Deanship of Graduate Studies

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Water Quality Index (WQI) for Water Resources in Jenin District

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Water quality index (WQI) for water resources in Jenin district

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Dedication

To the heart I love my husband Sakher

To my soul Malaak and Kareem

To my father Sami and my mother Nuha

To my beloved family for their support

Lubna Ibrahim

Declaration

I certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged and that this thesis (or any part of the same) has not been submitted for a higher degree to any other university or institution.

Signed:

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Thanks God for helping and supporting me.

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Abstract

The water quality index is a key, and useful tool for determining the quality and suitability of drinking water for the end consumers. The study of water quality index has been carried on the ground water of Jenin governorate, by collecting 36 samples from 9 deep wells covering more than 97% of the study area. The water quality index was developed by subjecting the samples to a comprehensive physicochemical analysis to the major 12 parameters that directly affect the quality of drinking water such as: pH, fecal coliform, total hardness, total dissolved solids, magnesium, sodium,calcium, potassium, sulphate, chloride, nitrate, and fluorides. The WQI has been calculated, and the values ranged from 25.6 to 71.6 which means good to excellent water quality levelfor the total of 36 samples.The water quality index in water distribution networks was also calculated for Jenin city by adding free chlorine as an additional parameterto detect the quality of water at the point of consumption and compare it with its original source. The WQI in the water distribution networks decreased and the level of water quality was ranged from good to excellent for the study area. This present study reveals that the groundwater in Jenin governorate is suitable for drinking and human consumption.

مؤشر جودة المياه (WQI) لموارد المياه في منطقة جنين

إعداد: لبنى سامي مجيد إبراهيم

المشرف: د. عامر مرعي.

الملخص

يعد مؤشر جودة المياه أداة رئيسية ومفيدة لتحديد جودة ومدى ملاءمة مياه الشرب للمستهلك النهائي. تم إجراء دراسة لمؤشر جودة المياه على المياه الجوفية في محافظة جنين من خلال جمع 36 عينة من 9 آبار عميقة تغطي أكثر من 97٪ من مساحة الدراسة. تم تطوير مؤشر جودة المياه عن طريق إخضاع العينات لتحليل كيميائي و فيزيائي يشمل أهم اثنى عشر من العناصر الكيميائية والفيزيائيةالتي تؤثر بشكل مباشر على جودة مياه الشرب وهي: الأس الهيدروجيني، القولونيات البرازية، عسر الماء الكلي، اجمالي المواد الصلبة الذائبة، المغنيسيوم، الصوديوم، الكالسيوم، البوتاسيوم، الكبريتات، الكلوريد، النترات، الفلورايد. تم حساب مؤشر جودة المياه لمحافظة جنين وتراوحت القيم من 25.6- 71.6 اذ تشير هذه النتائج أن مستوى جودة المياه يتراوح بين الحاله الجيده الى الممتازه. كما تم حساب مؤشر جودة المياه في شبكات توزيع المياه لمدينة جنين عن طريق إضافة الكلورالحركمؤشر اضافي للعناصر الفيزيائية والكيميائية الأخرىللكشف عن نوعية المياه عند

نقطة الاستهلاك ومقارنتها بمصدرها الأصلي. انخفض مؤشر جودة المياه في شبكات توزيع المياه وكان مستوى جودة المياه يتراوح من جيد إلى ممتاز في شبكات المياه التي تغطي مدينة جنين.تشير نتائج هذه الدراسة أن المياه الجوفية في محافظة جنينصالحة للشرب والاستهلاك الادمي.

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List of abbreviations

Abbreviation	Title
MCM/Y	Million cubic meters per year
NEAB	North-Eastern Aquifer Basin
Km^2	Square kilometers
WHO	World Health Organization
PCBS	Palestinian Central Bureau of Statistics
WQI	Water Quality Index
PWA	Palestinian Water Authority
PCBS	Palestinian Central Bureau Statistics
ARIJ	Applied Research Institute –Jerusalem
TDS	Total Dissolved Solids
WDS	Water Distribution Networks
Mm	millimeters
ppm	Parts per Million
WBWD	West Bank Water Department
MoH	Ministry of Heath
TH	Total Hardness
ICP-OES	Inductively Coupled Plasma Optical Emission Spectroscopy
PSI	Palestinian Standard institution
l/c/d	Liter per capita per day

Chapter One:

Introduction

1.1 Background

Water is the basis of life for all beings;the world suffers from the lack of fresh water, as a result of excessive human consumption, it is an important issue in every community in world not only in the Middle East (Daghrah, 2010). Palestine is not far from this, it suffers from scarcity of water resources due to natural, and man-made practices, mainly as a result from the Israeli occupation (ARIJ, 2015).

Over a period of time the shortage of water will increase in Palestine and become a real problem because of population growth, expected climate change, higher standards of living, and mainly, Israeli restrictions and practices imposed on the water resources (ARIJ, 2015).

Palestine has three main sources of freshwater including; the West Bank's Aquifer, the Jordan River, andthe Coastal Aquifer (ARIJ, 2015).Israel controls nearly all shared water resources (surface and ground water)therefore, water resourcesare inadequate to meet the demands of the present population (Al-Khatib et al., 2003).

Groundwater is the main source of fresh water in the West Bank for the Palestinians, and provides over than 90% of all water supplies (PWA, 2012).

Three main groundwater basins are dominant in the West Bank located according to regional groundwater flow directionsthese are: theeastern, western and northeastern aquifers, all are shared with Israel.The annual sustainable yield of the aquifers are shown in Table 1.1.

Table 1.1: Reported aquifer basin recharge (PWA, 2012).

Basin	Recharge (MCM/Y)
Eastern	145-185
North Eastern	100-145
Western	362-400
Total	607-730

The North Eastern Aquifer Basin (NEAB) extends from the area south of Nablus to the north beyond the borders of the West Bank(see figure 1.1). This basin is the smallest of the three groundwater basins, its area is about 1424 km^2, and has the smallest portion of recharge (PWA, 2012).

Figure 1.1: Water resources in West Bank & Gaza Strip(PWA, 2017).

The annual sustainable yield of the NEAB has ranged from 100-145 MCM. In spite of this, the Israelis utilize this aquifer at a rate of nearly 103 MCM/Y, majority of this quantity taken from springs in Galbou' Area.In 2012, The Palestinian use around 23 MCM/Y, from springs and wells, most of this quantity being from the shallow Eocene aquifer(PWA, 2012).

