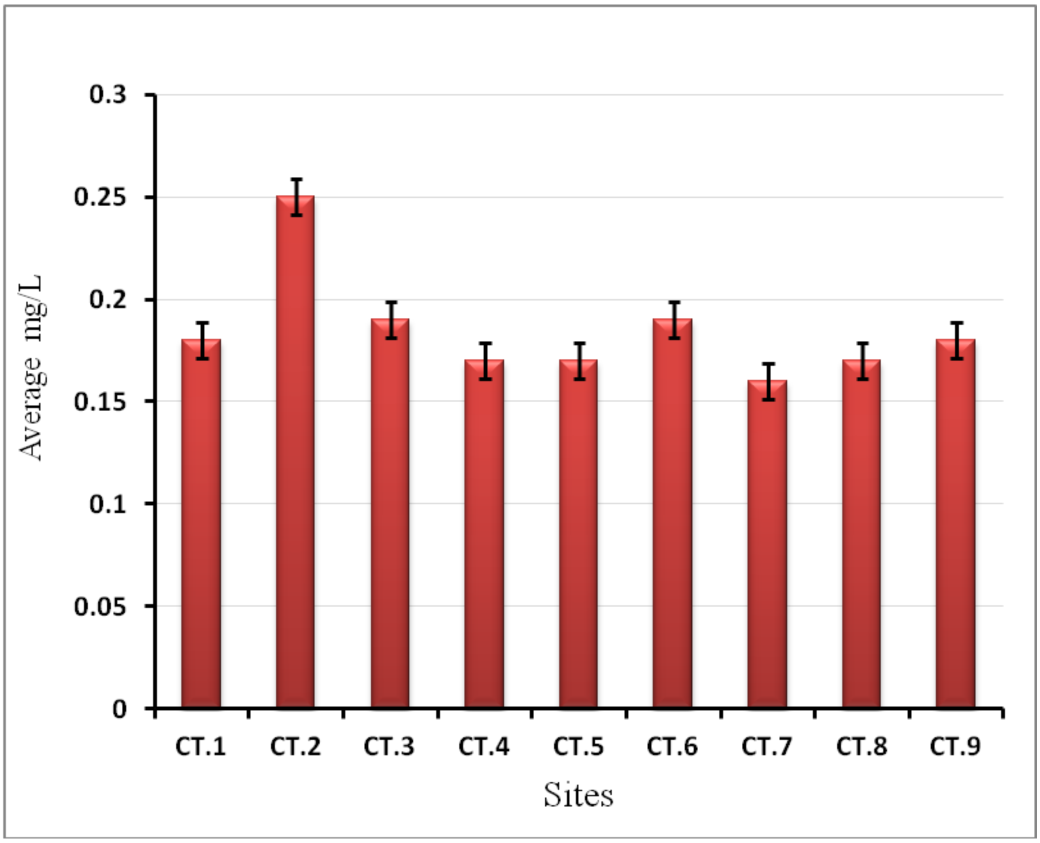

Figure (2), Regionally average for residual chlorine in summer seasons during 2010.

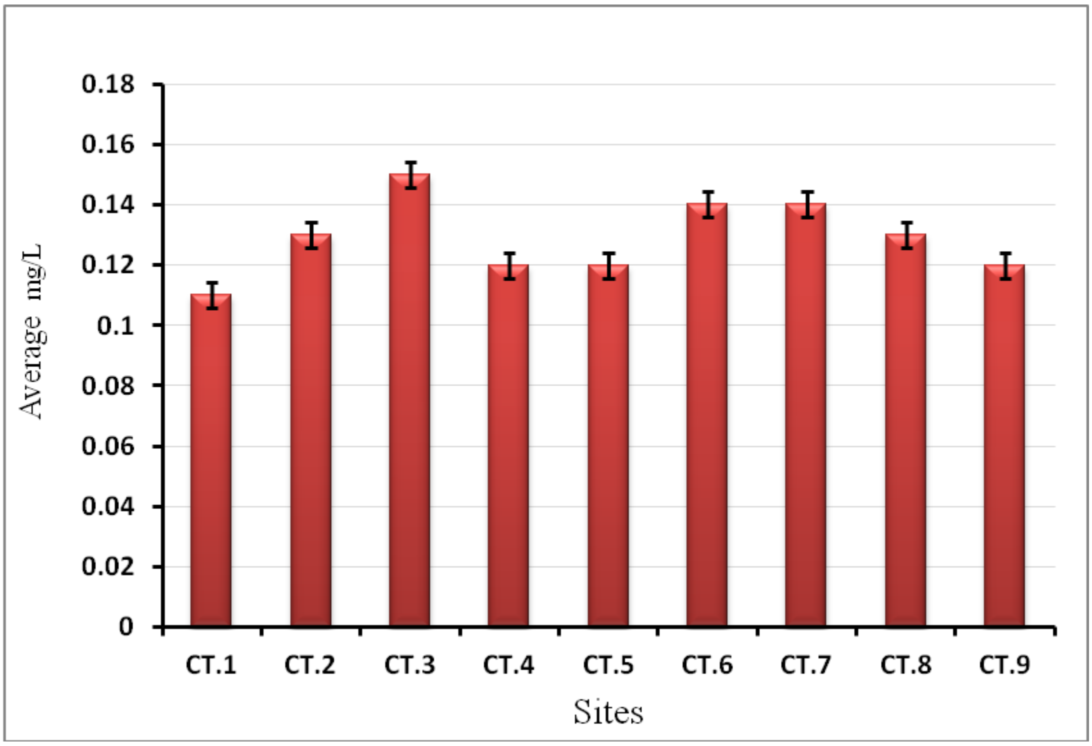

Figure (3), Regionally average for residual chlorine in winter seasons during 2010.

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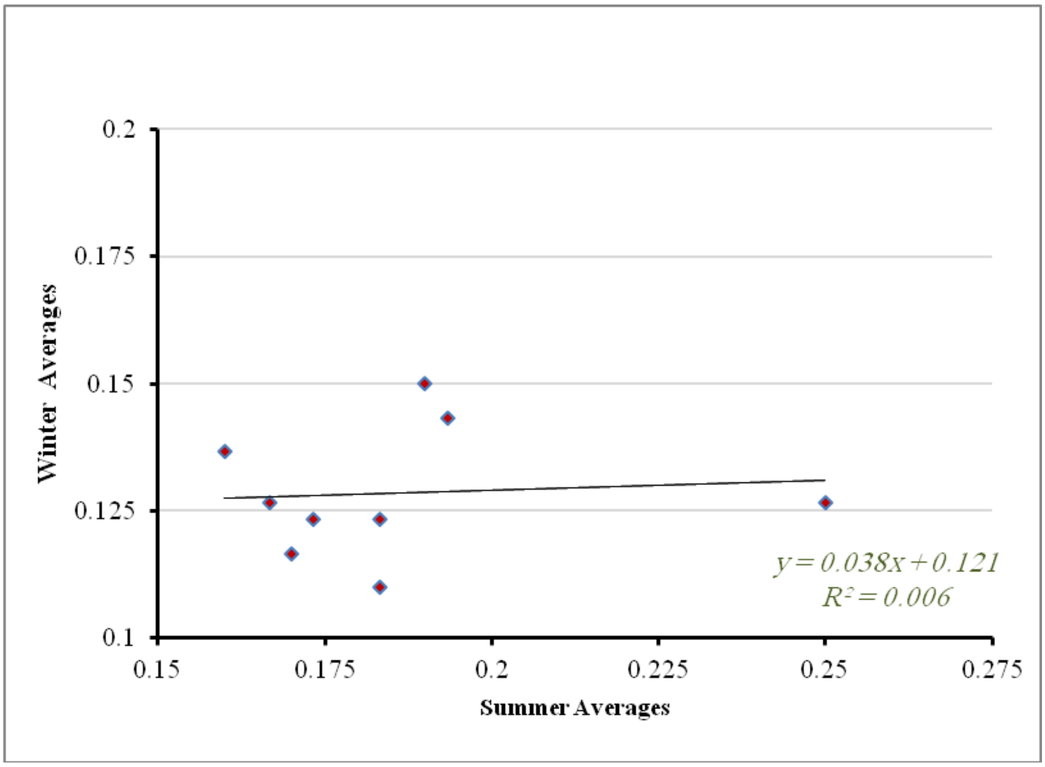
Figure (4), Correlation factor between summer & winter seasons during 2010.



Correlations

		Sammer.Avrg2010	Winter.Avrs2010
Sammer.Avrg2010	Pearson Correlation	1	.184
	Sig. (2-tailed)		.636
	N	9	9
Winter.Avrs2010	Pearson Correlation	.184	1
	Sig. (2-tailed)	.636	
	N	9	9

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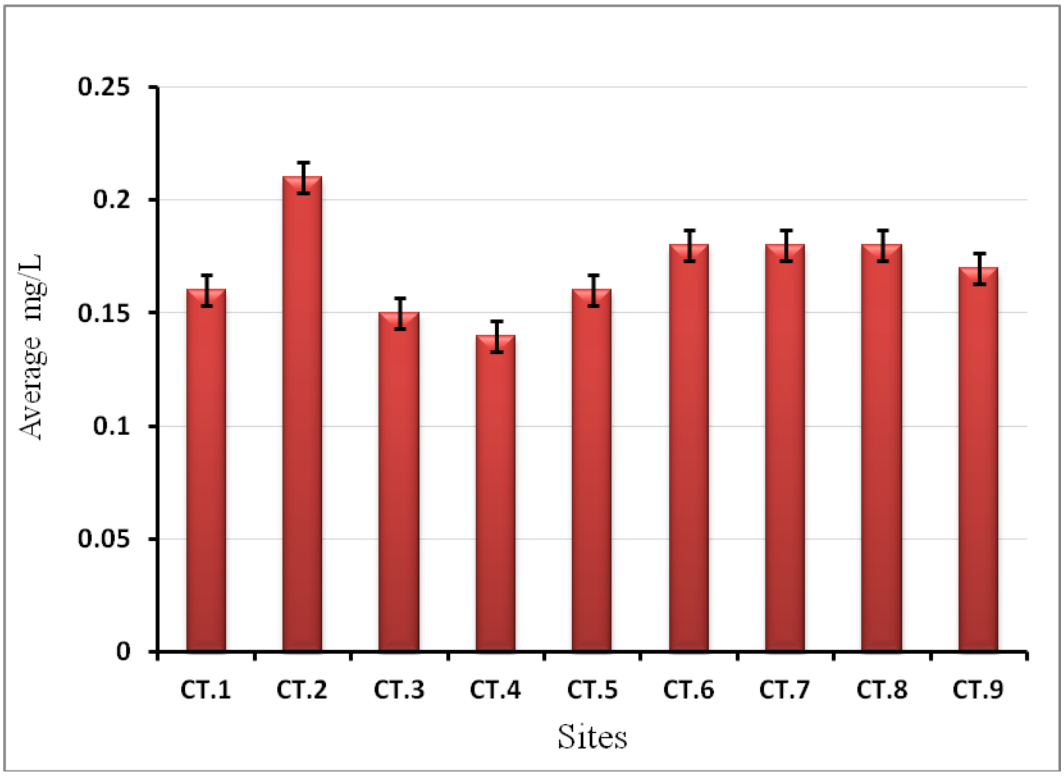

