An-Najah National University

Faculty of Graduate Studies

Toward a Better Understanding of the Nitrate Contamination of the Groundwater in the West Bank The Case Study of the Eocene and the Western Aquifers

By

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This Thesis is Submitted in Partial Fulfillment of the Requirements of the Degree of Master of Water and Invironmental Engineering, Faculty of Graduate Studies, An- Najah National University, Nablus-Palestine.

2019

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This Thesis was defended Successfully on 5/5/2019 and approved by:

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Dedication

"قل إن صَلاتي ونُسُكي وَمَحْيَايَ وَمَمَاتِي لِلَّه رَبِّ الْعَالَمِينَ"

(سورة الأنعام: 162)

To

My Father: Tayseer Aljundi

My Mother: Amneh

My Lovely sister: Mais

My supportive friends: Asma, Shireen, and Ola

This thesis is dedicated to all of them

Acknowledgement

I would like to extend my deepest gratitude and appreciation to Dr. Mohammad N. Almasri for advising my research and for all his patience and teaching. I would like to extend my thanks to my defense committee.

Special thanks for my friend Ibrahim Hantash, am grateful for your support and assistance. Thanks go also to Eng. Tariq Judeh and Eng. Bilal Abu-alrub for their assistance. I would like to thank friend Reem Odeh from the deep of my heart.

I would like to acknowledge the Netherlands reprehensive office (NRO) in Ramallah through PADUCO II project for their financial support. I am deeply honored by their recognition.

Thanks for the Water and Environmental Studies Institute (WESI), for providing all the service for research laboratory tests especially Dr. Abdel-Fattah Hasan, and to the staff of WESI for their assistance.

الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Toward a Better Understanding of the Nitrate Contamination of the Groundwater in the West Bank The Case Study of the Eocene and the Western Aquifers

أقر بأن ما اشتملت عليه هذه الرسالة انما هي نتاج جهدي الخاص، باستثناء ما تمت الإشارة اليه حيثما ورد، وان هذا الرسالة ككل أو أي جزء منها لم يقدم من قبل لنيل أي درجة علمية أو بحث علمي لدى أي مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any degree or qualification.

Student's Name: **اسم الطالب:**

Signature: **التوقيع:**

Date: **التاريخ:**

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List of Abbreviations

ARIJ	Applied Research Institute Jerusalem
ARPAC	Environmental Protection Agency of the Campania region in Italy
EA	Eocene Aquifer
MCDA	Multi Criteria Decision Analysis
MCL	Maximum Contaminant Level
MO	Management Option
PWA	Palestinian Water Authority
UNEP	United Nation Environment Program
US-EPA	United State- Environmental Protection Agency
WAB	Western Aquifer Basin
WESI	Water and Environmental Studies Institute
WHO	World Health Organization

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Abstract

Groundwater is the main source of fresh water for the Palestinians in the West Bank and Gaza strip. Therefore, assessment and monitoring of its quality and quantity is essential. Recent studies have indicated an increasing trend in the nitrate contamination in the Eocene Aquifer (EA) and the Western Aquifer Basin (WAB). Nitrate contamination is mainly due to intense use of fertilizers, the seepage of wastewater from cesspits, and the lack of integrated wastewater systems. Elevated nitrate concentrations in drinking water may cause health problems such as methemoglobinemia in infants and stomach cancer in adults.

This research aims to understand the spatial and vertical distribution of nitrate contamination in the groundwater of the West Bank by taking the EA and the WAB as case studies. A total of 16 wells within the WAB located in the northern part of Tulkarm governorate (Ash-Shaarawieh) were visited and tested to study the spatial distribution of nitrate concentration, while another six adjacent wells within the boundary of the Eocene aquifer that are located in Qabatiya town were considered to study the vertical distribution of nitrate concentration.

These measurements were carried out on monthly basis between the period of September 2018 and March 2019. Results showed that there are elevated concentrations of nitrate beyond the maximum contaminant level (MCL) which equals 50 mg/l-NO_3 in Ash-Shaarawieh particularly in Illar and Attil. These wells are located beneath irrigated areas and have the maximum range of nitrate concentrations resulted mainly from intensive agricultural activities (e.g. fertilizing, irrigation). While, wells that are located within the built-up areas have nitrate concentration ranges between 26 and 50 mg/l-NO_3. This reflects the improper disposal of wastewater which is widely spread in these areas. For the vertical distribution, there is an inverse relation between the depth of sampled wells and the nitrate concentration in Qabatiya town.

Finally, some practical management options to control the problem of nitrate pollution in the study areas were suggested. Modeling should be utilized for the selection of proper management options to control the nitrate occurrence in groundwater. In addition, more frequent and well distributed samples should be promoted through a well-developed strategy for groundwater monitoring.

Chapter One
Introduction

1. Introduction

1.1 General Background

Groundwater is the main source of fresh water for the Palestinians in the West Bank and Gaza strip (PWA, 2011). Groundwater is utilized to meet domestic, agricultural and industrial water demands. Therefore, its status requires a good understanding and assessment in order to preserve its quality from any source of contamination. It is essential to manage groundwater resources in terms of quality and quantity.

The West Bank lies over the Western, the Northeastern, and the Eastern basins. The Northeastern basin is the smallest one and has the lowest safe yield, while the Western aquifer basin (WAB) is the largest basin with the largest yield per year (PWA, 2011). Water is supplied to the residents in the West Bank from groundwater wells[1], springs[2], and purchased water. Recharge of these aquifers is mainly from rainfall (ARIJ, 2015).

The geologic formations of the West Bank aquifers are composed from karsts, limestone, chalk and dolomite with inner bed of marls. Karst formation has high permeability rates, and thus these aquifers will be

[1] The total number of groundwater wells in the West Bank is 382, where 112 of them are not pumping or need rehabilitation (PWA, 2011).
[2] There are 300 main spring within the boundary of the West Bank, the total annual discharge has been decreased recent years and most of them have dried out (PWA, 2011).

highly vulnerable to contamination (SUSMAQ, 2003; Jebreen, Wohnlich, Banning, Wisotzky, Niedermayr, & Ghanem, 2018).

Aquifers vary in their vulnerability to contamination. The high vulnerability aquifers are more susceptible to pollutants than others. This is obvious in areas of shallow water table and high recharge rates (Almasri, et al., 2005)

Worldwide, there is a problem of nitrate contamination in groundwater (Goodchild, 1998; Joosten, et al., 1998; Almasri, 2007; Re, et al., 2017). The sources of contamination are widespread due mainly to human activities such as agricultural, urbanization, waste dumping, and inadequate wastewater disposal (Almasri, et al., 2005).

Nitrate can be found abundantly in aquifers due to point and nonpoint pollution sources (Almasri, et al., 2005). Agriculture is the main nonpoint polluter of groundwater in irrigated areas from the uncontrolled agriculture practices (e.g. the intensive use of agrochemicals). Point sources of nitrate are mainly from cesspits outflow that drains from the root zone to recharge the aquifers (Chowdary, et al., 2005).

Nitrogen gas (N_2) is found abundantly in atmosphere with a percentage of 78%. In addition, Nitrogen is available within soil in many forms like nitrite (NO_2), nitrate (NO_3), ammonium (NH_4), ammonia (NH_3) and organic nitrogen.

Fertilizer is the main source of nitrogen in soil. Although fertilizers are essential to increase crop yield, it may lead to environmental and health negative impacts when reaches drinking water (Viers, et al., 2012).

Nitrate (NO_3^-) is a very soluble compound which can leach to aquifers with percolated water through the unsaturated zone (Chowdary, el al., 2005; Almasri, 2007). Concentration of nitrate in drinking water must not exceed the Maximum Contaminant Level (MCL) as established by the US Environmental Protection Agency (US EPA) and equals to 50 mg/l NO_3 or 10 mg/l NO_3-N (US EPA, 2018) and according to the Palestinian Standards Institutes, nitrate concentration must not exceed 70 mg/l NO_3.

Elevated nitrate concentrations in drinking water may cause health problems such as methemoglobinemia in infants and stomach cancer in adults (Lee, 1992; Wolfe & Patz, 2002). Nitrate may be an indication of the presence of microbial pollution (bacteria, viruses and protozoa), if the source of nitrate is from leaking septic tanks or cesspits (Almasri & Kaluarachchi, 2004). Likewise, nitrate contamination of groundwater is a health and environmenatl concern.