This study was carried out in the northern of the West Bank, particularly in Jenin city and the area around it. Jenin Governorate is one of the West Bank governorates that has critical water resources, it lies over the North-Eastern Aquifer.

Ground water is considered the main source of water in Jenin area which represented by both wells and springs (Ra’fat, 2012). One significant study that provides suitable knowledge about quality of groundwater is the water quality index (WQI) for evaluating the quality of groundwater as well as its appropriateness for drinking purposes.

Water quality index "WQI" was developed for the first time by Horton in the early 1970s, is mainly a mathematical means of calculating a single value that derived from multiple test results. The index result represents the level of water quality in aim study area. After Horton a number of workers all over the world developed WQI based on rating of different water quality parameters (Miller et al., 1986).

A water quality index gives a single number that expresses overall water quality based on several water qualityparameters at a particular location and time. A single number cannot tell the whole story of water quality; there are many other water quality parameters that are not included in the index. However, a water quality index based on some very important parameters can provide a simple indicator of water quality (Yogendra and Puttaiah, 2008).

Although Water Quality Index (WQI) is usually orientated to qualify urban water supply, it has been widely used by environmental planning decision makers. The quality of the groundwater has to be evaluated to avoid or, at least, to minimize impacts on human health (Mohammed, 2011).

This study attempt to evaluate the water quality status for the main groundwater resources in Jenin district for drinking purposes by the water quality index (WQI).

1.2 Research Goal and Objectives

The main research goal of this thesis is to calculate water quality index (WQI) for drinking water in Jenin depending on the analysis of 12 parameters in 4 years (2015 – 2018) for 36 samples from 9 deep wells.

The specific objectives are:

- To classify water in Jenin into excellent quality, good, poor, very poor, or unfit for drinking.
- To study the changes in the water quality along the period for the study area.
- To depict the overall water quality status by converting complex water quality data into understandable information that is helpful for the choice of suitable treatment techniques and for legislative decisions.

1.3 Beneficians of the work

This work is of high importance, as this index improve health, environmental protection and economy.

Chapter two

Study Area

2.1 Location and Population

Palestine is divided into two physically separated areas known as the West Bank with a total area 5.661 km^2 and Gaza Strip with a total area 362 km^2 according to (PCB, 2017).

The total population of Palestine according to the Palestinian Central Bureau of Statistic as the end of 2017, was approximately4.781.248 persons. The population of the West Bank was nearly 2.881.957 persons, and 1.899.291 persons in Gaza Strip(PCBS, 2017). The West Bank inhabitants irregularly distributed through the eleven governorates which are Jericho& Al Aghwar, Ramallah& Al bireh, Bethlehem, Hebron, Jerusalem, Nablus, Qalqiliya, Tulkarm, Jenin, Tubas& Northern Valleys and Salfit) (ARIJ, 2010).

Jenin Governorate (the Study area) has an area of about 583$km^2$is located in the northern part of the West Bank, with highest point reaches 750 m above sea level and the lowest elevation is 90 m above sea level (ARIJ, 1996).

Jenin's population was 314.866 persons at the end of 2017 living in 84 communities, 61.2% of the total population living in urban areas, 35.5 % in rural areas, and 3.3% are from Jenin Refugee Camp (PCBS, 2017).

2.2 Topography

Jenin district topography are divided into three areas:

1. The eastern slopes.
2. Mountain crests.
3. Western slopes.

2.3 Environmental Situation

Palestine in general and Jenin in particular has the Mediterranean Sea climate, mild and rainy in winter, hot and dry in summer(ARIJ 1996). The rain is the only source that feeds the groundwater aquifers. In the West Bank rainfall vary from the western slopes (700–850) mm, to (100–150) mm in the eastern regions and from (500-800) mm in the mountainous regions annually.

In Jenin area, the rainy season begins in the middle of October and extend to the end of April. The relative humidity in the governorates reaches 65.5%. During winter the humidity increase to 84% and drops to 39% in May (Saqer, 2005).

2.4 Water Sources

Besides the groundwater which is the main source of water for the Palestinian peoples, Jordan River is the only source of surface water that the Palestinians don’t have the ability to use because of Israeli occupation restrictions. Moreover, rainwater is an additional source of water Palestinians depend on (PWA, 2015).

2.5 Available water resources and water use

According to Oslo Ⅱ agreement(September 28, 1995)Israel is committed to supply the Palestinians with 1.4 MCM/Y for Jenin area to domestic uses.Supplying water for several purposes in Jenin area is limited by the productivity and availability of wells and springs in addition to the quota which has been set by Israel (ARIJ, 1996).

Jenin Governorate depends mainly on groundwater, as the rest of the West Bank cities, where its water resources are from wells and springs. Around 63 artesian wells in Jenin used for domestic and irrigation uses, 58 of them are owned by the private sector and used mainly for irrigation. The remaining five wells are owned by either the municipalities such as (Jenin and Ya'bad municipal wells) or by Israeli Mekorot water company like (Arabba', Qabatiya and Sanour wells) used for domestic supplies.There are 42 springsIn Jenin; most of them lose the water through the run-off, they are seasonal and drought- prone (Yala, 2017).

Israel provided Jenin of 104 million cubic meters yearly of water for daily uses in accordance with Oslo agreement (13 Sep, 1993). Moreover the rainwater harvesting wells are an extra source of water to people (Saqer, 2005).

Winter in Jenin starts normally in the mid-October and ends in April. Around 3.2% of the rainfall falls in October annually, while around 80% falls in November to February annually. The rainfall starts to decline in March around 12% and rare in June to September (ARIJ, 1996).

Chapter Three

Literature Review

The previous studies of the Water Quality Index (WQI) studied the groundwater resources for domestic and drinking purposes in different countries such as India and Iran and others in the world. The main findings of these studies are as follows:

- **Logeshkumaran et al. 2015;** has studied the geochemical characteristics of the drinking water in Anna Nagar, Tamil Nadu, India. By collecting some of the groundwater samples and analyze specific parameters such as: pH, electrical conductivity, total dissolved solids, carbonate, bicarbonate, chloride, sulphate, nitrate, calcium, magnesium, sodium, potassium and total hardness. Obtained results of the study has relieved that the groundwater is pure and clean. According to WQI, the results show that the majority of the samples are good to excellent and suitable for drinking water purposes. Na and Cl are dominant ions among cations and anions
- **Mohebbi et al. 2013;**conducted a study about the water quality in all resources of the groundwater that are used for drinking water in urban areas of Iran in 2011. The study indicated that the modified DWQI and its sub-indices could describe the overall water quality of water bodies easily, reliably and correctly and have the potential suitability for extensive application all over the world. The modified DWQI contains the two sub-indices: health-based index as "modified HWQI" and acceptability index as "modified AWQI". The modified DWQI and its sub-indices scores range from 0 to 100 and classify water quality in five categories as poor, marginal, fair, good and excellent, respectively.