Figure (5), Regionally average for residual chlorine in winter seasons during 2011

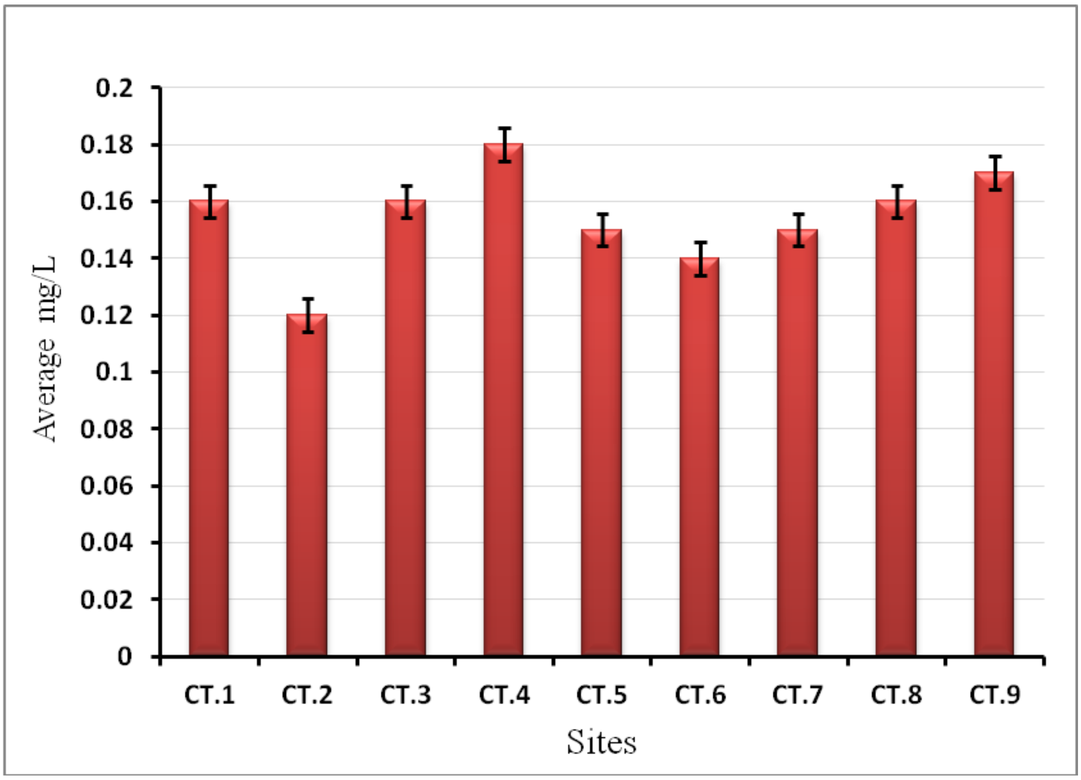

Figure (6), Regionally average for residual chlorine in winter seasons during 2011.

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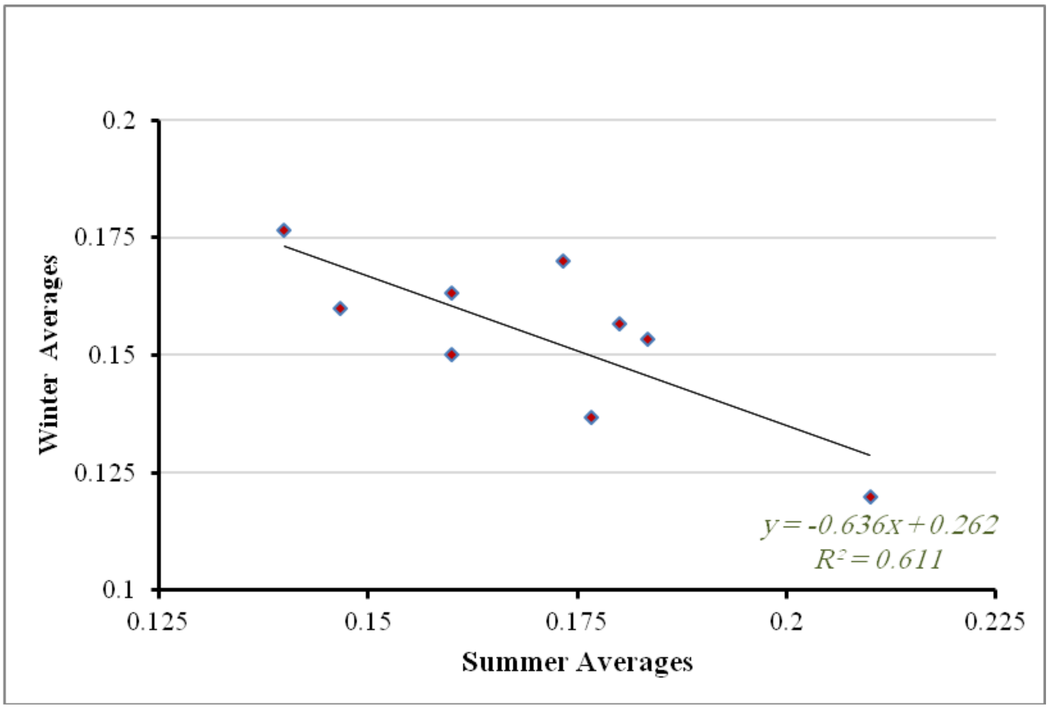
Figure (7), Correlation factor between summer & winter seasons during 2011.



Correlations

		Sammer.Avrg2011	Winter.Anrs2011
Sammer.Avrg2011	Pearson Correlation	1	-.836-**
	Sig. (2-tailed)		.005
	N	9	9
Winter.Anrs2011	Pearson Correlation	-.836-**	1
	Sig. (2-tailed)	.005	
	N	9	9

**. Correlation is significant at the 0.01 level (2-tailed).

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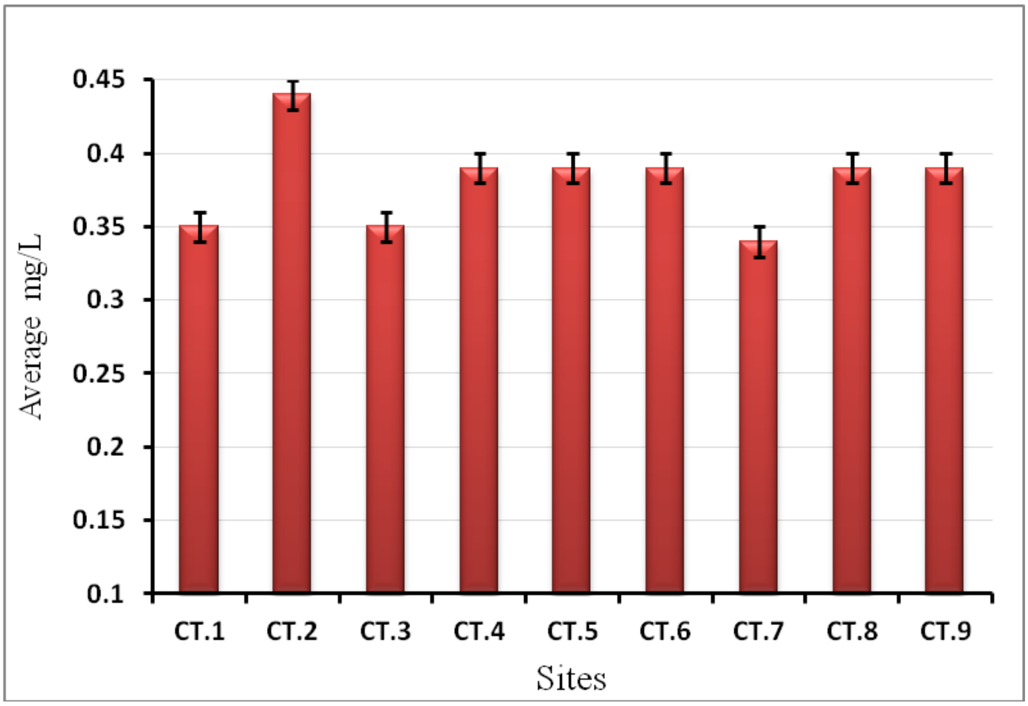

Figure (8), Regionally average for residual chlorine in summer seasons during 2012.

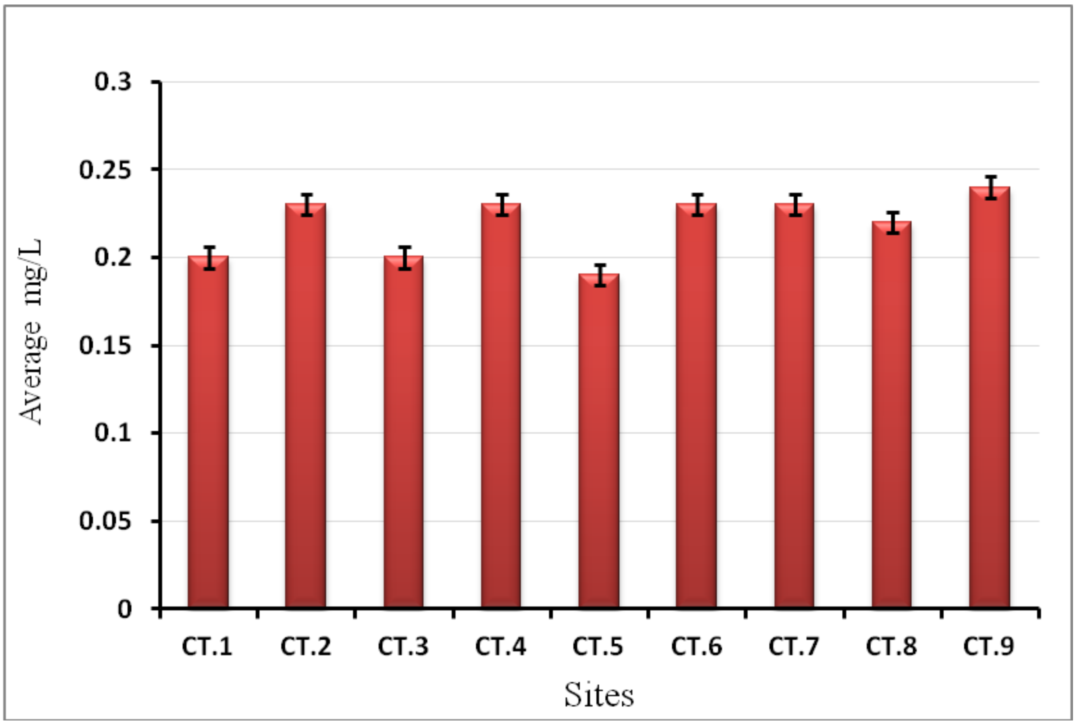

Figure (9), Regionally average for residual chlorine in winter seasons during 2012.