This research will identify the vertical and spatial distribution of nitrate in groundwater in selected areas within the boundaries of the EA (part of the Northeastern aquifer basin) and the WAB in the West Bank.

Overall, this research will help in better understanding the problem of nitrate contamination in the West Bank.

1.2 Research Objectives

The main objective is to better understand the problem of nitrate contamination in the West Bank. The sub-objectives of this research are as follow:

1. To study the vertical and spatial distributions of nitrate concentrations in the Eocene and the Western aquifers in the West Bank.

2. To recommend practical management options for the minimization and control of the nitrate occurrence in the groundwater of the West Bank.

1.3 Study Area

In this study, the areas under consideration are the Eocene (part of the Northeastern) and the Western aquifers. Figure 1 depicts the groundwater basins of the West Bank.

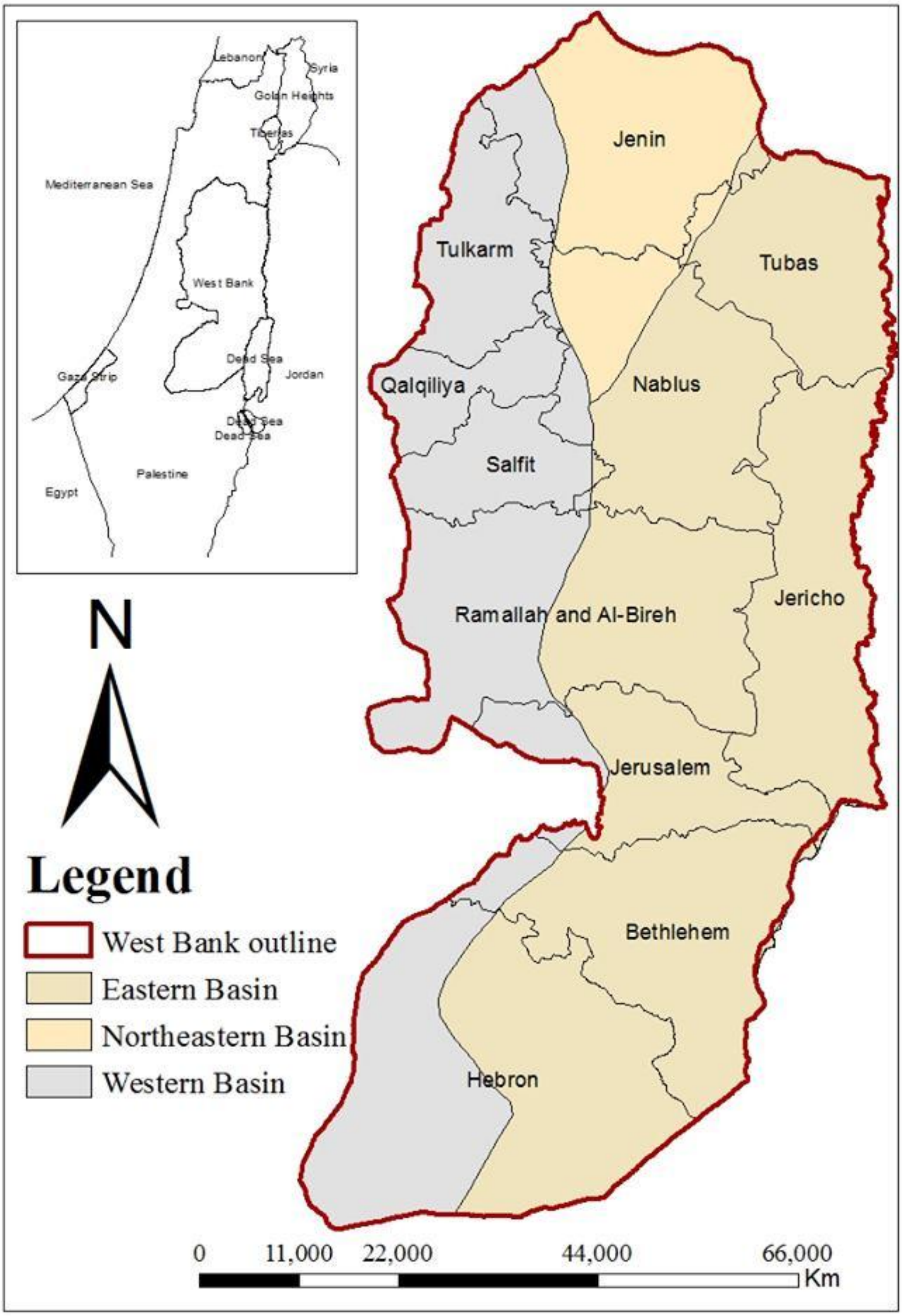

Figure 1: Groundwater basins of the West Bank

1.3.1 The Western Aquifer Basin (WAB)

The Western aquifer basin (WAB) is the largest aquifer in the West Bank (PWA, 2011). The outcrop area of aquifer that is located within the West Bank boundaries is 1,276 km^2, distributed mainly in the mountain and foothills of the West Bank (UN-ESCWA & BGR, 2013). The WAB flows to the west towards the Mediterranean Sea.

The geologic formations of the WAB consist of karstic limestone and dolomites with some chalks and marls (PWA, 2013). Figure 2 shows the general hydrogeological cross section of the WAB.

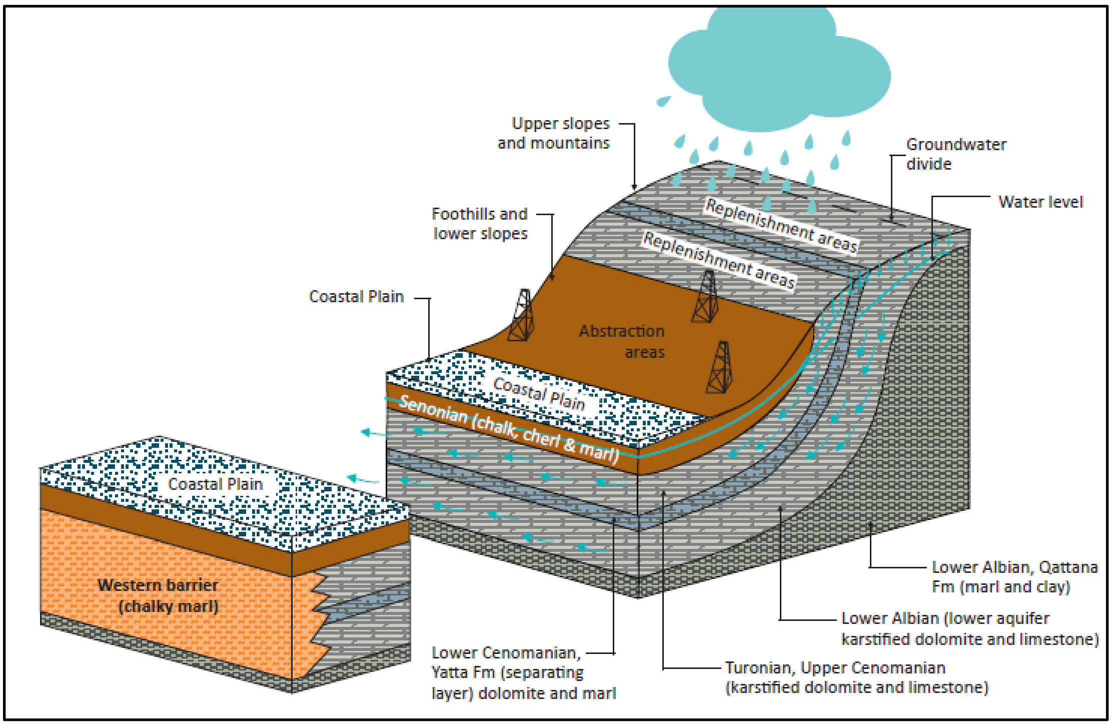

Figure 2: Hydrogeological cross section of the WAB (Abusaada, 2011)

The aquifer system of the WAB extends from Beer-Sabi’ in the south to the Carmel Mountain in the north, and from the mountains in the east toward the coastal plain in the west (PWA, 2013). This aquifer is divided into two sub-aquifers: Upper Cenomanian and Lower Cenomainian separated by a marly aquitard (Yatta formation).The aquifer thickness is 600-800 m (PWA, 2013).