- **Tyagi et al. 2013;** the only valuable and unique to rate anddepictthe overall status of water quality in a single term that help to select the useful mechanism to match the needed issuesis Water Quality index (WQI). It indicates and depicts the compositions of the water resources with different qualities and provides the information about the water to the public and legislative decision makers. Some of the attempts have been made to review the WQI to determine the best water drinking resources.
- **Ketata-Rokban et al. 2011;**evaluated the quality of the groundwater in El Khairat deep aquifer in Enfidha City-in northeastern Tunisia to know its suitability for the drinking water purposes.For the first time an attempt has been made in order to identify the spatial distribution for the quality of the groundwater parameters, and also to determine the best quality places for drinking through the study according to an integrated analysis of physical-chemical parameters by using the Geographical Information System in addition to Water Quality Index calculation. WQI was used to evaluate the groundwater suitability in the study area for human consumption. A comparison of the physical and chemical results was made with the WHO standard guidelines for drinking and public health, in order to have an overview of the present groundwater quality. To determine the suitability of groundwater in the study area for human consumption WQI, was used. From the WQI assessment, the results indicate that more than 82% of the water samples are in ‘‘Poor’’ and ‘‘Very poor’’ standing categories, suggesting that groundwater from the south-eastern of the El Khairat deep aquifer is unsuitable for drinking purposes.
- **Aghazadeh et al. 2010;**identifies both of physical and chemical parameters of groundwater like electrical conductivity, pH, Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}, total dissolved solids, HCO_3^{-}, CO_3^{-2}, Cl^{-}, SO_4^{-2}, NH_3, PO_4^{-2}, NO_3^{-}, Fe^{+3}, F^{-}. So this study has

evaluated the groundwater quality in the Oshnavieh plain is part of the West Azarbaijan province, northwestern of Iran. According to the analytical outcomes, groundwater in that area is mostly fresh and hard to very hard. The profusion of the major ions is as follows: HCO_3^->SO_4^{-2}>Cl^- and Ca^{+2}>Mg^{+2}>Na^+>K^+. The dominant hydro chemical facieses of groundwater is Ca-HCO_3 and Ca-Mg-HCO_3 type. The groundwater in study area is chemically suitable for both drinking and agricultural usages. The groundwater chemical quality is linked to the lithology of the area.

- **Alobaidy et al. 2010**; in this study the relative weight from (1-4) assignedto each parameter according to the importance of the parameter for aquatic life. The results indicated that water quality of Dokan Lake declined from Good in the years 1978, 1979, 1980, 1999, 2000 and 2008 to Poor in 2009. So this study applied the Water Quality Index (WQI) in Dokan Lake, Kurdistan region, Iraq by using (10) water quality parameters including(Nitrate, Biochemical Oxygen Demand, pH, Dissolved Oxygen, Hardness, Alkalinity, Conductivity, Sodium, Turbidityand Nitrite). The application of the WQI is also suggested as a very useful application and tool that helps the public and decision makers to assess water quality in Iraqi lakes. The influence of various anthropogenic and human activities was evident on some parameters such as the EC and BOD.
- **Pei-Yue et al. 2010;** has assessed the groundwater quality in Pengyang County based on an improved water quality index. For calculating WQI and assess the groundwater quality. Groundwater samples were collected and subjected to comprehensive physicochemical analysis. 26 parameters were analyzed for each groundwater sample. For computing the WQI, 14 parameters were chosen including chemical oxygen demand (COD), chloride, pH, sulphate, total dissolved solid (TDS), total hardness (TH), nitrate, ammonia nitrogen, fluoride, iodine, total

iron (TFe), arsenic, aluminum, nitrite, free carbon dioxide and metasilicic acid. The high value of WQI is found to be closely associated with the high values ofsulphate, TDS, fluoride, TH and nitrite. The view of point of the groundwater conservation, the groundwater still need protection and long term monitoring in case of future rapid industrial development.

- **Reza and Singh. 2010;** has studied the quality of the ground water by using the water quality index (WQI) inAngul-Talcher region of Orissa-India. The groundwater samples were collected. So a technique of rating water quality is an effective tool to evaluate spatial and temporal changes in ground water quality. The higher concentration of dissolved solids during post monsoon samples exhibits poor quality of water as compared to summer season. Water quality index status was carried out to quantify overall ground water quality level for the study area. The values of WQI have been affected mainly by the concentration of dissolved ions (F, NO, Ca and Mg) in ground water. It may be due to more seepage and movement of ground water during post-monsoon.
- **Yisa and Jimoh. 2010;** to evaluate the quality of River Landzu the study has used the application of the Water Quality Index (WQI) for public uses. This was done by the water samples subjected to comprehensive physicochemical analysis. The results were compared with Nigerian Industrial Standard (NIS) also World Health Organization (WHO) indicates that a river was polluted, so the water is not safe for domestic use and would need further treatment.
- **Rajankar et al. 2009;** this study has calculated, from different groundwater sources, the Water Quality Index. For example, dug wells, bore wells and tube wells at Khaperkheda region and Maharashtra (India). In post monsoon,winter and summer, different sites were selected to calculate the Water Quality by WQI

calculator given by National Sanitation Foundation (NSF) information system. The results show that fair water quality rating in all seasons while the quality was differ slightly in Summer and Winter than in post monsoon season; so that the Water Quality changing and measurement imports are required.

- **Ramakrishnaiah et al. 2009;** this study have assessed the Water Quality Index (WQI) for Tumkur taluk groundwater. The collecting groundwater samples have subjected to comprehensive physicochemical analysis.12 parameters of them have considered for WQI calculating (pH, total hardness, calcium, magnesium, bicarbonate, chloride, nitrate, sulphate, total dissolved solids, iron, manganese and fluorides). The WQI high values was from the higher values of nitrate, hardness, fluorides, bicarbonate total dissolved solids, iron and manganese found in the groundwater.

Chapter Four

Methodology

4.1 Data sources and data collection methods

The data was collected from different sources, previous studies about the subject were collected from the internet and global scientific magazines from which the water quality index were taken at global, local and theMiddle East level.