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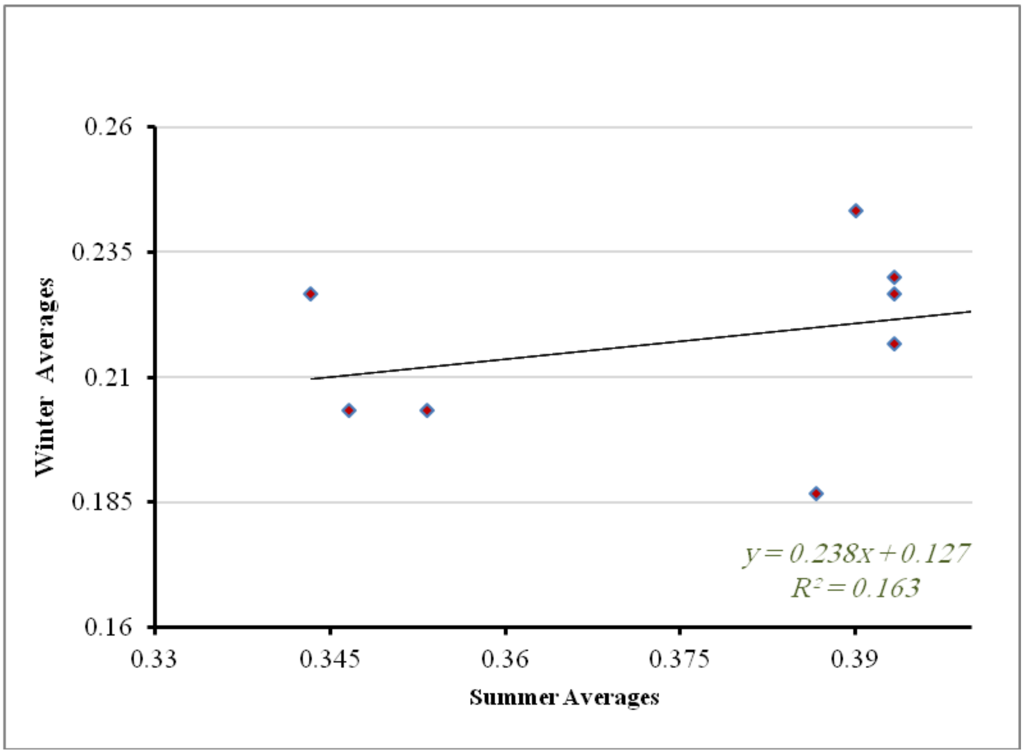
Figure (10), Correlation factor between summer & winter seasons during 2012.



Correlations

		Sammer.Avrg2012	Winter.Avrg2012
Sammer.Avrg2012	Pearson Correlation	1	.350
	Sig. (2-tailed)		.356
	N	9	9
Winter.Avrg2012	Pearson Correlation	.350	1
	Sig. (2-tailed)	.356	
	N	9	9

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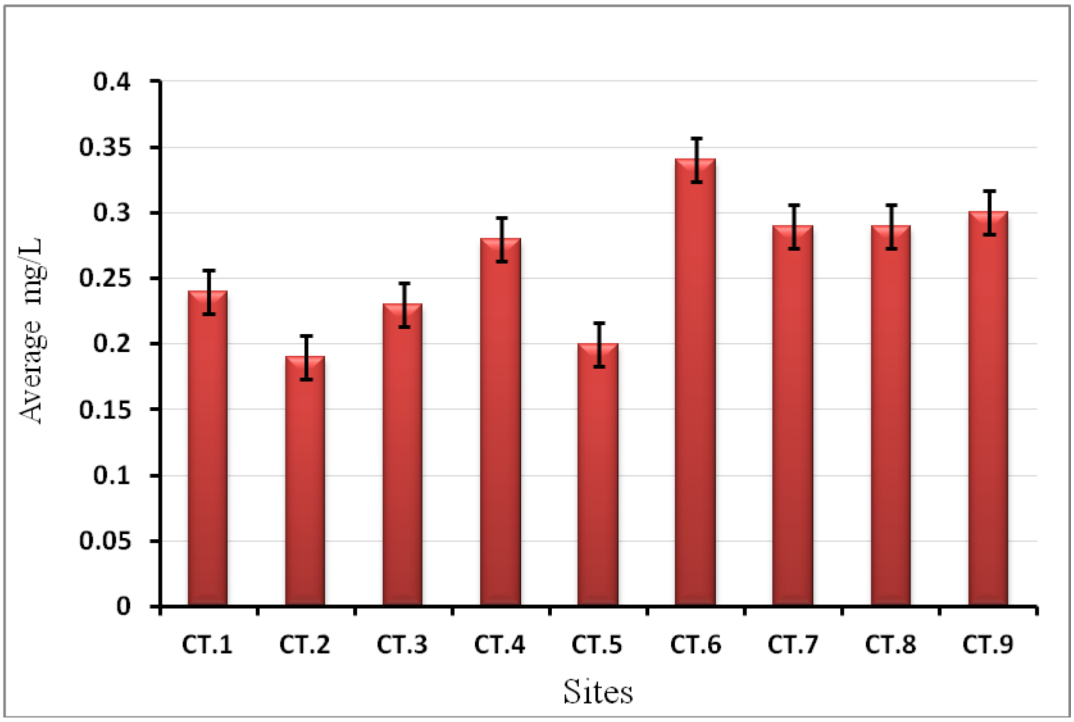

Figure (11), Regionally average for residual chlorine in summer seasons during 2013.

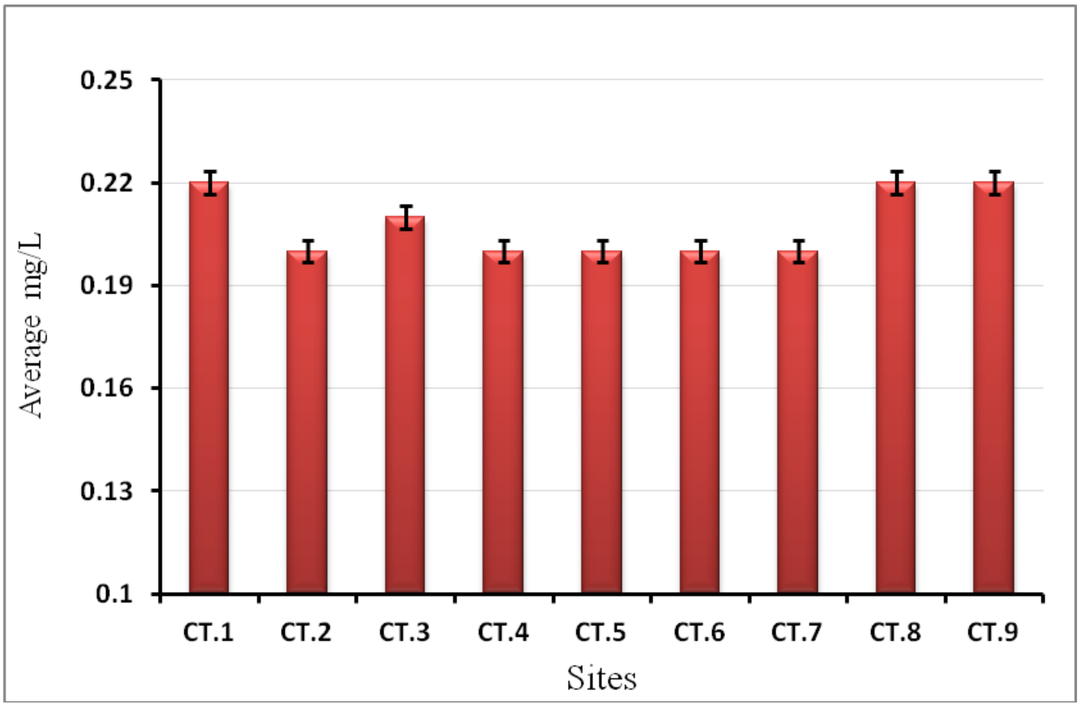

Figure (12), Regionally average for residual chlorine in winter seasons during 2013.

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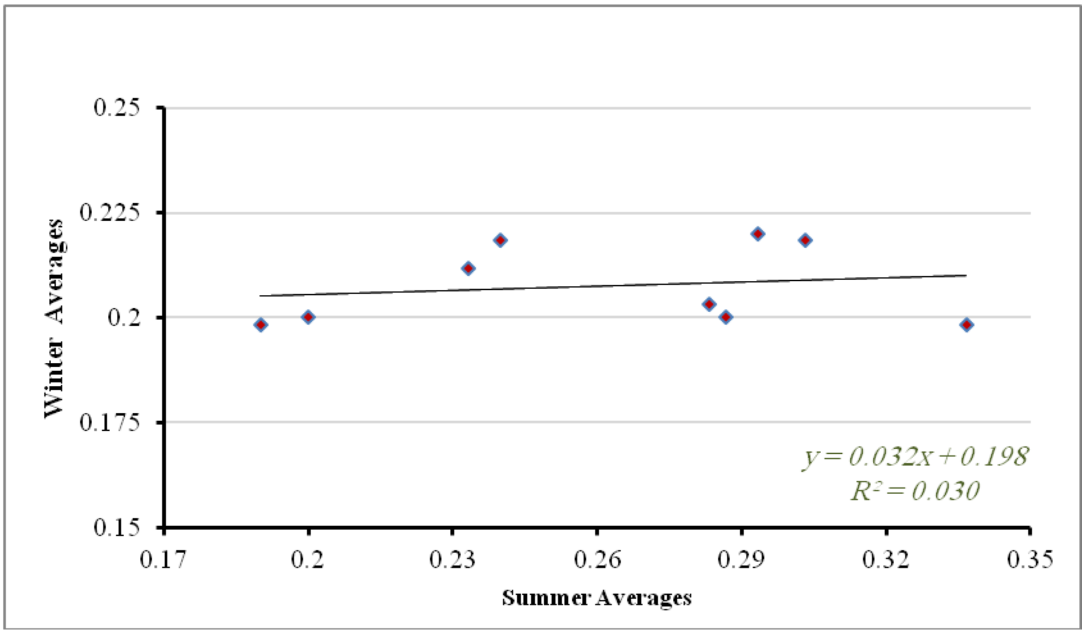
Figure (13), Correlation factor between summer & winter seasons during 2013.