The total number of springs in the WAB is 48 springs (PWA, 2013). There are 140 groundwater wells within the WAB boundaries that are utilized for agricultural and municipal uses (UN-ESCWA & BGR, 2013).

The Climate in the WAB area is considered as semi-arid. It is characterized by the Mediterranean climate, which is wet in winter and dry in summer. The rainy season is between October and May with annual rainfall range of 550-700 mm (UN-ESCWA & BGR, 2013). Palestinians live within the WAB boundaries includes residents of Tulkarm, Salfit, Bethlehem, Qalqilia, and parts of Hebron and Ramallah governorates (UN-ESCWA & BGR, 2013).

1.3.2 The Eocene Aquifer

The Eocene aquifer (EA) is part of the Northeastern basin. This aquifer system is utilized by the Palestinian residents in Nablus, Jenin and Tubas governorates for domestic and agricultural purposes. The outcrop area is about 526 km^2 (SUSMAQ, 2003). Figure 3 depicts the boundaries of the Eocene aquifer.

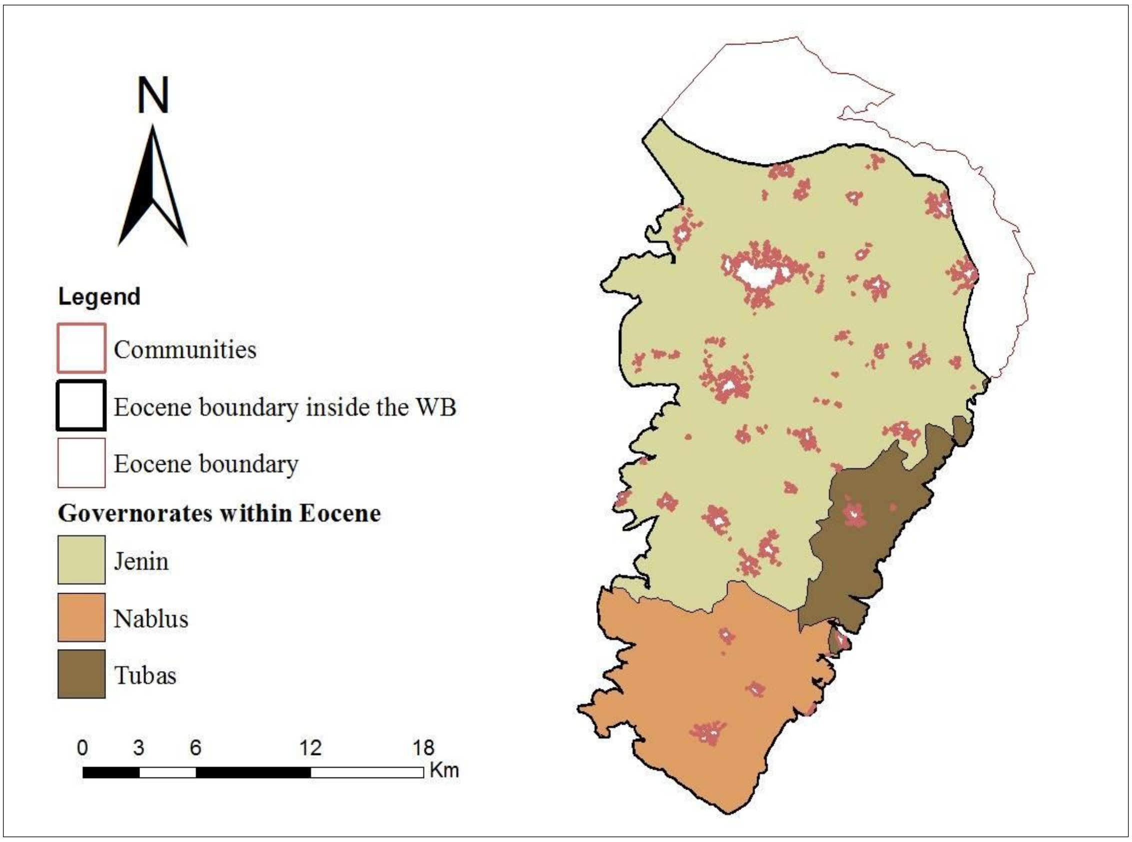

Figure 3: The boundaries of the Eocene aquifer

The geologic formation of the EA is composed of karstic limestone and soft chalk. The aquifer system is unconfined and shallow (SUSMAQ, 2003; PWA, 2011).

This aquifer overlies the upper Cenomanian-Turonian aquifer, separated with chalk layer of thickness varying from 0 to 480 m. This formation is represented by the Jenin subseries of the Tertiary age. It forms a fully utilized shallow aquifer (SUSMAQ, 2003). The natural outlets of this system are springs at Gilboa, in the area of Nablus, Jenin, and Faria (PWA, 2013).

The direction of groundwater is to the north-east. Figure 4 depicts the flow direction of the Eocene aquifer.

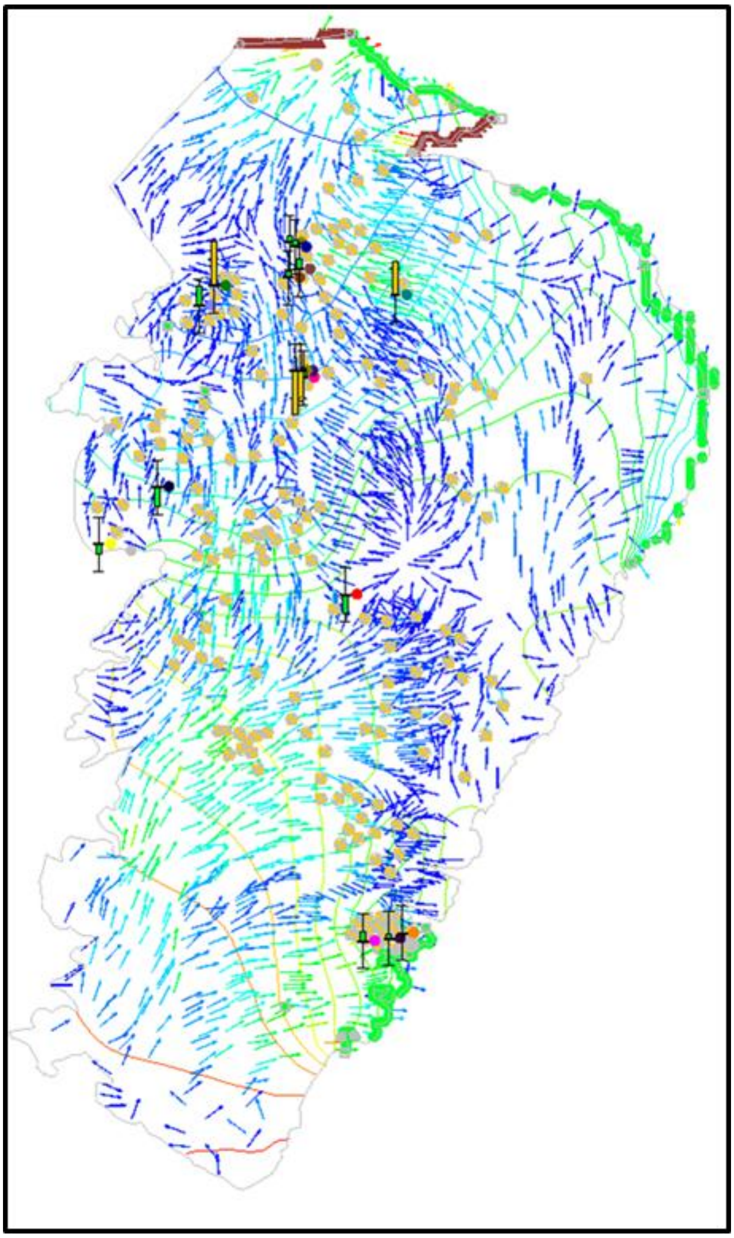

Figure 4: Groundwater flow direction of the Eocene aquifer[3]

The springs of the Eocene aquifer are divided into two groups: eastern and north-eastern springs that include Al-Faria and Al-Badan springs and

[3]Source: The conceptual model of the Eocene Aquifer developed by Dr. Muath Abu Sadah/ Hydro-Engineering Consultancy (2019).

northern and north-eastern springs which include Amal, Shoqeq and Jalod (SUSMAQ, 2003).