The Ministry of Health gave information about samples sites and results, including (microbial and physico-chemical tests).All the statistics and numbers were taken from the Palestinian Central Bureau of Statistics of different volumes have been issued.

Reports issued by The Applied Research Institute-Jerusalem (ARIJ) were drawn upon.

4.2 Water quality data

The Palestinian Water Authority is concerned with the water quality from the water resource itself, while the quality of water after being supplied to the consumers is considered a Health Ministry's responsibility and the results of their tests are obtained upon request. There is a difference between the type, number, intensity, and results of the tests conducted by the two facilities as the quality of supplied water for different purposes could be hindered during the transmission from the water source to the consumer due to the presence of pollutants in addition to the deteriorating water networks.

4.3 Groundwater sampling

The population of the Governorate distributed over 72 communities, including 68 served with water networks, and 4 with no water networks and piped water supply; depend on water collected in cisterns during the winter, and water purchased from tankers and private agricultural wells or springs in the area. Drinking and domestic water supply management in Jenin is carried out through the municipalities, local councils and the joint water services council for the northwest Jenin villages. The service providers are supplied in bulk by the WBWD, and some of the communities are supplied by Jenin Municipality (PWA, 2012).

Jenin Governorate has nine wells for domestic uses and these wells provide 3.6 Mcm/year. The springs produce approximately 0.152 Mcm/year and another source is 2 Mcm/year as purchased water from Mekarot Company (Ra'fat, 2012).

The quality of groundwater in the Jenin district (represented by the study area) was determined by taking 36 water samples from nine wells (AlSa'adeh well and Jenin Municipality well which supply Jenin city, Ya'abad Municipality well, Arrabeh well, Qabatyeh well, Alyamoun well, Jaba' well, Zbobamekarot well and Maithaloon well) that serves more than 97% localities from the whole study area. Table 4.1 illustrates the main groundwater wells in Jenin district, the depth in addition to the abstraction rate by cubic meter per year.

Table 4.1: Groundwater wells in Jenin district, the depth and the abstraction rate

Name	Code	Depth	Abstraction M^3/Year	Year of Reading
Jenin municipality well	17-20/033J	20	173589	2018
Alsa'adeh well	17-20/051J	895	978090	2018
Ya'bad well	16-20/006	500	494848	2018
Jaba' well	16-19/012	466	925645	2018
Alyamoun well	17-21/035	425	113759	2018
Zbobamekorot	وصلة مياه			
Arrabeh well	17-20/051A	370	376620	2018
Maithaloon well	17-19/009	1301	1086489	2018
Qabatyeh well	17-20/050Q	580	695545	2017
Total	-	-	4844585	-

Sterilized bottles were using to collect the samples applying the standard procedure for grab (or) catch samples according to the Ministry of Health (MoH) standards. The analysis of various physico – chemical parameters namely pH, total hardness,TDS, chloride, sulphate, nitrate, fecal coliforms, magnesium, calcium, fluoride, sodium and potassium were carried out – as per the methods described in WHO and PSI standards one time at least each year.

In situ, measurements included free chlorine. Laboratory tests were carried out to find the concentrations of the ion of (Na^+, Ca^{+2}, K^+, Mg^{+2}, Cl^-, So_4^{-2}, F^-, and No_3^-) in (mg/l). Statistical measures, like minimum, maximum and the mean analytical results were done for the parameters of the study.

4.4 Water analysis

The purpose of water analysis was to test the suitability of water samples for its intended purpose to help ensure that the drinking water sources are safe by regular monthly testing for the samples in Central Public Health Lab at ministry of health. The way to accomplish this purpose was through measuring the water quality parameters, chemical parameters (major cations, major anions, and pH), physical parameters (TDS), and microbiological parameter (Fecal Coliform).

4.4.1 Chemical parameters

- **Measurement of major ions**

Water samples from Jenin district were analyzed for main cations calcium (Ca^{+2}), sodium (Na^{+}), magnesium (Mg^{+2}), and potassium (K^{+}). Both calcium and magnesium are abundant in rocks and soil, particularly limestones and dolomites. They are relatively soluble. Currently, there are no health concerns associated with these ions, however, concentrations of calcium plus magnesium greater than 100 mg/L (parts per million) are classified as hard. While sodium concentrations are related directly to salinity problems as a very important factor for irrigation water. Higher concentrations of potassium are considered as toxic; mainly the highest recommended value by the Palestinian Standard Institution (PSI) for drinking water is 10 mg/L (PSI, 2004). Sodium, potassium, calcium, and magnesium analyzed using ICP-OES Perkin Elmer DV7300.

The major anions that were measured for some of the collected samples were sulfate (SO_4^{2}), chloride (Cl^{-}) and nitrate (NO_3^{-}). Sulfate was measured by turbidimetric method. Chloride was measured by Mohr method, in which the water sample is titrated with standard silver nitrate using potassium chromate as indicator. Nitrate was measured using spectrophotometric screening method (using UV 300/ UV-Visible spectrophotometer/ UNICAM, λ=220 nm). Concentration was easily determined after plotting calibration curve of several nitrate standards. Total Alkalinity, Chloride, and Total Hardness analyzed using titrimetric method. Chloride and nitrate parameters are the significant parameters because they are indicators of pollution due to their lower concentrations in natural and not contaminated waters and their mobility and stability.

The pH of all samples was measured at Central Public Health Lab after collecting the samples.

4.4.2 Physical parameters

For certain of samples, total dissolved solids (TDS) were measured using Inolab WTW Conductivity meter 750.

4.4.3 Biological parameters

The samples from the sources were taken and analyzed for microbial pollution, total coliform (TC) and fecal coliform (FC), to determine the potential pollution sources as cesspits, wastewater infiltration and the uncontrolled disposal of waste. Microbial tests were carried out at the Central Public Health lab using membrane filtration method.

4.5 Materials and method

Representative 36 groundwater samples were obtained from 9 main wells in Jenin governorate;these samples were selected according to geographical variation. The depth ranges between 20–1301 m. The Inolab WTW75 was used to measure the pH and TDS. Sodium, potassium, calcium and magnesium were analyzed using ICP-OES Perkin Elmer DV7300. Chloride and Total Hardness were analyzed by the titrimetric method. Nitrate was analyzed using Spectrophotometer. The Tubrbidmetric Method using Turbidity meter was used to analyze the sulfate. And Fluoride was analyzed using Ion Selective Electrode byInolab WTW Conductivity meter 750. All the analyses were carried out as suggested by“standards methods, for examinations of water and wastewater”. The physical and chemical parameters of the groundwater analytical results were compared with the standard guideline values recommended by the PSI.