Correlations

		Sammer.Avrg2013	Winter.Avrg2013
Sammer.Avrg2013	Pearson Correlation	1	.140
	Sig. (2-tailed)		.719
	N	9	9
Winter.Avrg2013	Pearson Correlation	.140	1
	Sig. (2-tailed)	.719	
	N	9	9

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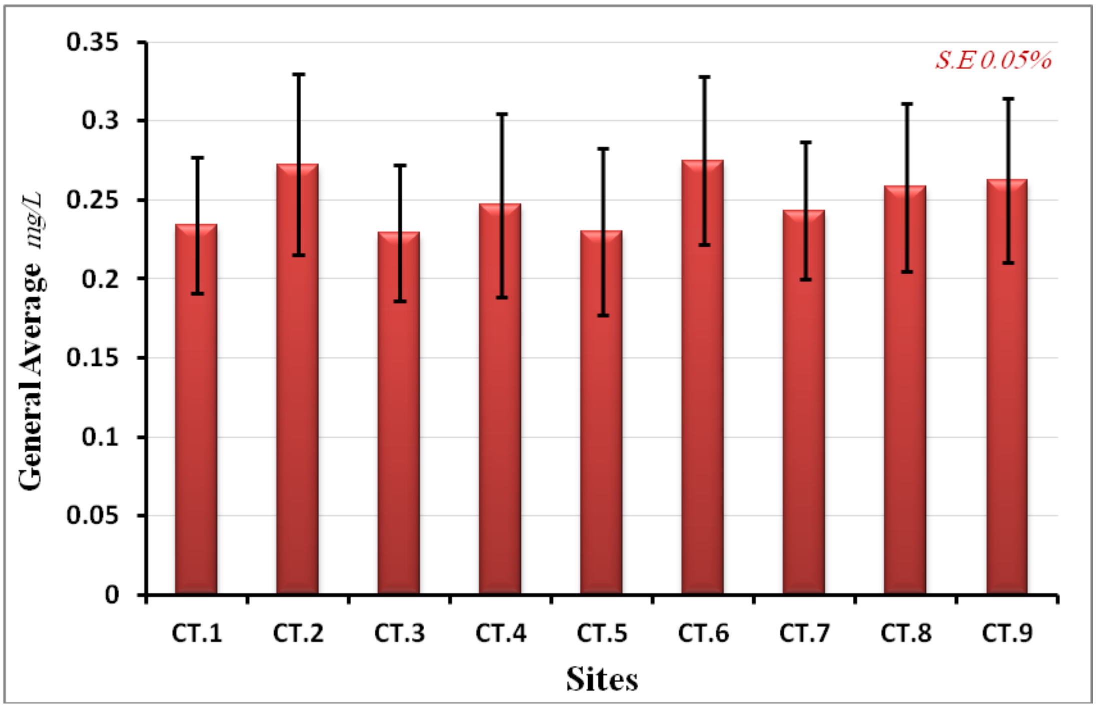

Figure (14), Regionally average for residual chlorine in summer seasons during 2010 to 2013.

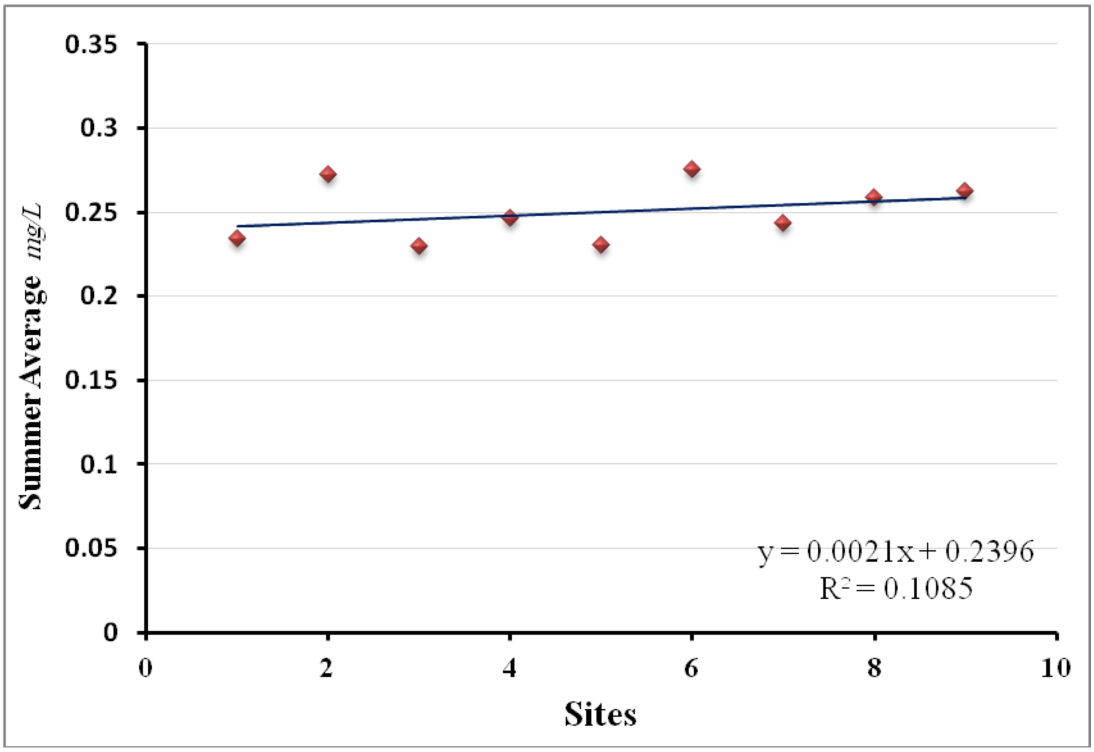

Figure (15), Correlation factor between summer seasons during 2010 to 2013.

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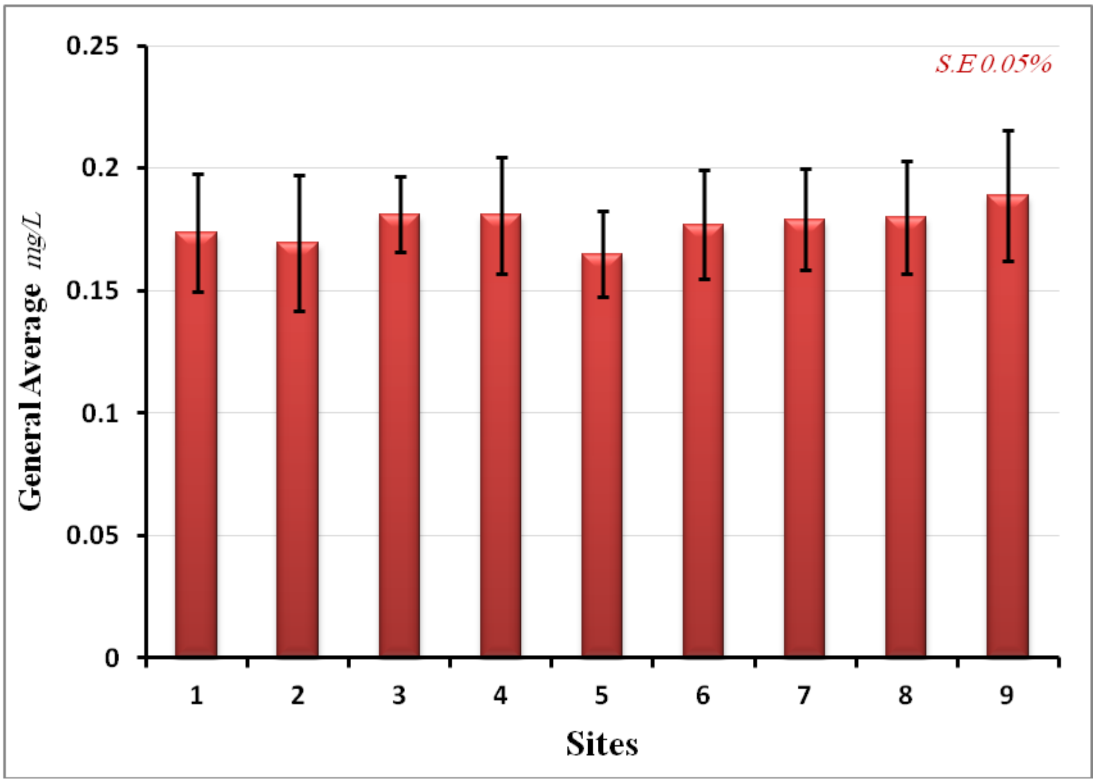

Figure (16), Regionally average for residual chlorine in winter seasons during 2010 to 2013.

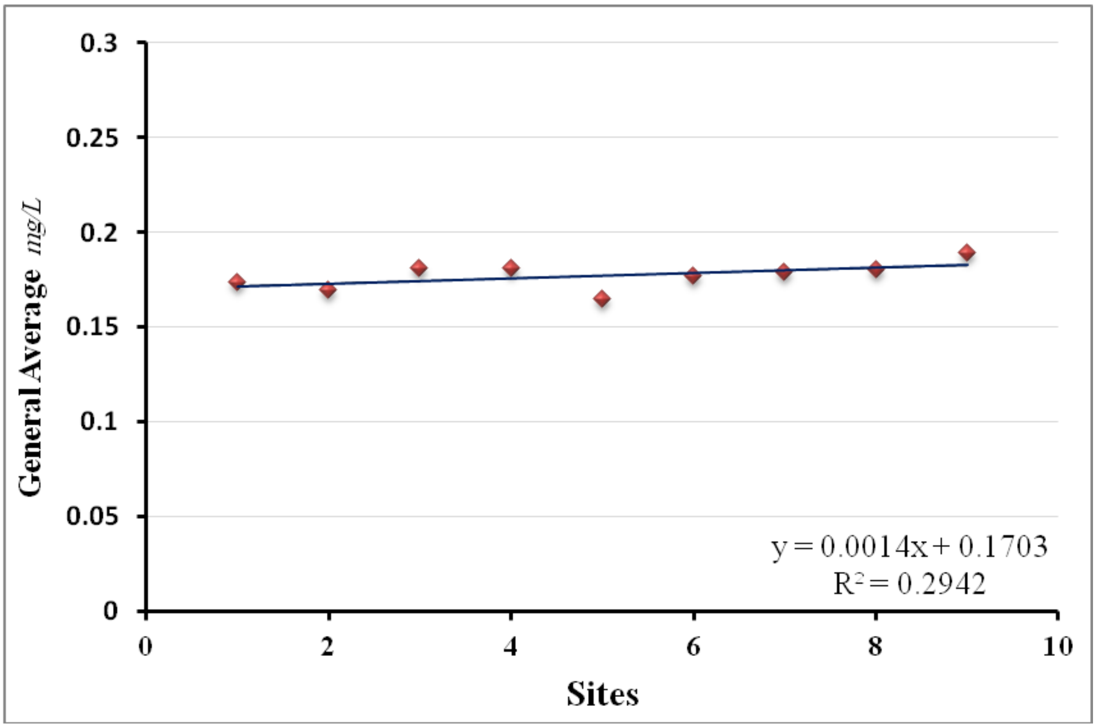

Figure (17), Correlation factor between winter seasons during 2010 to 2013.