Climate of the Eocene aquifer is the Mediterranean climate, which is wet rainy in winter and hot dry in summer. The rainy season extends from October to May. The annual rainfall was 433 mm in 2011 (PWA, 2011). There are 27 communities within the Eocene aquifer boundaries located in Nablus, Jenin, and Tubas governorates. According to the Palestinian Central Bureau of Statistics (PCBS) the total population was 200,000 inhabitants in 2016.

1.4 Methodology

At the beginning, relevant studies about the groundwater status in the West Bank were reviewed. In addition, personal interviews were employed for data collection and early evaluation. After that, the selection of sampled wells was considered. Well locations were selected in areas which have potential of nitrate contamination resulted either from improper disposal of sewage or uncontrolled agricultural activities. In addition, the selection process was attributed to many factors such as: (i) accessibility to well location (ii) availability of an in-charge person (iii) owner acceptance and willingness to collaborate (iv) personal communications and (v) the presence of surrounding uncontrolled human activates such as agricultural activities that can be linked to nitrate pollution. Ash-Shaarawieh area that is located in northern part of Tulkarm governorate and within the boundary of the WAB was selected to investigate the spatial distribution of nitrate concentration. Shapefiles of land use and well location were used in data analysis. Qabatiya town that is located within the boundary of the EA was selected to study the vertical distribution of nitrate concentration. The mentioned process was useful to cover the objective of the research. Through monthly field visits, a total of 56 water samples were collected at 22 sampling sites for laboratory analysis. Nitrate concentration was analyzed in the laboratory of the Water and Environmental Studies Institute (WESI) at An-Najah National University.

After field visits and water sampling, lab results were processed and analyzed, this was achieved by using MS Excel and GIS. Using MS Excel provides tools for preparing illustrative graphs and figures used in data analysis. Geographic information system (ArcGIS10.5) was useful in data processing, visualization, analysis, computation, and map preparation. Elevated nitrate concentrations were analyzed based on nearby land use classes and human practices such as agricultural.

Finally, conclusions and recommendations were identified. Figure 5 illustrates the methodology that was carried out for this research.

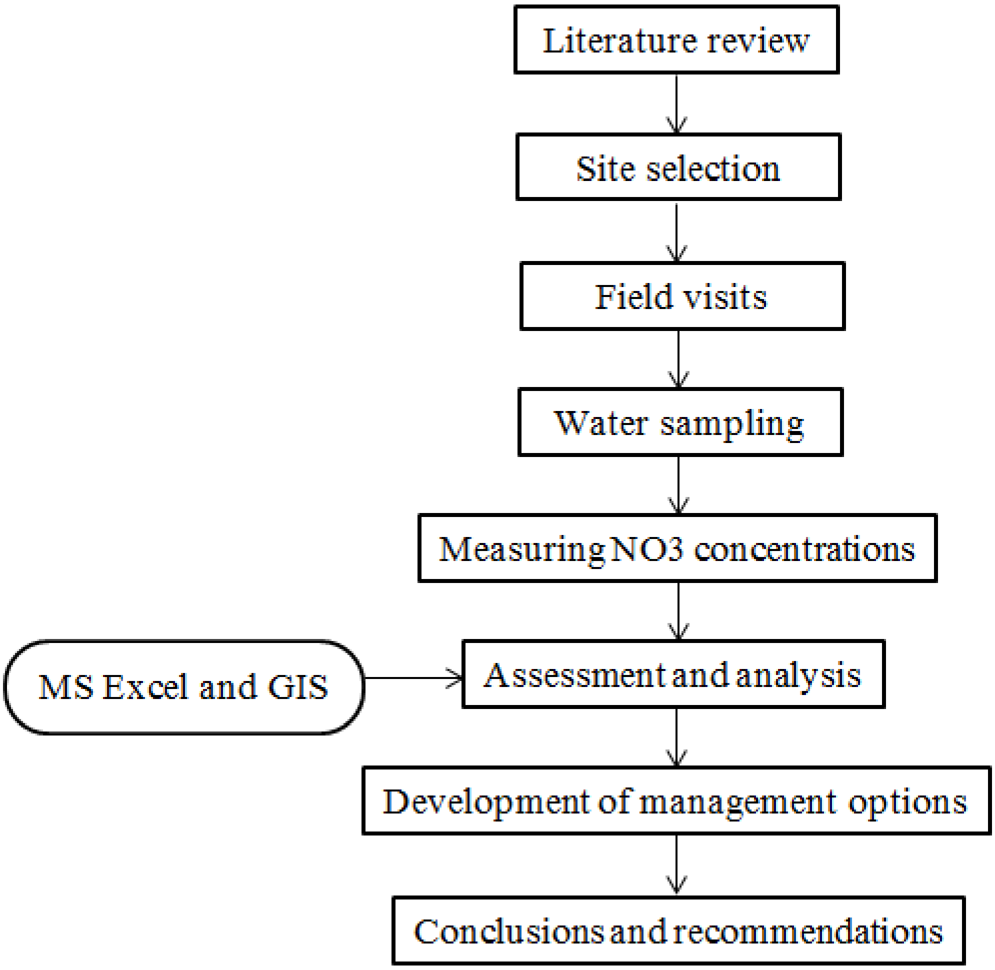

Figure 5: Research methodology

1.5 Literature Review

The concerns regarding the groundwater quality have grown in recent years and have focused on nitrate pollution in aquifers. Therefore, a lot of studies were carried out to assess, manage, and understand the occurrence of nitrate due to human activities on the ground surface with emphasis on agriculture.

These studies were conducted for long term environmental sustainability. Therefore, assessment should be based on both quality and quantity and the interaction between them. Several studies were carried out to assess the groundwater quality in the West Bank.

PWA identified the status of water quality in the West Bank aquifers based on the available data between 2005 and 2011 for selected representative wells in the Jordan Valley, Qalqilia and Tulkram governorates. Results showed that, there is an increasing trend in nitrate concentrations in groundwater aquifers resulted from the agricultural practices in these areas (PWA, 2011).

A report about the status of the environment in the state of Palestine was published by the Applied Research Institute – Jerusalem (ARIJ) in 2015. It highlights the problem of groundwater quality as the most serious problem which faces the water sector in recent years.

In particular, the main problem that was mentioned is the nitrate contamination of groundwater at high concentrations, due to the intensive use of agrochemicals in addition to the inflow of sewage into the aquifers.

For Faria catchment, groundwater is a very important water resource since it is utilized for domestic and agricultural purposes in the northeastern part of the West Bank. (Shadeed, Sawalha, & Haddad, 2016) concluded that there is deterioration in the quality of the groundwater in Faria catchment, resulted from the uncontrolled agricultural practices and wastewater leakage from cesspits in rural areas. Research involved sampling and testing of chemical parameters for selected wells. Results showed that nitrate concentration reached 81 mg/l in several wells, which is above the MCL.

The previous conclusion well matched the one of Anayah & Almasri (2009) that the nitrate concentrations in West Bank aquifers are increasing. During the period from 1982 to 2004, more than 50% of the maximum annual nitrate concentrations were above the MCL. Elevated concentrations in both the WAB and the EA are attributed to the intensive use of agrochemicals particularly in areas of Jenin, Tubas, Qalqilia and Tulkram Governorates. Thus fertilizers are considered as the main nonpoint source of nitrate contamination in the West Bank (Anayah & Almasri, 2009).

In the year 2003, United Nation Environment Program (UNEP) carried out a desk study about the environmental situation in the West Bank. This study involves the assessment of groundwater quality and quantity, and the degradation of water quality in some areas. Results showed that nitrate contamination was due to leakage of raw sewage, infiltration of fertilizers (UNEP, 2003).

An assessment study of groundwater pollution in Tulkarm area (Ghanem & Samhan, 2012) was conducted to evaluate the effect of human activities on the quality of groundwater. A spatial distribution of nitrate concentration was analyzed through carrying out an investigation for 40 wells (domestic and agricultural) in Tulkarm area. The results of the investigation showed that 55% of the sampled wells have elevated nitrate concentrations that exceed the WHO standards.

Table 1 summarizes a review of some local and worldwide studies that focus on the investigation of nitrate concentrations.