4.6 Water Quality Index (WQI) model

Groundwater chemistry is often used as a tool to identify the quality of drinking water (Subba Rao 2006; Vasanthavigar et al. 2010). Water quality index (WQI) is a useful parameter for recognizing the water quality and its sustainability for drinking purposes (Subba Rao, 1997; Magesh et al. 2013).The standards for purposes of drinking have been considered for calculation of WQI as recommended by WHO and PSI.

The water quality index (WQI) is a mathematical instrument used to convert large quantities of water quality data into single numberrepresenting the water quality level. It is a set of standard test parameters used to compare water quality all around the country.

The index was designed to:

- Provide directly comparable numbers such that various waters can be judged for use in specific categories.
- Allow for comparison of water quality changes over time.
- Provide information that managers and other nontechnical personnel can use easily.
- Indicate waters of "good" and "bad" water quality for specific-use categories.

This researchfocuseson the development of WQI for drinking purposes and human consumption. The weighted arithmetic index method has been used for the calculation of WQI of the water body. For computing the WQI, 12 parameters were considered. The total water samples analyzed for physicochemical parameters by following the established procedures and the results of parameters were evaluated and compared with according to the standards recommended by (WHO 1996 and Palestinian standard institution 2005 (PSI)) for water quality standards.

4.7 Water quality index calculation

The Water Quality Index (WQI) was calculated to determine the impact of natural and anthropogenic activities on various key parameters of groundwater chemistry. For WQI computation; three steps are followed to calculate the WQI (Vasanthavigar et al. 2010).

In the first step, each of the twelfth parameters (pH, FC, total hardness, K, Cl, TDS, Ca, Mg, Na, NO_3, SO_4, and F) has been assigned a weight (w_i) based on its relative importance in the total quality of water for drinking uses. The maximum and minimum weights were given on the basis of their importance in water quality. The maximum weight of 5 in this study has been given to chloride, nitrate and Fecal Coliform, because of its major importance in assessing water quality and considered as indicators of pollution in groundwater samples. Other parameters were allocated weight from 1 and 5 relying on their significance in water quality determinationin this study the weight of 2 has been assigned to the other parameters (pH, TDS, TH, Ca, Na, K, Mg, SO_4, and F). (Table 4.2).

Table 4.2: WQIparameters, an assigned weight and guideline values as per PSI and WHO

Parameters	**Unit**	**PSI Drinking Water Standard (S_i)**	**WHO**	**Weight (w_i)**
Fecal coliform	Colonies/100mL	0	0	5
PH	S.U.	6.5-8.5	6.5-8.5	2
TDS	Mg/L	1000	1000	2
Total Hardness	Mg/L	500	500	2
Ca^{+2}	Mg/L	100s	-	2
Mg^{+2}	Mg/L	100	--	2
Na^{+}	Mg/L	200	-	2
K^{+}	Mg/L	10	-	2
Cl^{-}	Mg/L	250	250	5
NO^{-}_{3}	Mg/L	70	50	5
SO_4^{-2}	Mg/L	200	250	2
F	Mg/L	1.5	1.5	2
				$\sum$wi=33

The parameters selection and the assigned weight of chemical parameters in WQI developed for drinking purposes are not the same as the parameters that will be selected inWQI developed for agriculture, treated wastewater, or any other intended uses.

In the second step, the relative weight (W_i) is computed from the Eq. 1:

$$W_i = \frac{wi}{\sum_{i=1}^{n} wi} , \qquad (1)$$

W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters.The relative weight (W_i) was computed for water quality parameters(Table4.3).

Table 4.3:Relative weight of chemical of physico-chemical parameters

Chemical parameters	**PSI Drinking Water Standard (S_i)**	**Weight (wi)**	**Relative Weight W_i**
Fecal coliform	0	5	0.15
PH	6.5-8.5	2	0.06
TDS	1000	2	0.06
Total Hardness	500	2	0.06
Ca^{+2}	100	2	0.06
Mg^{+2}	100	2	0.06
Na^{+}	200	2	0.06
K^{+}	10	2	0.06
Cl^{-}	250	5	0.15
NO^{-}_{3}	70	5	0.15
SO_4^{-2}	200	2	0.06
F	1.5	2	0.06
		$\sum wi=33$	$\sum W_i = 1.00$

The quality rating scale (qi) to each parameter is assignedin the next step, by dividing the concentration of each parameter in water sample by its respective standard in accordance with the PSI guidelines, then the results is multiplied by 100 (Equation 2)(Cogentoa,2016).

$$qi = (Ci / Si) \times 100 \qquad (2)$$

Where *qi* is the quality rating, *Ci* is the concentration of each chemical parameter in each water sample in milligrams per liter. *Si* is Palestinian standard institution for each chemical parameter in milligrams per liter in accordance to the guidelines of the PSI.

Take AlSa'adehwell as an example according to the above equation the well's data are tabulated in Table 4.4

Table 4.4: Parameters for AlSa'adeh well water samples from (2015-2018)

Years	pH	TDS	T.H	Ca	Mg	Na	K	Cl	NO_3	SO_4	F	FC
2015	7.1	389	404	97	39	55	2.9	126	11	22	0.42	0
2016	7.3	617	446	109	42	56	3.1	114	12.6	29	0.36	0
2017	7.3	597	439	108	41	57	3.3	111	12.6	22	0.35	0
2018	7.2	614	437	106	42	60	3.3	118	12.5	26.5	0.35	0

To calculate the (qi) the concentration of each parameter in water sample present in table 4.5 was divided by its respective standard as given in table 4.2 in accordance with the PSI guidelines and the data as shown below in table 4.5.

Table 4.5: The quality rating scale (qi) to each parameter from AlSa'adeh well samples

Years	pH	TDS	T.H	Ca	Mg	Na	K	Cl	NO_3	SO_4	F	FC
2015	101	39	81	97	39	28	29	50	16	11	28	100
2016	104	62	89	109	42	28	31	46	18	15	24	100
2017	105	59	88	108	41	28	33	44	18	11	23	100
2018	102	61	87	106	42	29	33	47	18	13	23	100

Finally, calculate the WQI, the SI is firstspecified determined for each chemical parameter based on the Eq. 3

SIi = Wi × qi (3)

Where SIi is the Sub-Index of its parameter, qi is the rating according to the concentration of its parameter, n is the number of parameters.