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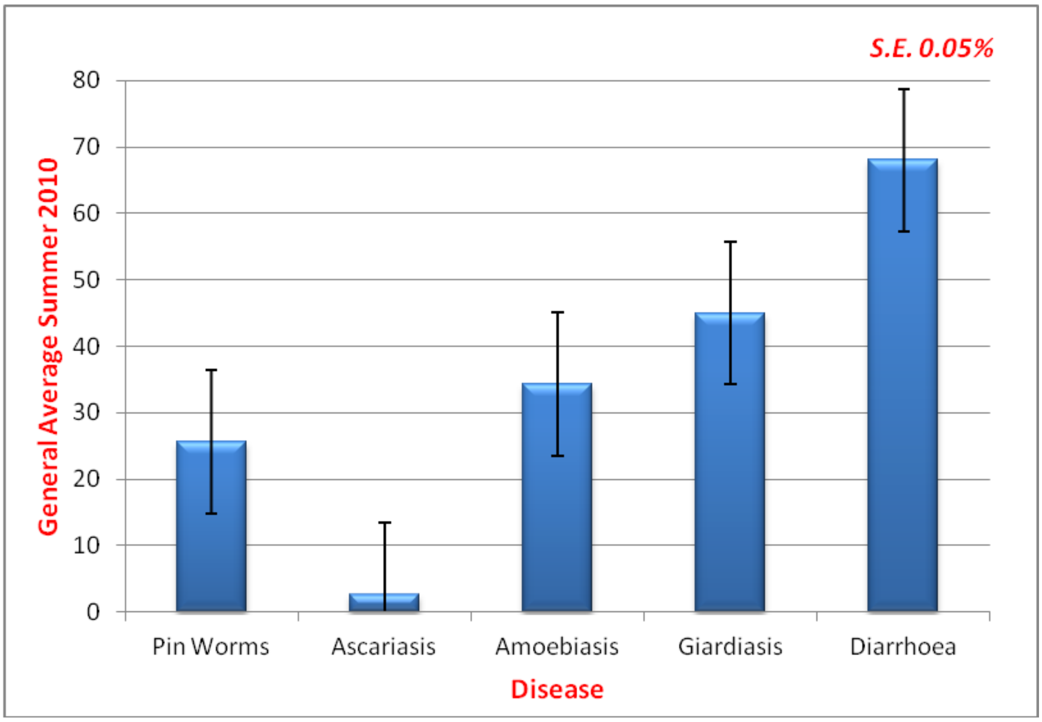

Figure (18), Average diseases reading during summer 2010.

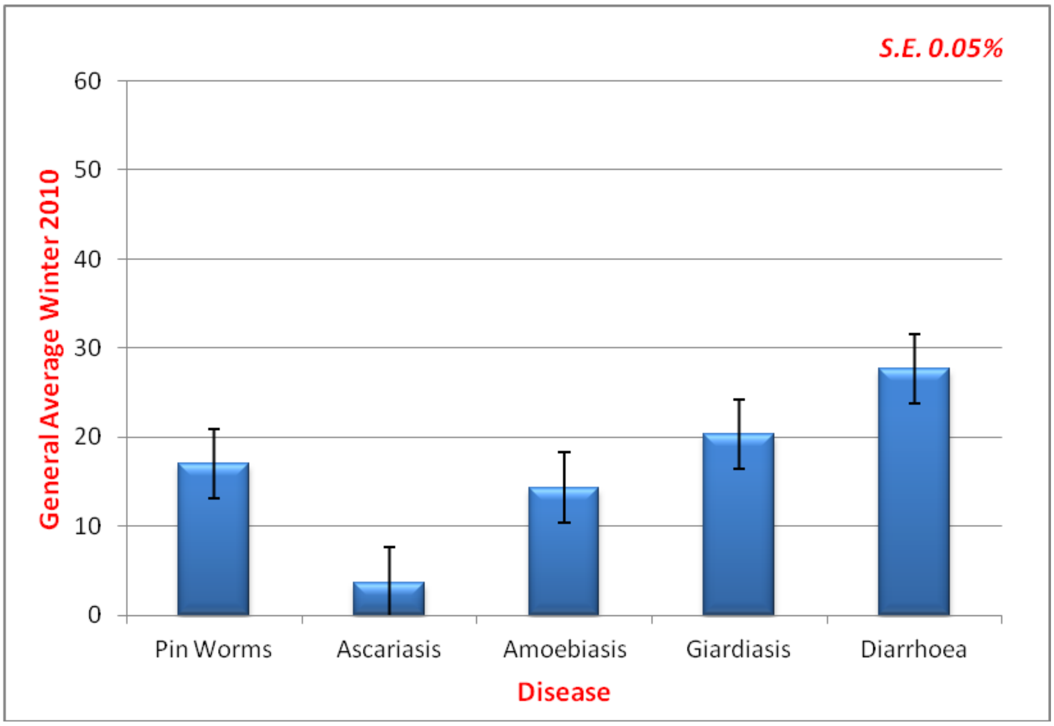

Figure (19), Average diseases reading during winter 2010.

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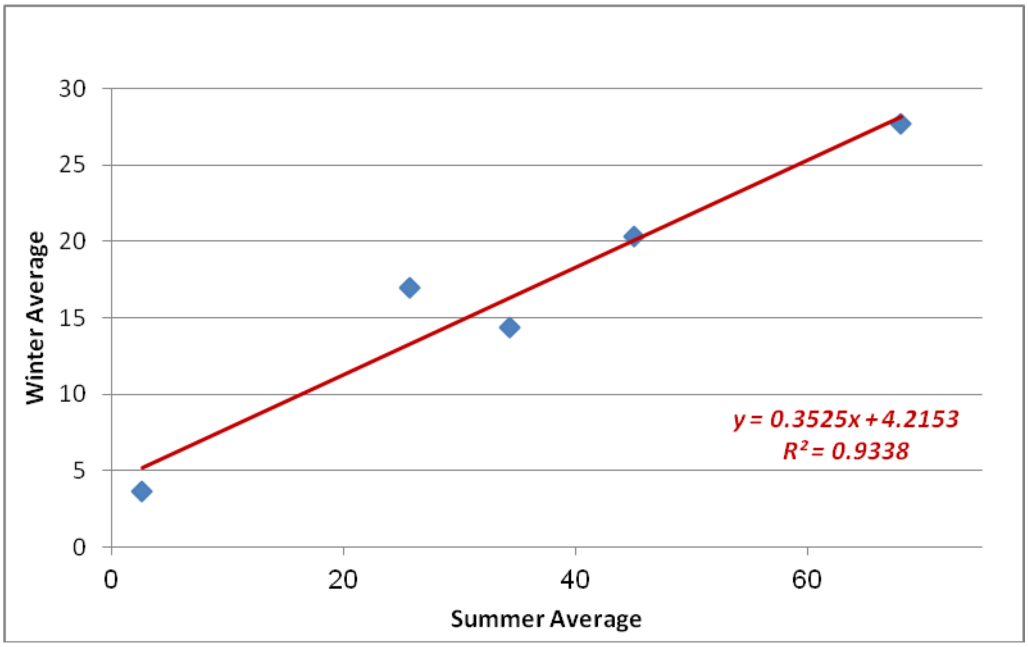
Figure (20), Correlation factors between summer and winter during 2010.



Descriptive Statistics

	Mean	Std. Deviation	N
Average.Summer2010	35.1333	24.09311	5
Average.Winter2010	16.6000	8.78888	5

Correlations

		Average.Summer2010	Average.Winter2010
Average.Summer2010	Pearson Correlation	1	.966**
	Sig. (2-tailed)		.007
	N	5	5
Average.Winter2010	Pearson Correlation	.966**	1
	Sig. (2-tailed)	.007	
	N	5	5

**. Correlation is significant at the 0.01 level (2-tailed).

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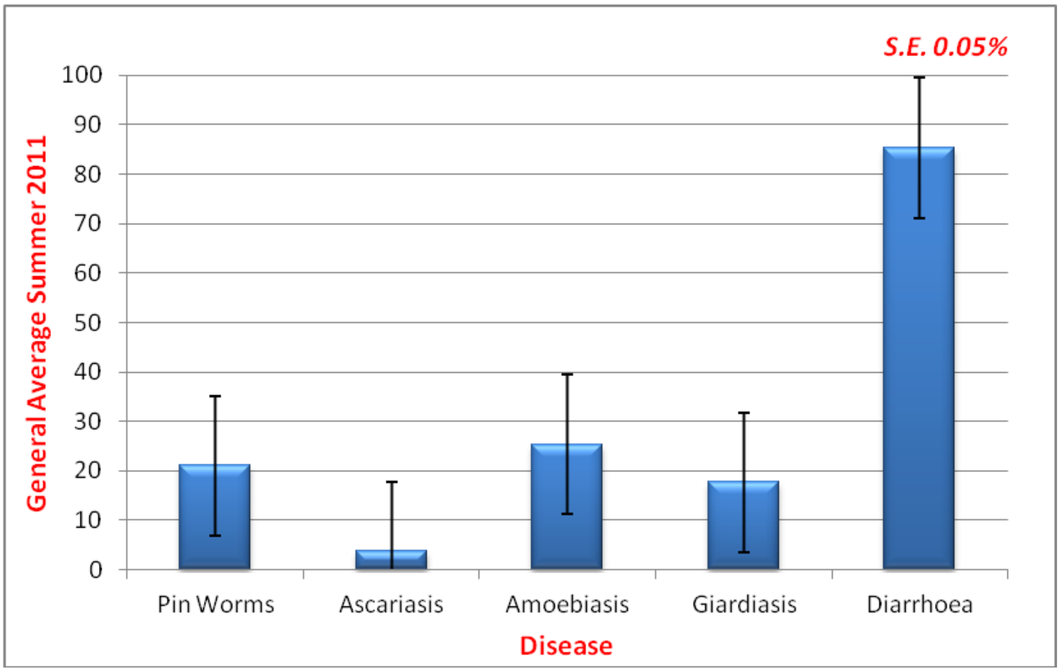

Figure (21), Average diseases reading during summer 2011.

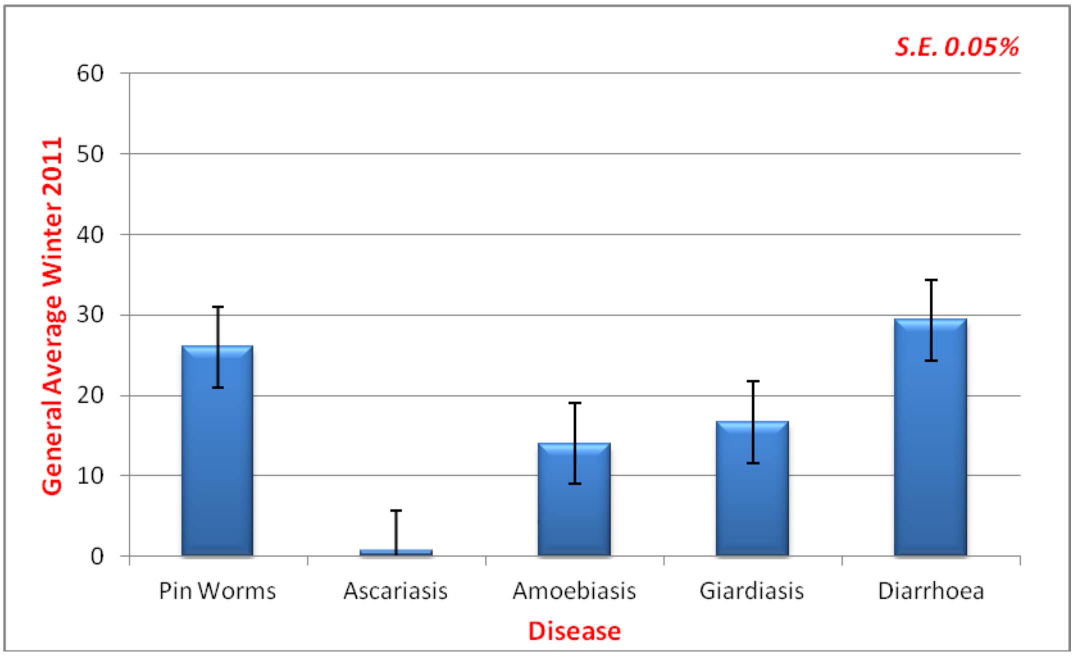

Figure (22), Average diseases reading during winter 2011.