Table 1: Literature review summary table

Local Studies			
Source	**Study Description**	**Purpose**	**Relative Result**
(Ghanem M. , Samhan, Carlier, & Ali, 2011)	Groundwater pollution due to pesticides and heavy metals in North West Bank. Study involved collection of 50 groundwater samples for laboratory analysis using standard method.	To determine the effect of pesticides on groundwater quality in Jenin and Tulkarm.	Found that the majority of the groundwater wells in Tulkarm area had nitrate concentrations above the MCL, due to agricultural practices mainly fertilization. The bacterial pollution was absent in most samples justifying that nitrate results from agricultural practices. Concluded that there is a direct relation between well depth and nitrate concentration.
(Abu Maila, El-Nahal, & Al-Agha, 2004)	Seasonal variations and mechanisms of groundwater nitrate pollution in the Gaza Strip. Study involved collection and analysis of groundwater samples in 100 shallow wells (agricultural and domestic) to investigate the seasonal variation in nitrate concentration.	To better understand the mechanisms and factors controlling nitrate pollution.	Results showed that 90% of wells have nitrate concentrations above the MCL. For the seasonal variation, nitrate concentrations of domestic wells are more observable than those of agricultural wells. Study identified the environmental factors which control the occurrence of nitrate in groundwater: lack of sewage system, population density, and the application of fertilizers.
Worldwide Studies			
Source	**Study Description**	**Purpose**	**Relative Result**
(Ducci, Morte, Mottola, Onorati, & Pugliano, 2019)	Nitrate trends in groundwater of the Campania region (southern Italy). The Environmental Protection Agency of the Campania region in Italy (ARPAC) manages the groundwater quality through a monitoring network. This study focused on a	To study the distribution of nitrate in groundwater and spatially and temporally based on the sampling points	Results showed that at present, only 7% of the sampling points had nitrate concentrations above the MCL. On the country, agricultural activities are widely spread in the region of Campina. This is due to the presence of carbonate aquifers.

	large coastal plain in Campania region, since nitrate concentrations exceeds 200 mg/l. The used instrument is a Dionex (now Thermo-Fisher Scientifics) ion chromatography.	during the period 2003-2015.	
(Atekwana & Geyer, 2018)	Spatial and temporal variations in the geochemistry of shallow groundwater contaminated with nitrate at a residential site. Residential shallow groundwater site was investigated monthly over a period of 38 months.	To identify the processes that control the spatial and temporal distribution of NO3 in shallow	The average nitrate concentration was 36.8 mg/l and the range of concentrations was 0.1 to 214.9 mg/l, thus nitrate concentration highly varied over space and time. identified the factors affect the variability of nitrate spatially and temporally: recharge and the application of fertilizers at specific locations.
(Kurunc, et al., 2016)	Seasonal changes of spatial variation of some groundwater quality variables in a large irrigated coastal Mediterranean region of Turkey. 220 monitoring wells were investigated through four sampling campaigns. Nitrate concentrations were analyzed with a portable spectrometer (DR 2800 hach-lange) using Nitraver-5 reagent powder pillow.	To study the spatial and temporal variations of groundwater table depth, pH, electric conductivity (EC), and nitrate (NO3).	Study concluded that land use and farming practices influenced spatial and temporal variation of NO3 in groundwater. Therefore, management options should be utilized for land use practices. This may be useful for areas with similar soil, land use, and climate within the Mediterranean region.
(Almasri & Kaluarachichi, 2004)	Assessment and management of long-term nitrate pollution of groundwater in agriculture-dominated watersheds. Historical nitrate concentrations data from 1999 to 2000 were used to assess the spatial and temporal variation of nitrate concentrations using the geographic information system (GIS).	To document and evaluate long-term trends of nitrate in the groundwater of agricultural watersheds.	Results showed that the areas with nitrate concentrations above the maximum contaminant level are characterized with heavy agricultural practices. In addition, nitrate concentration deceased as sampling depth increased. Shallow aquifers were found to contain high mean nitrate concentrations. Analysis showed that high nitrate concentrations were related to high groundwater recharge and high on ground nitrogen loading.

Chapter Two

Methods and Data Analysis

2. Methods and Data Analysis

This chapter describes water sampling, method of nitrate measurements, corresponding results and discussions.

2.1 Water Sampling

Two sampling campaigns for the investigation of nitrate concentrations in the 16 wells in Ash-Shaarawieh area were carried out in December 2018 and January 2019. The purpose of this investigation was to gain insight into the spatial distribution of nitrate concentrations in the WAB. Table 1 identifies the well name, community, type, and well depth for selected wells.

Table 2: The selected groundwater wells for sampling within the WAB

ID	Well name	Community	Type	Well depth (m)
1	Deir Al Ghusun Village Council	Deir AlGhusun	Domestic	188
2	Abed Al-Majeed Qasem	Deir AlGhusun	Agricultural	200
3	As'ad Rabee' & Partners	Attil	Agricultural	190
4	Haseeb I'Mus	Attil	Agricultural	152
5	'Attil Cooperative Society	Attil	Agricultural	310
6	Muhammad Nemer Barakat	Attil	Agricultural	202
7	Zeita Village Council	Attil	Agricultural	262
8	Faris & Rushdee Abu Sabhah	Zeita	Agricultural	135
9	Muhammad 'Abed Al Razeq & Partners	Illar	Agricultural	200
10	Rasheed Samarah & Tahseen Shadeed	Illar	Agricultural	220
11	'Abed Al Jabbar Samarah	Zeita	Agricultural	160
12	Muhammad Khalaf	Baqa ash Sharqiya	Agricultural	133
13	Azeez Mas'ud	Baqa ash Sharqiya	Domestic	198
14	Qaffin Village Council	Qaffin	Agricultural	176
15	'Awni 'Abd Al Hadi	Qaffin	Agricultural	180
16	Adeeb Kittanah	Annazla ash Sharqiya	Agricultural	160

Sampling of another 6 adjacent wells that are at different depths and located in Qabatiya Town in Jenin governorate within the boundary of the EA. Samples were collected to achieve the vertical distribution goal on monthly basis. Table 2 identifies the selected sampled wells in Qabatiya town.

Table 3: The selected groundwater wells for sampling within the Eocene aquifer

ID	Well name	Type	Well depth (m)
1	Ahmad zakarya Kamil	Domestic	350
2	Abu Anwar	Agricultural	310
3	Alaa Zakarna	Agricultural	320
4	Abu Mostfa	Agricultural	300
5	Abu Yaseen	Agricultural	300
6	Abu Naser	Agricultural	260

2.2 Analytical Method

Water samples were stored into pre-washed plastic container (100 ml) and transferred inside icebox at 4°C. The collected samples were transported to the laboratory within 48 hours and were stored at a temperature less than 4°C until the analysis. Nitrate concentrations in mg/l were analyzed through cadmium reduction method using a spectrophotometer. The used reagent is Nitraver-5 NO3 powder pillow.

The following procedures and the instructions were identified by the manufacture [4]. First and before starting the analysis let the sample temperature increase to room temperature.

[4] For more information about the instrument, visit https://www.hach.com/dr6000-uv-vis-spectrophotometer-with-rfid-technology/product-details?id=10239244800.

Start the instrument and select the program for the used reagent. Then fill the cell sample with 10 ml of sample, add the contents of one powder pillow reagent, and select the instrument timer (1 minute for the reaction). Shake the sample until the timer expires. The color will change into amber color if nitrate is present after 5 minutes. During this period blank sample of distilled water should be prepared to set zero concentration. Finally insert the prepared sample into the instrument and read. Result will appear on the screen as mg/l NO3-N. Figure 6 depicts the nitrate measurement instrument used for laboratory analysis.

Figure 6: Spectrophotometer used for laboratory nitrate measurement

2.3 Results and Discussion

2.3.1 Spatial Distribution of Nitrate

Figure 7 depicts the nitrate concentrations at well location based on the results of laboratory analysis for Ash-Shaarawieh area.