Table 4.6: The Sub-Index (SIi)for chemical parameters according to equation three forAlSa'adeh well water samples

Years	pH	TDS	T.H	Ca	Mg	Na	K	Cl	NO_3	SO_4	F	FC
2015	**0.06**	**2.4**	**4.9**	**5.9**	**2.4**	**1.67**	**1.79**	**7.6**	**2.46**	**0.68**	**1.7**	**15.15**
2016	**0.06**	**3.7**	**0.1**	**6.6**	**2.5**	**1.7**	**1.89**	**6.9**	**2.74**	**0.89**	**1.5**	**15.15**
2017	**0.06**	**3.6**	**5.3**	**6.5**	**2.5**	**1.7**	**1.97**	**6.7**	**2.74**	**0.67**	**1.4**	**15.15**
2018	**0.06**	**3.7**	**5.3**	**6.5**	**2.5**	**1.8**	**1.98**	**7.2**	**2.69**	**0.8**	**1.4**	**15.15**

While the equation 4 shows the water quality index as the sum of the water SI (Cogentoa, 2016).

$$WQI = \sum SIi \text{ , (4)}$$

The computed WQI values are grouped into five types from excellent water to unfit for drinking (Sahu and Sikdar 2008). The status of WQI for drinking purposes is tabulated in Table 4.7.

Table 4.7: Status of water quality based on water quality index (WQI) specified for drinking water

Water quality index level	Water quality status
< 50	Excellent water quality
50-100	Good water quality
100-200	Poor water quality
200-300	Very poor water quality
>300	Unfit for drinking

According toStatus of water quality based on water quality index (WQI) specified for drinking water.WQI values for AlSa’adeh well are shown in table 4.8.

Table 4.8: Water types of groundwater fromAlSa’adeh well for a period of (2015-2018)

Years	WQI values	Water quality status
2015	46.65	Excellent water quality
2016	43.76	Excellent water quality
2017	48.41	Excellent water quality
2018	49.1	Excellent water quality

Chapter five

Results and discussion

Statistical analysis was carried out on the physical and chemical parameters and the concentration of the major ion to determine the relationship and differences between groundwater samples for each analysis period of (2015, 2016, 2017, and 2018)).

5.1 Physical and chemical analysis for Groundwater

5.1.1 pH

pHplays a major role in the disinfection process of drinking water. The pH should be less than eight for the effective disinfection with chlorine and the water with pH less than seven is more likely to be corrosive, and the high corrosion can cause contamination of the drinking water and bad effect on its appearance and taste (Singh, 2016).

PalestinianStandard institution (PSI) has prescribed permissible limit of pHto be 6.5–8.5. In the present study the pH value has been analyzed for the groundwater samples lies in the range (6.98-8.19) which is with the preferable limit.

5.1.2 Fecal coliform (FC)

Fecal coliform bacteria are a group of bacteria that are passed through the fecal excrement of humans, livestock and wildlife. Fecal coliform concentrations are reported in units of the number of bacterial colonies per 100 mL of sample water (colony/100 mL). The drinking water standard is zero colony/ 100ml. In our study no fecal coliform contamination has been detected.

5.1.3 Total dissolved solids (TDS)

The existence of dissolved solids may affect the water taste. The acceptable taste of drinking water has been evaluating by a group of tasters in accordance to its TDS level and rating as follow: excellent for the results less than (300mg/l), good (300-600 mg/l), from (600-900 mg/l) is fair, poor from (900-1200 mg/l), and acceptable (>1200mg/l)(Singh, 2016).

According to the PSI 500 mg/l is acceptable limit and 2000 mg/l is the permissible limit for TDS in the drinking water samples.In the current study, the TDS concentration of the analyzed samples ranges from (235-810 mg/l). The TDS of the samples is well within the permissible limit.

5.1.4 Total Hardness (TH)

Thecause of water hardness is the presence of magnesium and calcium salts in the fresh water sources. Water with a hardness of more than 200 mg/l may cause a scale deposition in the distribution system.In contrast, water with hardness less than 100 mg\l will be more corrosive for water pipes (Ramesh and Elango, 2006). In the current study, total hardness (TH) of groundwater samples is found to be in the range of 157.99 mg/l to 522.00 mg/l as $CaCo_3$. The maximum permissible limit of TH for drinking usage is 500 mg/l and the most desired limit is 100 mg/l as per according to the WHO standard. One sample from Ya'abad Municipality well exceeding the permissible limit of 500 mg/l.

5.1.5 Chloride (Cl)

Taste thresholds of the chloride anion related to the associated cations(Singh, 2016). Based on taste threshold PSI has prescribed 250 mg/l as the acceptable limit. The concentration of chloride in the samples were in the average of 4-242 mg/l.

5.1.6 Sulphate (SO_4)

The existence of sulphate in drinking water can cause detectable taste. Taste thresholds have been from 250 mg/l for sodium sulphate and for calcium sulphate is 1000 mg/l(Singh, 2016).

The concentration of sulphate in the groundwater samples was observed from9.6-52.9mg/l. Though, the concentration in all samples in the study area were within the acceptable limit as prescribed by PSI.

5.1.7 Nitrate (NO_3)

NO_3 which is an important nutrient for plants, is found naturally in the environment. THE presence of nitrate in the drinking water in large quantities is a possible health hazard(Singh, 2016).

The maximum permissible nitrate concentration as per PSI for drinking water is 70 mg\l as NO_3.The range of nitrate in the study area was between 0.5-94 mg/l. some groundwater samples were above the desirable limit. The high NO_3 observed in the study area ranges from 94.3to 51.9 mg/l; the rise may be as a consequence of leaching from natural vegetation or from nitrogen fertilizers.

5.1.8 Calcium (Ca)

The analysis of calcium in all the samples in the present study has also been carried out. The concentration lies in the range of 39-153 mg/l. The acceptable limit is 100 mg/l.as PSI standard. The higher concentration of Ca^{2+} in groundwater of the study area was above the maximum permissible limit of 100 mg/l in nearly 11 samples over the last four years. Six groundwater samples was from Jenin Municipality well which have the highest value of

Ca^{2+} and AlSa'adeh well in Jenin city, 3 samples from Ya'abad Municipality well, in addition to Qabatyeh well and Alyamoun well.

5.1.9 Magnesium (Mg)

Magnesium also an additional parameter that has been analyzed in this study in all the groundwater samples. Which is important and found to be in the range of 8.6 – 51.4 mg/l and acceptable according to the PSI value which is 100 mg/l.