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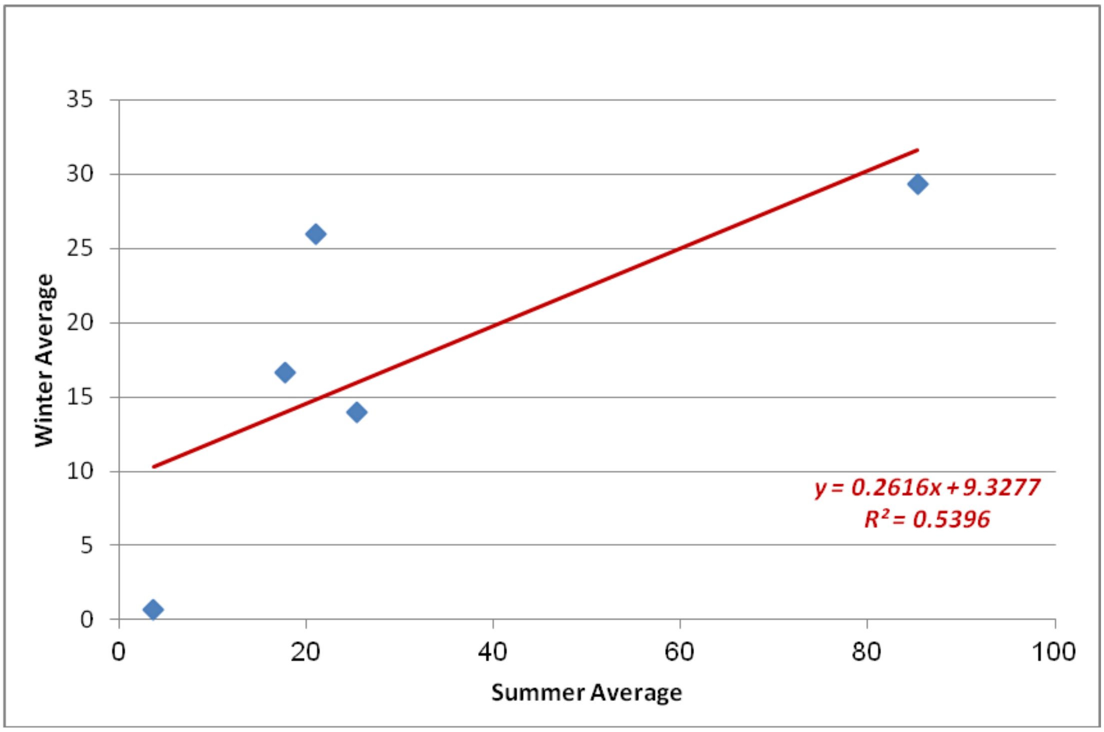
Figure (23), Correlation factors between summer and winter during 2011.



Descriptive Statistics

	Mean	Std. Deviation	N
Average.Summer2011	30.6000	31.65561	5
Average.Winter2011	17.3333	11.27436	5

Correlations

		Average.Summer2011	Average.Winter2011
Average.Summer2011	Pearson Correlation	1	.735
	Sig. (2-tailed)		.157
	N	5	5
Average.Winter2011	Pearson Correlation	.735	1
	Sig. (2-tailed)	.157	
	N	5	5

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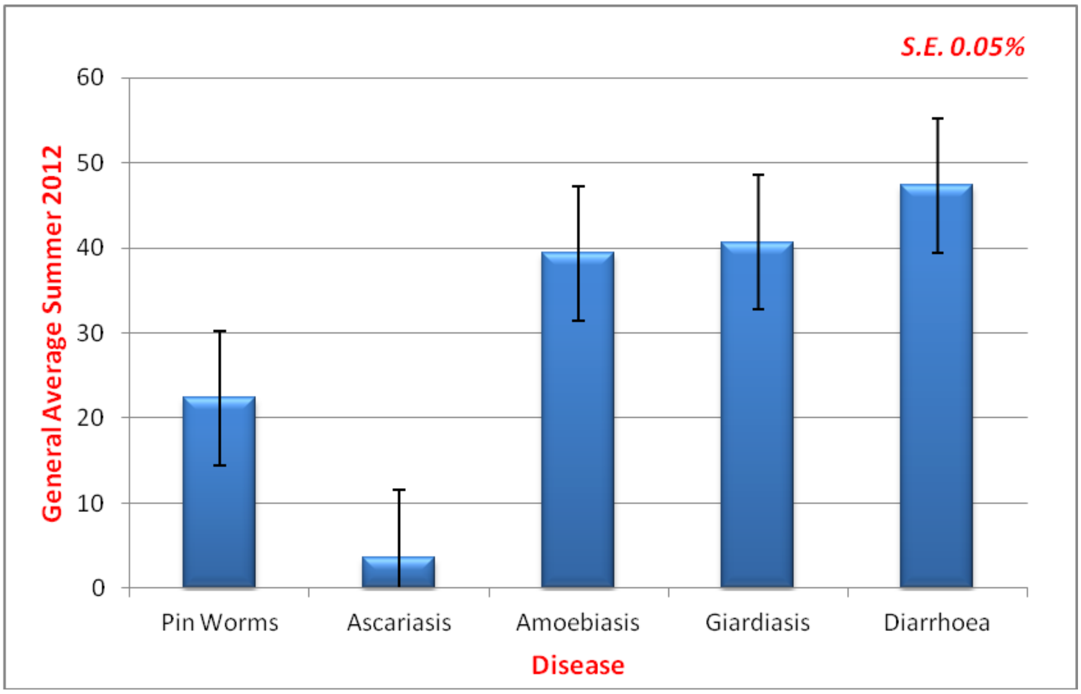

Figure (24), Average diseases reading during summer 2012.

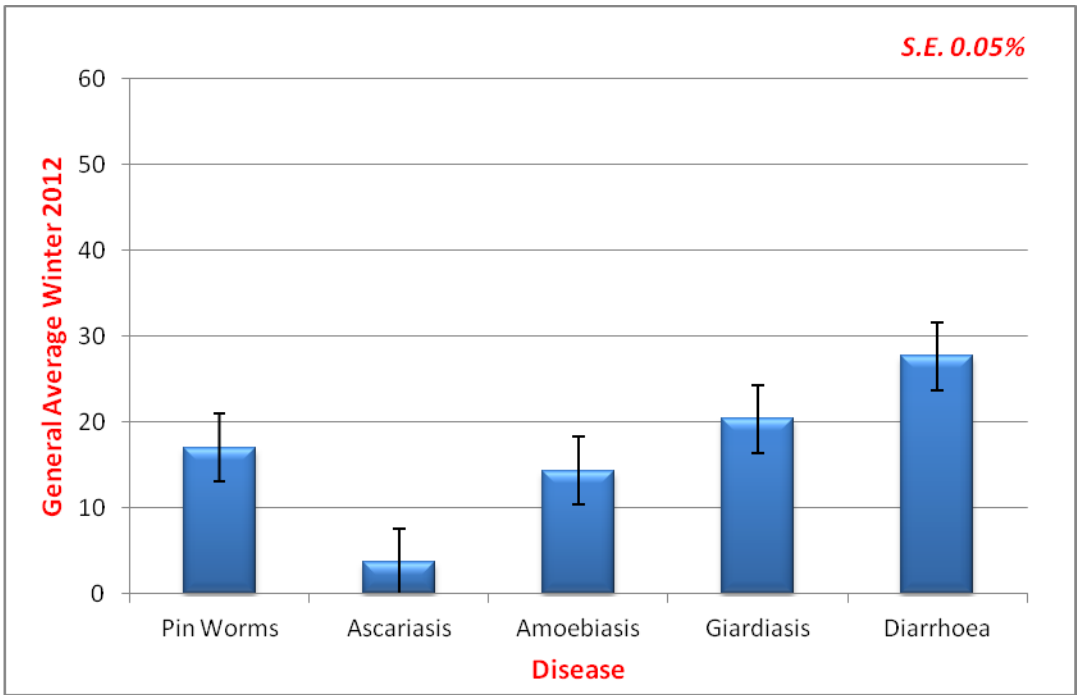

Figure (25), Average diseases reading during winter 2012.

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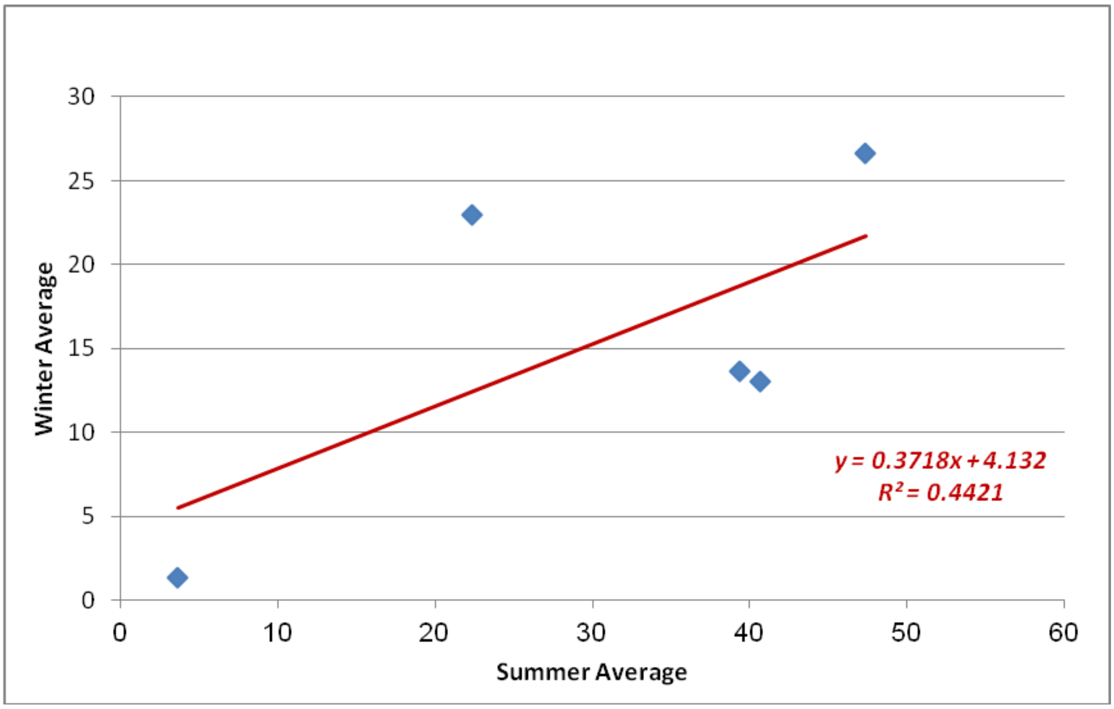
Figure (26), Correlation factors between summer and winter during 2012.