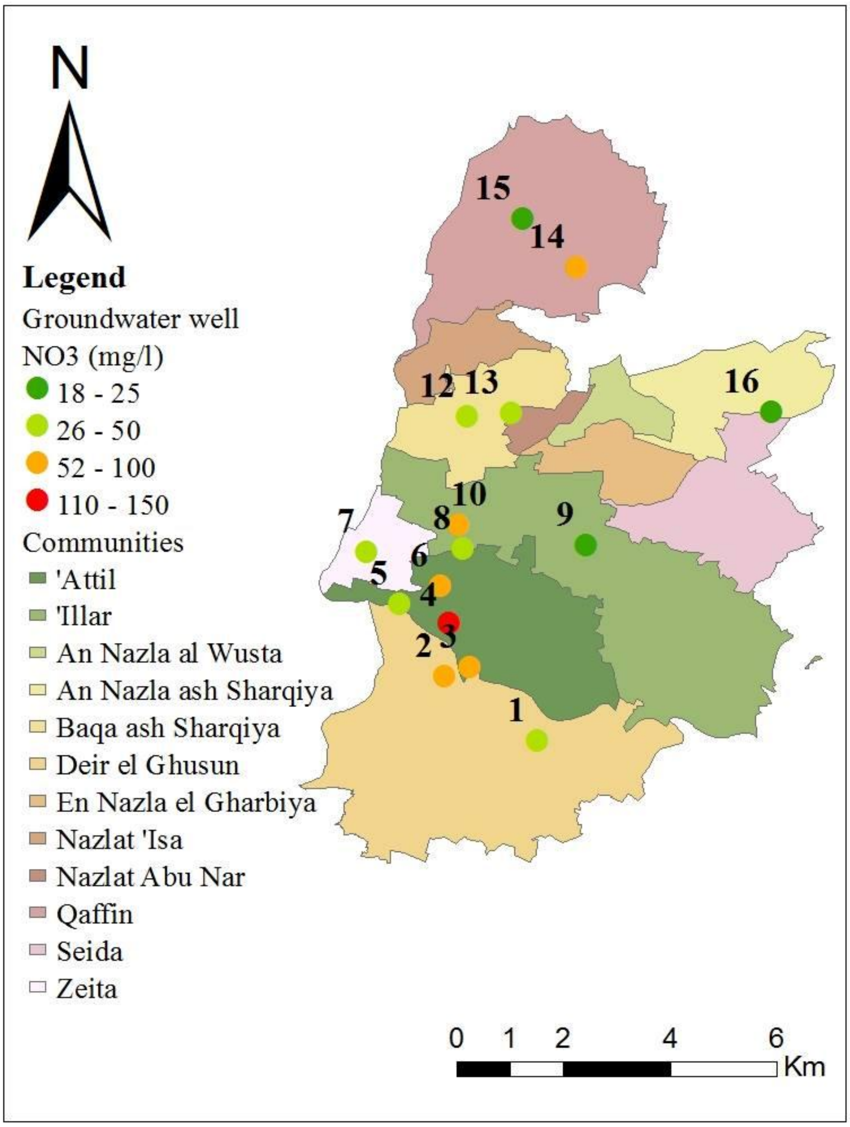

Figure 7: A map of nitrate concentrations in the groundwater of Ash-Shaarawieh

The elevated nitrate concentrations were observed in Attil and Illar. While another adjacent well in Deir Al Ghusun has the second elevated range of nitrate concentrations (52-100 mg/l). The maximum nitrate concentration was observed in January 2019 and equals to 181.06 mg/l at Haseeb I'mus well in Attil.

Wells of high nitrate concentrations are utilized for agriculture and are located where a large areas of irrigated agriculture exists. Irrigated agriculture includes cucumbers, tomatoes, citrus, molokhia, pepper and other vegetables. These concentrations reflect the intense agricultural practices such as fertilizers, pesticides, and irrigation.

In addition to the presence of other point sources like cesspits and improper disposal of sewage that is a widely spread activity in this area. Locals dispose their sewage in areas very close to irrigated areas. This was noticed through field visits and forms a point source of nitrate pollution which is then discharged into the shallow aquifer. Figure 8 depicts outfall of wastewater system that is located in Zeita.

Figure 8: Outfall of sewage system forms as point source of nitrate pollution in Ash-Shaarawieh

Nitrate concentrations below the MCL were observed in Qaffin, An Nazle Asharqiya, and Baqa Asharqiya, where wells of domestic type are utilized.

It should be noticed that fate and transport processes take place and lead to the appearance of nitrate in many locations. This means that human activities in the upstream areas may affect water quality of wells located in the downstream areas. As seen in figure 7, well No.4 and Well No.10 are located to the west and utilized for irrigated farming. Figure 9 depicts the land use of Ash-Shaarawieh area.

It is obvious that large area of permanent crops is located within the boundaries of studied area, while irrigated areas are concentrated in the western part of the area in Illar, Attil, and Deir Al Ghusun, and this justifies the high nitrate concentrations that were observed in these areas.

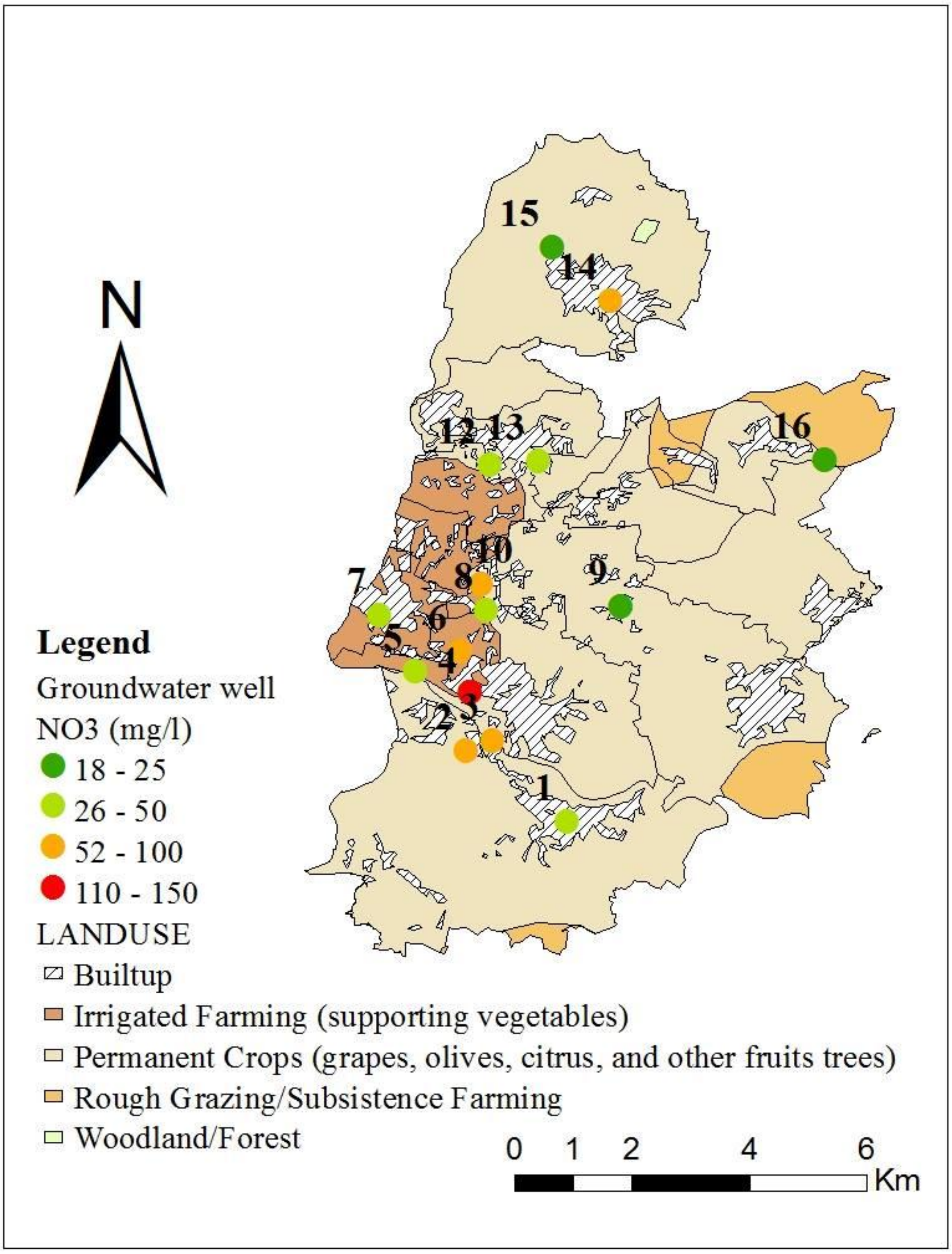

Figure 9: A map of land use and selected wells in Ash-Shaarawieh

In general, the nitrate pollution has an increasing trend in the Western aquifer. Nitrate concentrations were higher beneath irrigated areas especially in the western part of the study area since the movement of groundwater in the WAB is toward the west. Figure 10 depicts the spatial distribution for the nitrate concentrations of Ash-Shaarawieh in January 2019.