5.1.10Sodium (Na)

Sodium is a highly reactive metal and does not occur in its free form in nature. High value of sodium may cause adverse effects on human with high blood pressure(Singh, 2016).

Na^{+}concentration ranges from 23.9 to 116.8 mg/l. According to the average taste threshold for sodium which is about 200 mg/l, all results are within the acceptable limit.

5.1.11 Potassium (K)

Potassium is seldom, and considered as an essential element for humans(Singh, 2016).The concentration of potassium in the study area samples ranges between 2.9-6.5 mg/l and within the permissible limit as prescribed by PSI which is 10 mg/l.

5.1.12Fluoride

Excess fluoride intake may cause different type of fluorosis. Palestinian standards institutions (PSI) the desired limit for fluoride is 1.5 mg/l. For the study area it has been found that the fluoride concentration is in the range 0.05-0.89 mg/l(Singh, 2016).

5.2Developed index for groundwater quality

This assessment of groundwater quality using WQI values is the first such attempt in Jenin district. The results obtained in this study cannot be compared with previous works and findings because no previously published data exists. However, the findings may be compared with the works carried out by researchers in different parts in Palestine.These studies proved the usefulness of WQI method in the assessment of drinking water quality.

The WQI value and water type of the individual samples are presented in Table 5.1.

In this study, the calculated WQI values varies from 25.62 to 71.56 for a total of 36 samples. This water quality rating study clearly reveals that the majority of the samples arranged from excellent to good classification and useful for drinking water and human consumption uses. Among these, 83.33 % of the samples revealed excellent water, 16.67 % of the samples fell under good water category. Hence, application of water quality index technique for the overall assessment of the water quality of the groundwater samples is a useful tool.

Table 5.1: Water quality index (WQI) classification for individual samples

Groundwater well samples	Sampling Date	WQI values	Water quality classification type
AlSa'adeh well	**28/4/2015**	**46.65**	**Excellent water quality**
	27/4/2016	**43.76**	**Excellent water quality**
	26/4/2017	**48.41**	**Excellent water quality**
	23/5/2018	**49.09**	**Excellent water quality**
Jenin Municipality well	**28/4/2015**	**64.31**	**Good water quality**
	27/4/2016	**71.56**	**Good water quality**
	26/4/2017	**36.11**	**Excellent water quality**
	23/5/2018	**65.17**	**Good water quality**
Ya'abad Municipality well	**28/4/2015**	**47.61**	**Excellent water quality**
	27/4/2016	**47.79**	**Excellent water quality**
	26/4/2017	**52.33**	**Good water quality**
	23/5/2018	**-**	**-**
Arrabeh well	**28/4/2015**	**43.33**	**Excellent water quality**
	27/4/2016	**-**	**-**
	26/4/2017	**42.19**	**Excellent water quality**
	23/5/2018	**42.94**	**Excellent water quality**
Qabatyeh well	**28/4/2015**	**41.22**	**Excellent water quality**
	27/4/2016	**36.23**	**Excellent water quality**
	26/4/2017	**48.19**	**Excellent water quality**
	23/5/2018	**40.80**	**Excellent water quality**
Alyamoun well	**28/4/2015**	**41.21**	**Excellent water quality**
	27/4/2016	**37.72**	**Excellent water quality**
	26/4/2017	**41.18**	**Excellent water quality**
	23/5/2018	**54.31**	**Good water quality**
Jaba' well	**28/4/2015**	**38.22**	**Excellent water quality**
	27/4/2016	**34.28**	**Excellent water quality**
	26/4/2017	**37.43**	**Excellent water quality**
	23/5/2018	**37.71**	**Excellent water quality**
Zbobamekarot well	**28/4/2015**	**51.64**	**Good water quality**
	27/4/2016	**25.62**	**Excellent water quality**
	26/4/2017	**36.93**	**Excellent water quality**
	23/5/2018	**32.92**	**Excellent water quality**
Maithaloon well	**28/4/2015**	**36.03**	**Excellent water quality**
	27/4/2016	**32.83**	**Excellent water quality**
	26/4/2017	**36.16**	**Excellent water quality**
	23/5/2018	**36.11**	**Excellent water quality**

5.3 Water quality index in water distribution networks (WDS)

The minor purpose of the research is to calculate the water quality index in water distribution networks by adding the free chlorine to the major parameters that measured from the main sources.

Because the presence of free residual chlorine in drinking water indicates the likely absence of disease-causing organisms, it is used as one measure of the potability of drinking water so, this index offers advantages to detect the water quality in drinking water at the point of consumption and compare it with the WQI from its original source.

The index was detected for specific main locations in Jenin city provided from AlSa'adeh well and Jenin Municipality well in addition to PWA water sources, using the free chlorine (Cl_2) concentration as an additional parameter to the previous water quality parameters such as pH, TDS, etc. Chlorine is present in most disinfected drinking-water at concentrations of 0.2–0.5 mg/liter. The weight has been assigned for free chlorine are summarized in table 5.2.

The purpose of a Water Distribution System (WDS) is to make water available to customers with at least acceptable pressure, flow, continuity and water quality. Water quality can be measure in terms of taste, odor, appearance and chlorine concentration between others parameters. Maintaining water quality through the WDS until the point of consumption is one of the most challenging task faced by the water utility industries (Clement et. al., 2004), taking in consideration the components of the WDS, such as pipe materials, tanks, valves etc. and other risks related to water distribution. The most common disinfectant used in water management is chlorine, and this index will show the variance between the quality at source before chlorination and at the point of consumption with free chlorine. Table 5.2.1 shows the weight of Cl_2 concentration in water samples.

Table 5.2: The weight of Chlorine results in Networks of drinking water

	Results (mg/l)	Weight (w_i)
Free chlorine	0.1 - 0.3	3
	0.3 - 0.5	4
	0.5 - 0.7	5

The higher the residual chlorine levels in the supply, the better and longer the chemical will be able to protect the system from contamination. However, high levels of chlorine make the water smell and give it a bad taste, which will discourage people from drinking it.

For normal domestic use, residual chlorine levels at the point where the consumer collects water should be between 0.2 and 0.5 mg/l. The higher level will be close to the disinfection point and the lower level at the far extremities of the supply network (WHO, 2011).

The appearance of free chlorine residues in drinking water indicates this a sufficient amount of chlorine was added to the water to inactivate most of the bacteria and viruses that cause diarrheal disease; and the water is protected from recontamination during transport to the home, and during storage of water in the household.