Descriptive Statistics

	Mean	Std. Deviation	N
Average.Summer2012	30.6667	17.68710	5
Average.Winter2012	15.5333	9.88995	5

Correlations

		Average.Summer2012	Average.Winter2012
Average.Summer2012	Pearson Correlation	1	.665
	Sig. (2-tailed)		.221
	N	5	5
Average.Winter2012	Pearson Correlation	.665	1
	Sig. (2-tailed)	.221	
	N	5	5

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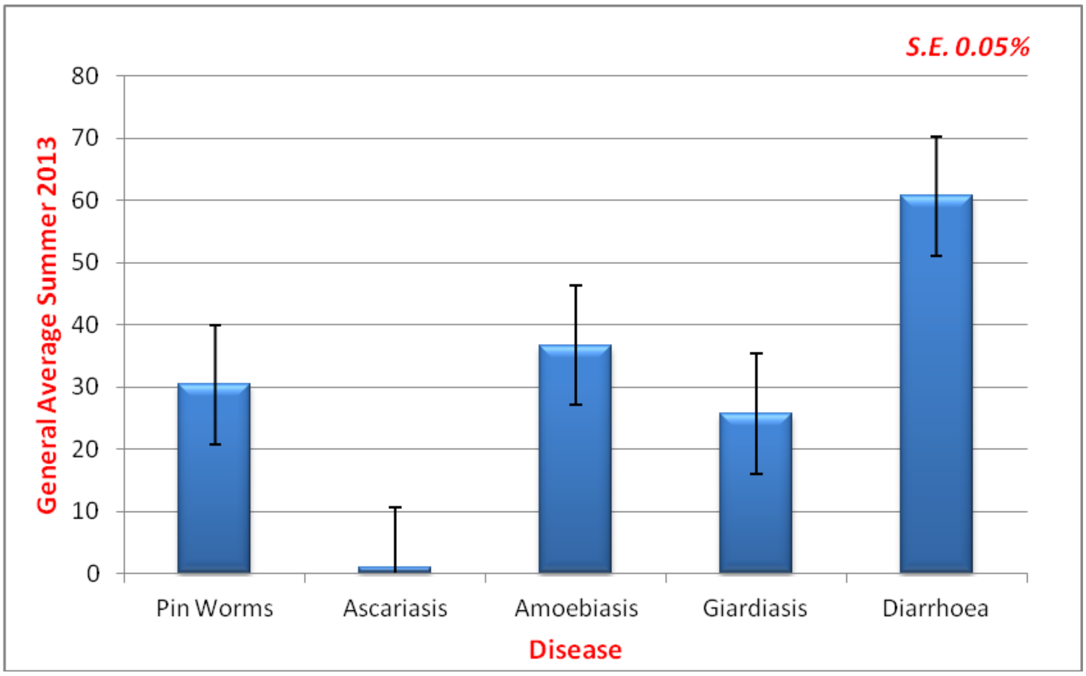

Figure (27), Average diseases reading during summer 2013.

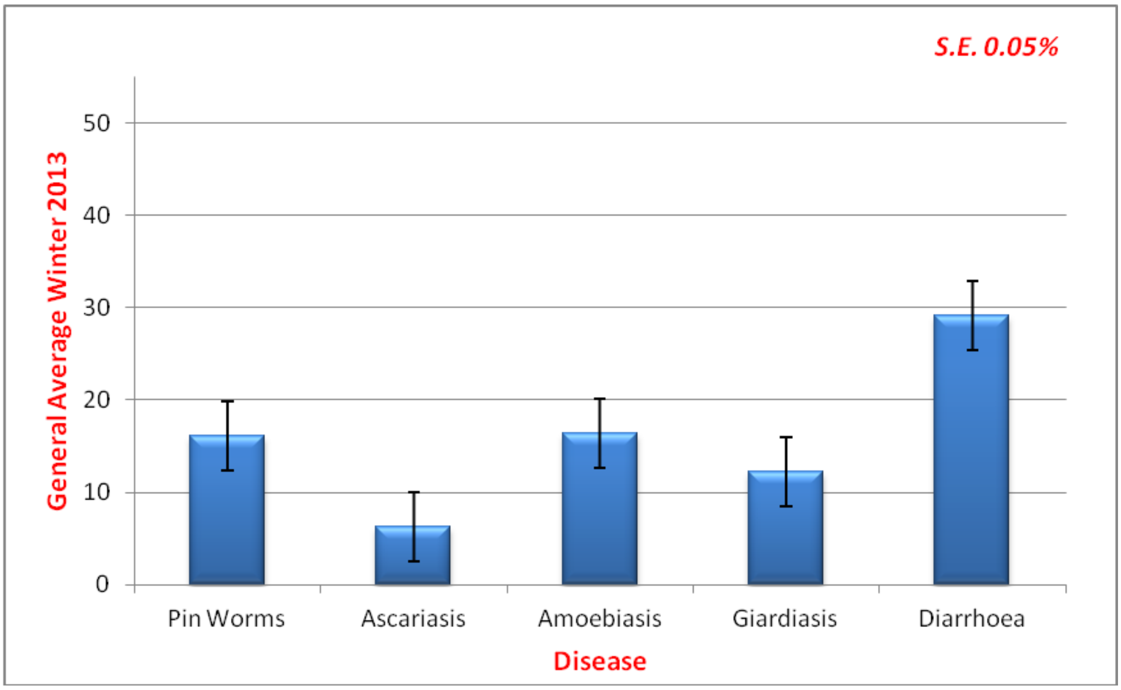

Figure (28), Average diseases reading during winter 2013.

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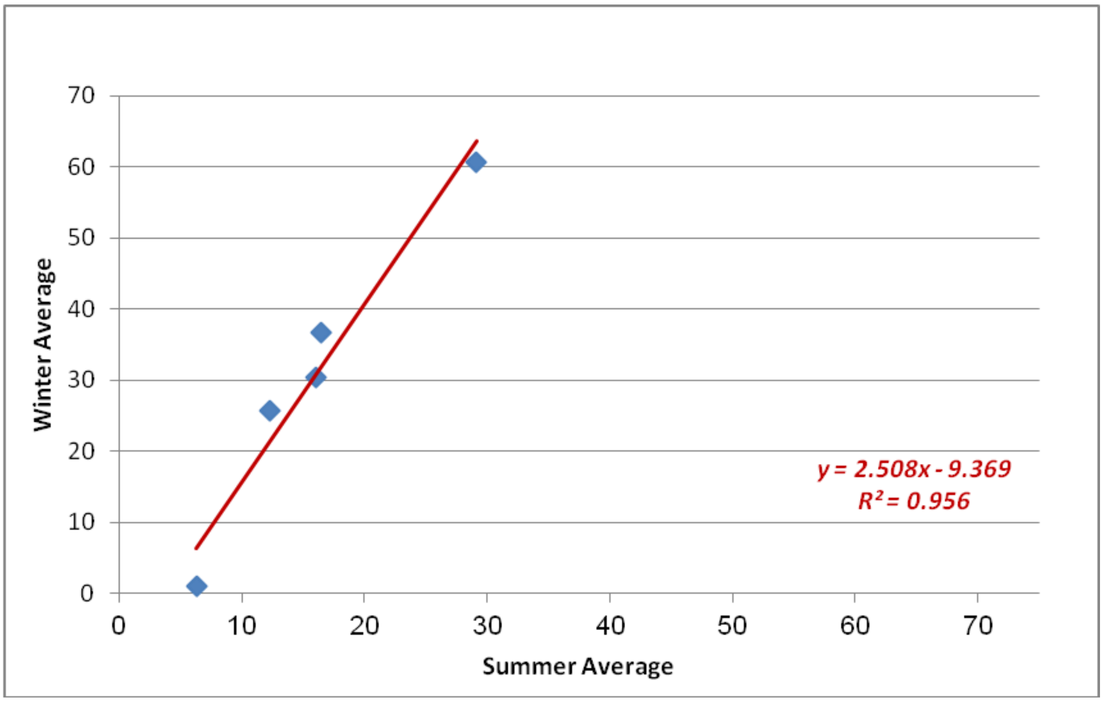
Figure (29), Correlation factors between summer and winter during 2013.



Descriptive Statistics

	Mean	Std. Deviation	N
Average.Summer2013	30.8667	21.45357	5
Average.Winter2013	16.0411	8.36558	5

Correlations

		Average.Summer2013	Average.Winter2013
Average.Summer2013	Pearson Correlation	1	.978**
	Sig. (2-tailed)		.004
	N	5	5
Average.Winter2013	Pearson Correlation	.978**	1
	Sig. (2-tailed)	.004	
	N	5	5