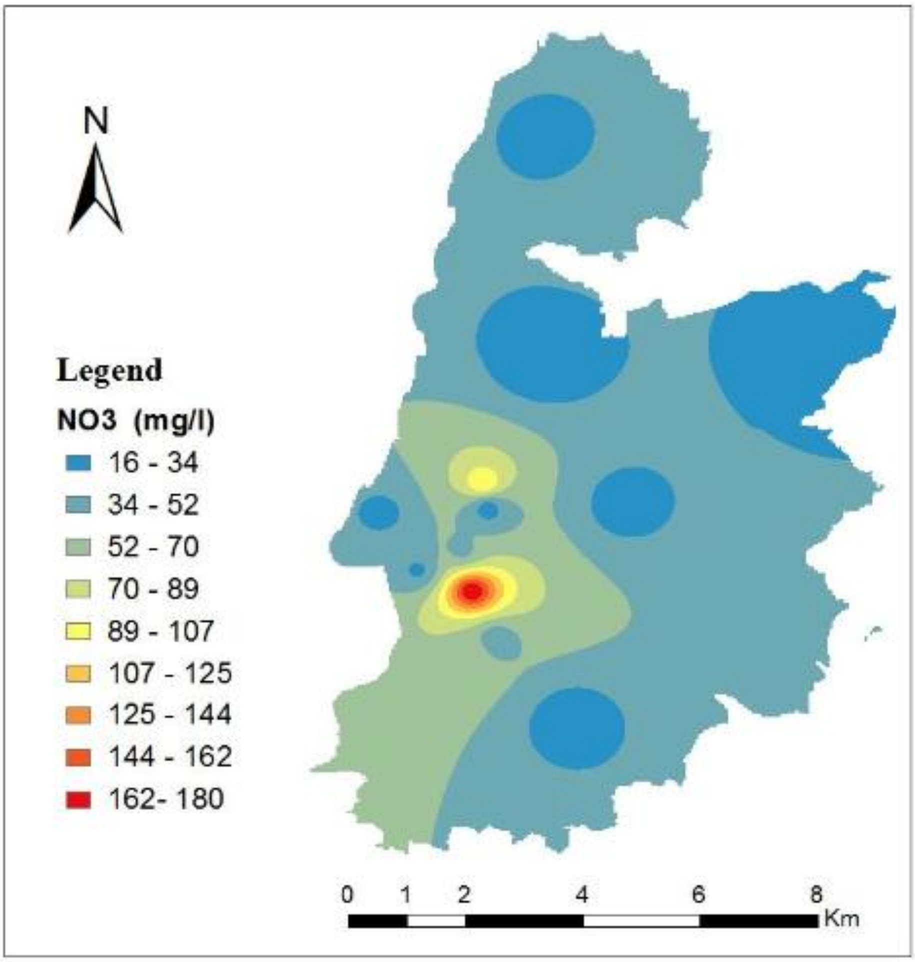

Figure 10: The spatial distribution for the nitrate concentrations of Ash-Shaarawieh in January 2019

The previous results well matched the nitrate measurements that were carried out by PWA for the period from 2003 to 2012. In year 2004, the 16 wells were tested and recorded in PWA database.

Nitrate pollution has an increasing trend in Ash-Shaarawieh area especially in the western part (Attil, Illar, and Deir AlGhusun) resulted mainly from intense agricultural activates. Figure 11 depicts the spatial distribution for the nitrate concentrations of Ash-Shaarawieh in May 2004.

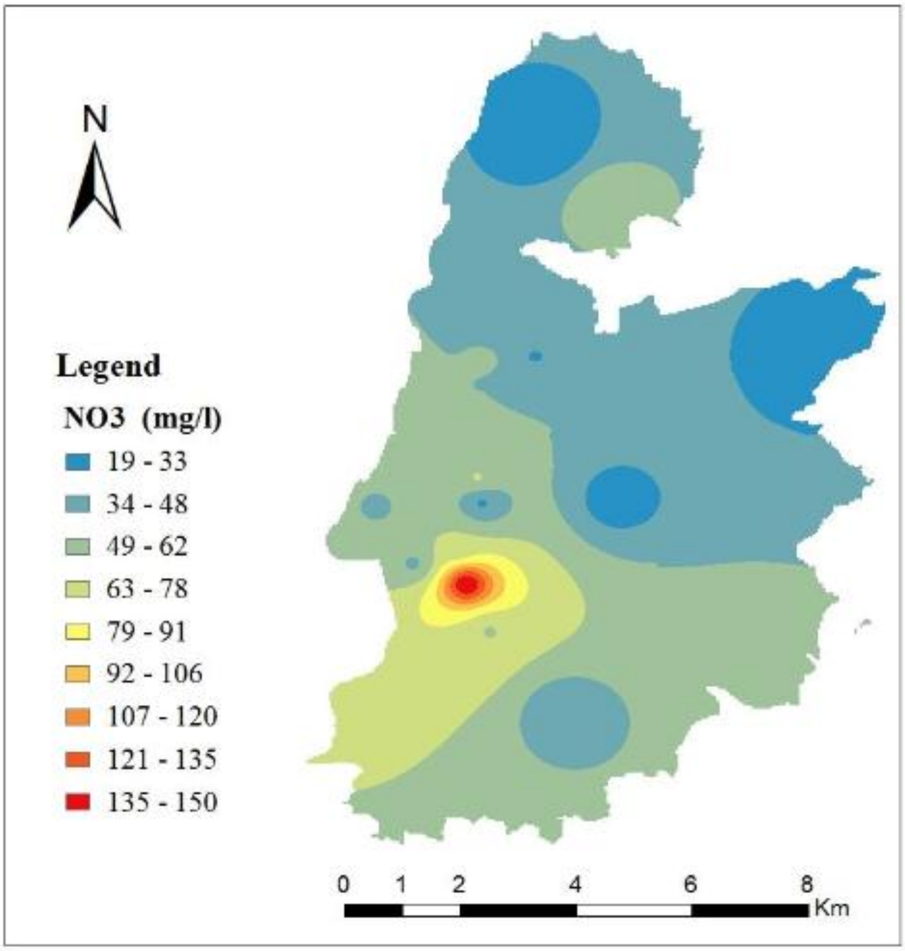

Figure 11: Spatial distribution for the nitrate concentrations of Ash-Shaarawieh in the year 2004 based on the available data in the PWA database

2.3.2 Vertical Distribution of Nitrate

The vertical variation of nitrate concentration was investigated at different sampling depths for six adjacent wells in Qabtiya town in Jenin governorate. This investigation was carried out on monthly basis between September 2018 and March 2019. Figure 12 depicts the locations of these sampled wells within the Eocene aquifer.