In this case study, the samples were taken for a period from January to June 2018 from a certain points fed from the main groundwater wells that serve Jenin city (Jenin Municipality well, AlSa'adeh well, and Arrabeh well) in order to ascertain the quality of drinking water also in water distribution networks for the customers. Table 5.5 shows the average results from the main 5 points over the six months, the WQI in the networks and for the source, in addition to the water quality classification type in the networks.

Table 5.3: The average results from the main 5 points, the WQI for networks, the WQI for Groundwater well, and the water quality status

Samples Location	Average results	Weight	WQI (Networks)	WQI (Groundwater well)	Water quality classification type (networks)
East of Jenin	0.25	3	51.39	65.17	**Good water quality**
Al-Marah area	0.32	4	34.64	42.94	**Excellent water quality**
North of the city	0.35	4	55.3649	65.17	**Good water quality**
Nablus street	0.33	4	54.74822	65.17	**Good water quality**
Al-Amal hospital	0.35	4	41.0394	49.09	**Excellent water quality**

The results obtained from the calculations show an increase in the water quality index, the samples location is constant. The east and north of Jenin city in addition to Nablus Street area get water from Jenin Municipality well and the results show that the WQI value decrease after adding the residual chlorine in the networks and still in the good water quality type.

Al-Marah area water source is from Palestinian water authority sources i.e. (Arrabeh well) which shows excellent water quality type after adding the free chlorine and also the index for Al-Amal hospital which fed from AlSa'adeh well shows decrease in the result and the water quality type remains in excellent classification.

Chapter Six

Conclusion and Recommendation

6.1 Conclusions

Thewater quality index rating was calculated to quantify overall water quality for drinking purposes and human consumption. The WQI for 36 samples ranges from 25.6 to 71.6 for study area. According to PSI 2005, all analyzed samples for physical and chemical parameters of the groundwater samples were under the maximum allowable limits. It has been observed that 83% of samples indicate an excellent water quality around the study area.The analysis reveals that the groundwater of the area is useful for drinking purposes.

6.2 Recommendations

Develop a map to show the water quality index for the main groundwater sources in Jenin governorate over the last 4 years using Geographical Information System GIS and Geostatistics techniques.

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Appendices

Appendix A: Statistics of physico-chemical parameters, major ions, World Health Organization (World Health Organization 2011) and Palestinian standard institution (PSI,2005) for drinking waters of study area

Groundwater well samples	parameters	pH (S.U)	Fecal coliform	TDS (mg/)	Total Hardness (mg/l)	Ca^{+2} (mg/l)	Mg^{+2} (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Cl^{-} (mg/l)	$NO^{-}{}_{3}$ (mg/l)	$SO4^{-2}$ (mg/l)	F(mg/l)
	PSI standards	**6.5-8.5**		**1000**	**500**	**100**	**100**	**200**	**10**	**250**	**70**	**200**	**1.5**
	WHO	**6.5-8.5**		**500**	**-**	**100**	**100**	**200**	**12**	**250**	**45**	**250**	**1.5**
AlSa'adeh well	**minimum**	7.09	-	389	404.41	97.41	39.14	55.02	2.96	110.94	11.36	22.07	0.35
	maximum	7.33	-	617	445.59	109.35	41.9	59.99	3.27	125.57	12.64	29.22	0.42
	mean	7.22	-	554.3	431.35	105.3	40.9	57	3.15	117.26	12.28	25.02	0.39
Jenin Municipality well	**minimum**	6.98	-	370	302.3	73.18	25.73	25.3	2.002	37.75	9.75	22.27	0.3
	maximum	8.12	-	810	488.03	152.9	29.05	116.8	4.29	207.36	94.33	52.94	0.43
	mean	7.55	-	590	395.2	113	27.4	71.05	3.15	122.56	52.04	41.6	0.37
Ya'abad Municipality well	**minimum**	7.2	-	522	393.81	102.4	33.54	29.37	4.25	4.25	46.06	12.86	0.18
	maximum	7.31	-	537	522	114.95	35.87	29.7	5.59	67.08	51.89	46.76	0.23
	mean	7.24	-	528.3	450.18	108.8	34.78	29.56	4.8	43.17	48.24	24.75	0.2

Arrabeh well	**minimum**	7.12	-	435	324.61	82.67	28.7	27.62	2.24	49.44	26.68	16.61	0.39
	maximum	7.55	-	482	345.09	87.81	30.57	29.26	2.505	57.77	27.75	20.51	0.44
	mean	7.31	-	453	335.93	86.07	29.39	28.31	2.39	52.32	27.25	18.91	0.46
Qabatyeh well	**minimum**	7.22	-	471	327.6	75.56	33.08	50.76	2.25	77.71	0.53	22.07	0.35
	maximum	7.33	-	597	438.47	108.05	40.96	56.77	3.25	110.94	11.65	29.67	0.89
	mean	7.29	-	513	361.53	86.25	35.5	53.12	2.55	86.71	3.45	26.56	0.65
Alyamoun well	**minimum**	7.23	-	434	325.59	85.6	27.16	31.69	2.36	49.52	5.88	16.48	0.13
	maximum	7.43	-	759	490.64	111.8	51.38	99.21	3.03	188.74	21.04	32.42	0.36
	mean	7.32	-	525.6	378.15	95.29	34.1	53.74	2.79	85.02	16.71	22.84	0.26
Jaba' well	**minimum**	7.14	-	389	300.11	80.03	24.35	24.07	1.31	41.14	16.22	13.69	0.29
	maximum	7.49	-	406	330.14	89.7	25.78	24.86	1.48	50.7	17.6	17.03	0.45
	mean	7.30	-	399	312.13	84.12	24.79	24.37	1.4	44.43	16.87	15.78	0.37
Zbobamekarot well	**minimum**	7.64	-	235	157.99	38.59	8.58	23.93	2.42	40.49	3.2	9.57	0.05
	maximum	8.19	-	662	241.7	49.11	31.97	123.6	6.51	242.3	4.9	41.01	0.26
	mean	8	-	395.5	193.42	43.81	18.22	64.77	4.43	122.55	4.05	25.52	0.13
Maithaloon well	**minimum**	7.5	-	370	278.49	66.41	27.36	24.76	1.9	34,49	9.76	20.28	0,37
	maximum	8.12	-	389	316.34	77	30.13	28.16	2.09	37,75	10.65	29.65	0.61
	mean	7.74	-	376.3	301.32	72.93	28.96	25.99	1.99	35,79	10.06	23.51	0.46