**. Correlation is significant at the 0.01 level (2-tailed).

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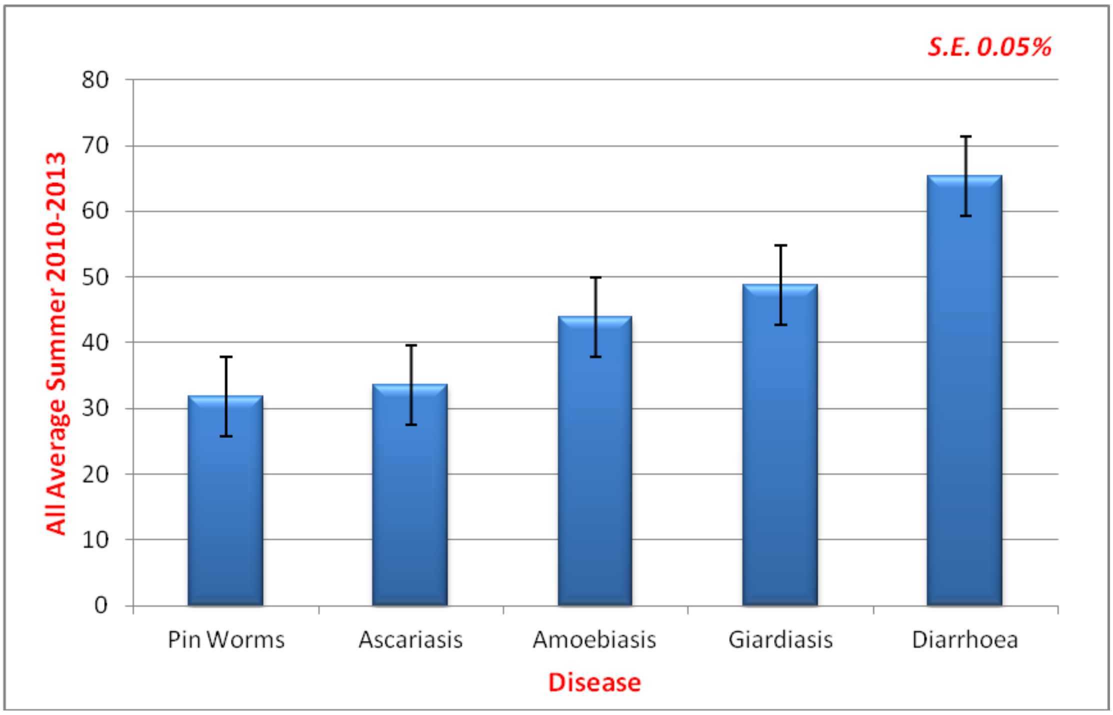
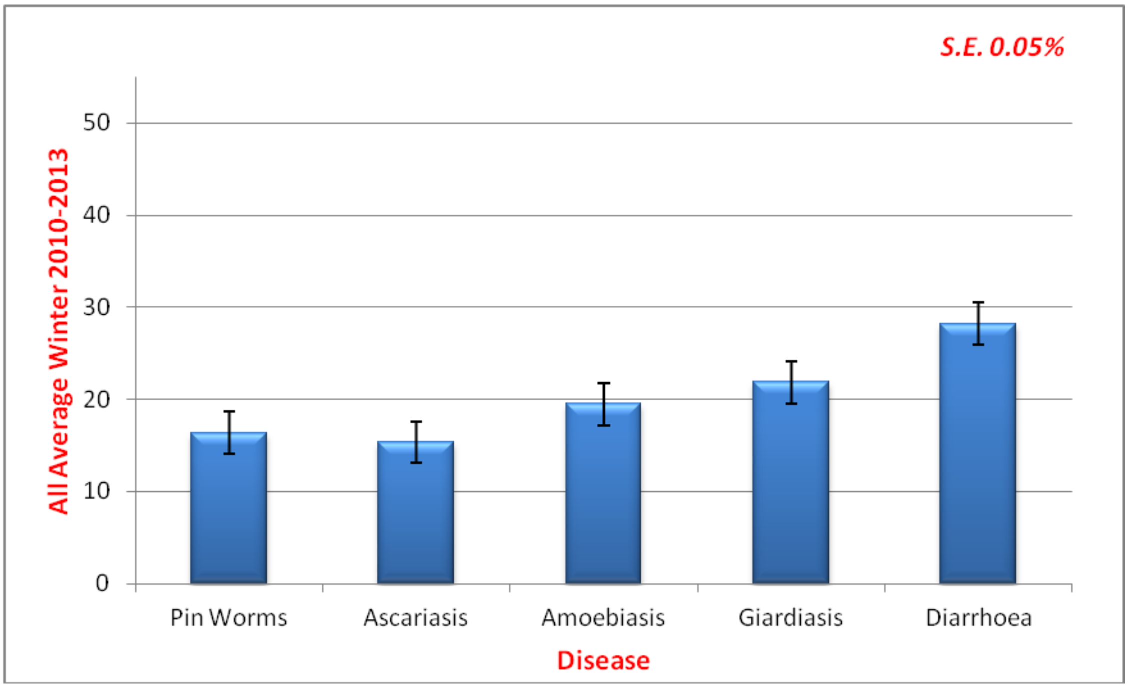


Figure(30), Average diseases reading during summer 2010 to 2013



Figure(31), Average diseases reading during winter 2010 to 2013

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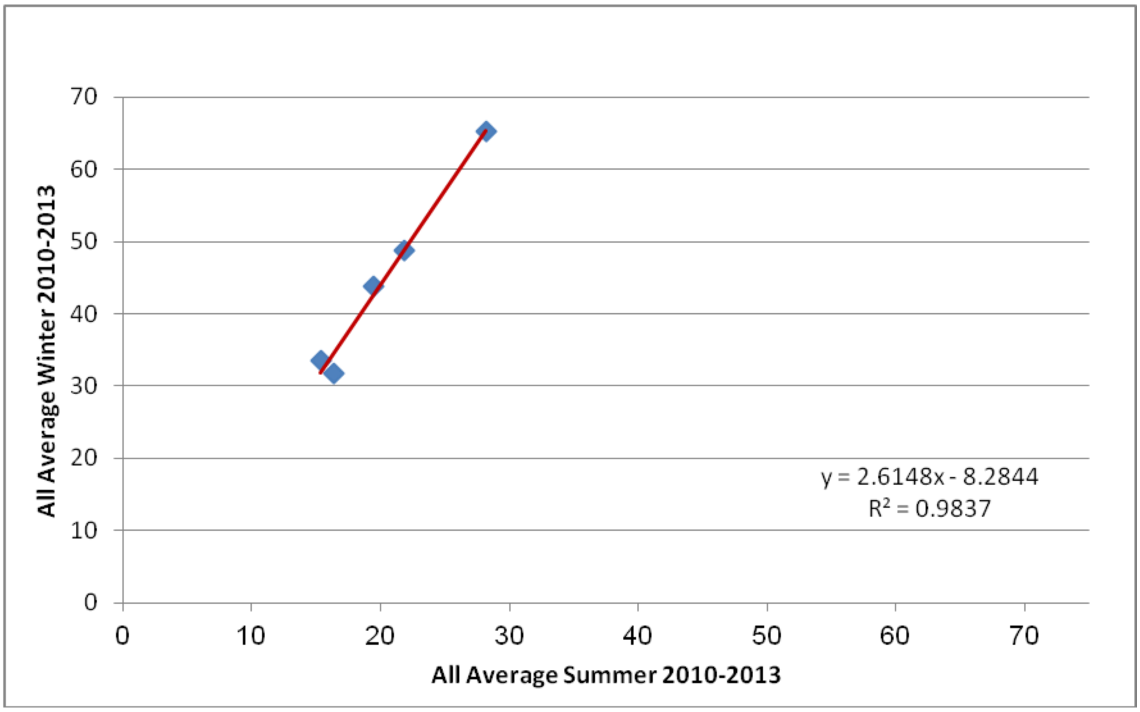
Figure(32),Correlation factors between summer and winter during 2010 to 2013



Descriptive Statistics

	Mean	Std. Deviation	N
All. Sum .Average	44.6675	13.53926	5
All. Win .Average	20.2507	5.13549	5

Correlations

		All. Summer Average	All. Winter Average
All. Sum. Average	Pearson Correlation	1	.992**
	Sig. (2-tailed)		.001
	N	5	5
All. Win. Average	Pearson Correlation	.992**	1
	Sig. (2-tailed)	.001	
	N	5	5

**. Correlation is significant at the 0.01 level (2-tailed).

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Appendix III

Descriptive Statistics

	Mean	Std. Deviation	N
Averages Chlorine in Summer	.2494	.09667	4
Pin Worms	24.8325	4.15830	4

Correlations

		Averages Chlorine in Summer	Pin Worms
Averages Chlorine in Summer	Pearson Correlation	1	-.008-
	Sig. (2-tailed)		.992
	N	4	4
Pin Worms	Pearson Correlation	-.008-	1
	Sig. (2-tailed)	.992	
	N	4	4

Descriptive Statistics

	Mean	**Std. Deviation**	**N**
Averages Chlorine in Summer	.2494	.09667	4
Ascariasis	2.7525	1.25985	4

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Correlations

		Averages Chlorine in Summer	Ascariasis
Averages Chlorine in Summer.	**Pearson Correlation**	1	.085
	Sig. (2-tailed)		.915
	N	4	4
Ascariasis	**Pearson Correlation**	.085	1
	Sig. (2-tailed)	.915	
	N	4	4

Descriptive Statistics

	Mean	Std. Deviation	N
Averages Chlorine in Summer	.2494	.09667	4
Amoebiasis	33.9150	6.07692	4

		Averages Chlorine in Summer	Amoebiasis
Averages Chlorine in Summer	**Pearson Correlation**	1	.796
	Sig. (2-tailed)		.204
	N	4	4
Amoebiasis	**Pearson Correlation**	.796	1
	Sig. (2-tailed)	.204	
	N	4	4

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Descriptive Statistics

	Mean	Std. Deviation	N
Averages Chlorine in Summer	.2494	.09667	4
Giardiasis	32.2525	12.77147	4

Correlations

		Average Chlorine in Summer	Giardiasis
Averages Chlorine in Summer	**Pearson Correlation**	1	.366
	Sig. (2-tailed)		.634
	N	4	4
Giardiasis	**Pearson Correlation**	.366	1
	Sig. (2-tailed)	.634	
	N	4	4

Descriptive Statistics

	Mean	Std. Deviation	N
Averages Chlorine in summer	.2494	.09667	4
Diarrhoea	65.3325	15.84134	4

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Correlations

		Averages Chlorine in Summer	Diarrhoea
Averages Chlorine in Summer	**Pearson Correlation**	1	-.912-
	Sig. (2-tailed)		.088
	N	4	4
Diarrhoea	**Pearson Correlation**	-.912-	1
	Sig. (2-tailed)	.088	
	N	4	4

Descriptive Statistics

	Mean	Std. Deviation	N
Averages Chlorine in Winter	.1775	.04291	4
Pin Worms	20.5175	4.77402	4

Correlations

		Averages Chlorine in Winter	Pin Worms
Averages Chlorine in Winter	**Pearson Correlation**	1	.021
	Sig. (2-tailed)		.979
	N	4	4
Pin Worms	**Pearson Correlation**	.021	1
	Sig. (2-tailed)	.979	
	N	4	4

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Descriptive Statistics

	Mean	Std. Deviation	N
Averages Chlorine in Winter	.1775	.04291	4
Ascariasis	2.9950	2.55752	4

Correlations

		Averages Chlorine in Winter	Ascariasis
Averages Chlorine in Winter	**Pearson Correlation**	1	.159
	Sig. (2-tailed)		.841
	N	4	4
Ascariasis	**Pearson Correlation**	.159	1
	Sig. (2-tailed)	.841	
	N	4	4

Descriptive Statistics

	Mean	Std. Deviation	N
Averages Chlorine in Winter	.1775	.04291	4
Amoebiasis	14.6100	1.24940	4

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		Averages Chlorine in Winter	**Amoebiasis**
Averages Chlorine in Winter	**Pearson Correlation**	1	.275
	Sig. (2-tailed)		.725
	N	4	4
Amoebiasis	**Pearson Correlation**	.275	1
	Sig. (2-tailed)	.725	
	N	4	4

Descriptive Statistics

	Mean	**Std. Deviation**	**N**
Averages Chlorine in Winter	.1775	.04291	4
Giardiasis	15.5700	3.71019	4

Correlations

		Averages Chlorine in Winter	**Giardiasis**
Averages Chlorine in Winter	**Pearson Correlation**	1	-.969-*
	Sig. (2-tailed)		.031
	N	4	4
Giardiasis	**Pearson Correlation**	-.969-*	1
	Sig. (2-tailed)	.031	
	N	4	4

* Correlation is significant at the 0.05 level (2-tailed).

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Descriptive Statistics

	Mean	Std. Deviation	N
Averages Chlorine in Winter	.1775	.04291	4
Diarrhoea	28.1950	1.25522	4

Correlations

		Averages Chlorine in Winter	Diarrhoea
Averages Chlorine in Winter	**Pearson Correlation**	1	-.223-
	Sig. (2-tailed)		.777
	N	4	4
Diarrhoea	**Pearson Correlation**	-.223-	1
	Sig. (2-tailed)	.777	
	N	4	4

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