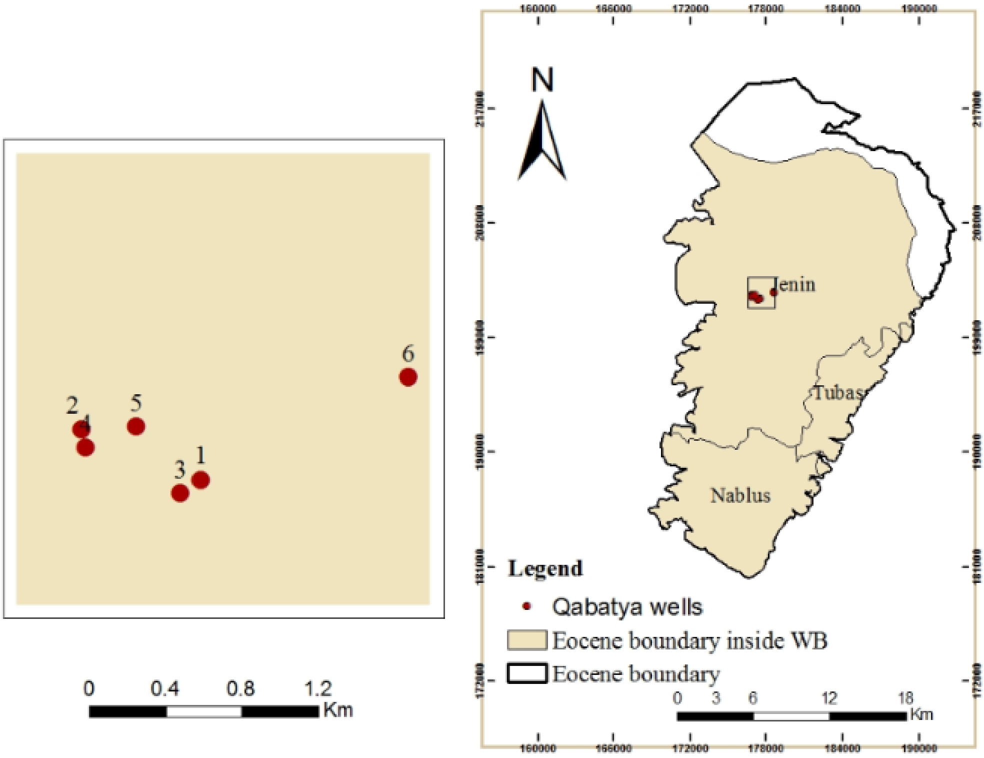

Figure 12: A map represents the location of sampled wells within the Eocene aquifer

Results illustrate that there is an inverse relation between the depth of well and the concentrations of nitrate. Figure 13 depicts the results of nitrate measurements versus the well depth.

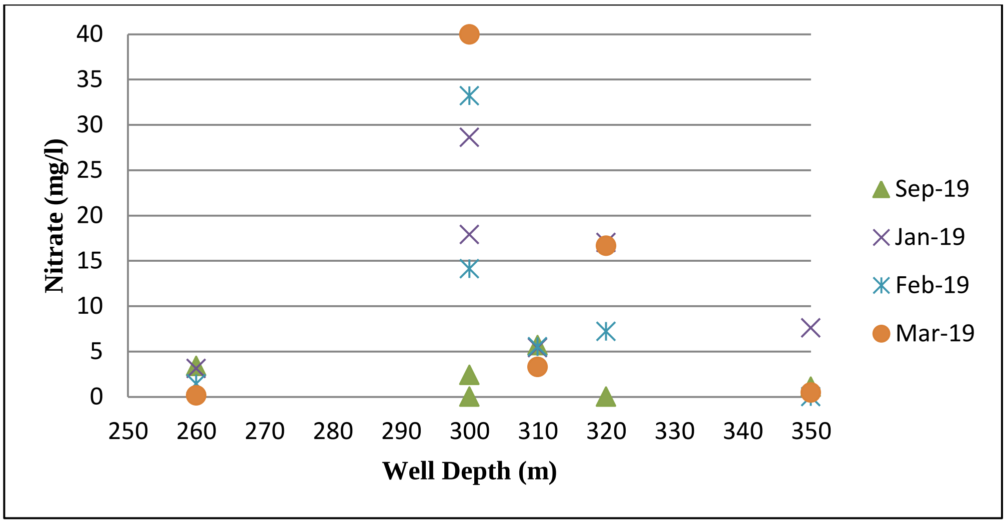

Figure 13: The concentrations of nitrate versus the depth for wells of Qabatiya within the Eocene aquifer

It obvious that the relation between nitrate concentrations and the depth is clear for depths between 300 m and 350 m. As depth increased, the nitrate decreased. While well of 260 m depth has the smallest nitrate concentrations less than 5 mg/l and does not indicate a relation.

Concentrations of nitrate varied vertically and temporally for the 6 wells of Qabatiya. Figure 14 shows the temporal variation of nitrate concentrations, it obvious that there was a large variation between September 2018 and January 2019. Concentrations have been increased due to recharge within the rainy season (winter).

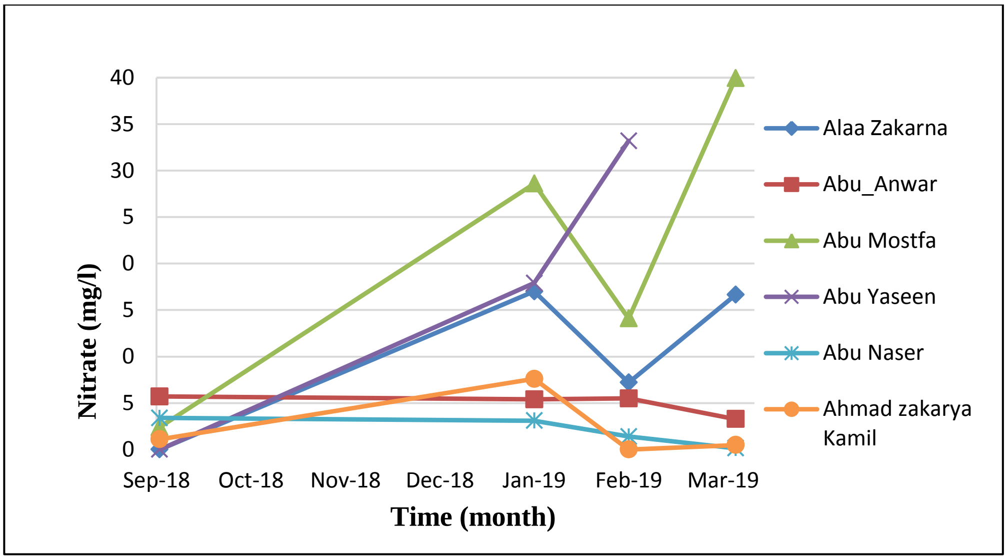

Figure 14: Temporal variation of nitrate for wells of Qabatiya within the Eocene aquifer

In general, nitrate decreases as the depth of sampling increases. Figure 15 depicts the variation of the nitrate concentrations with respect to well depth in the Eocene aquifer based on both, the PWA data that includes 432 nitrate readings that represent 28 different wells for the years 1982 to 2012 and the field sampling for 24 different wells conducted in 2017 by PADUCO project.

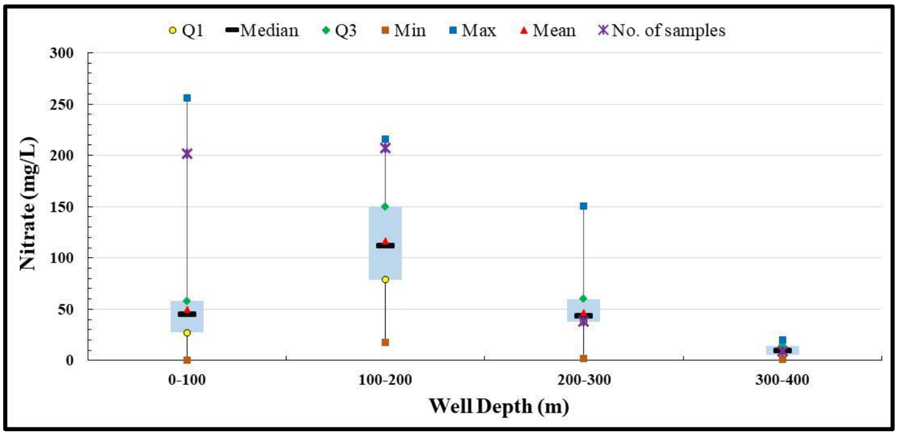

Figure 15: Statistics of nitrate concentration for the different sampling depths in the Eocene Aquifer for the period from 1982 to 2017.

Chapter Three

Management of Nitrate Contamination

3. Management of Nitrate Contamination

3.1 Background

Nitrate can easily reach aquifers due to its high mobility (Tesoriero, et al., 2000; Almasri, et al., 2005) making it a high contaminating chemical. Leaching of nitrate from unsaturated zone depends on many factors such as land use activities, groundwater recharge, on-ground nitrogen loading, soil characteristic, and depth to water table ((Birkinshaw & Ewen, 2000; Almasri & Kaluarachchi, 2004). Figure 12 depicts a schematic of nitrate leaching due to on-ground nitrogen loadings. Apparently, controlling on-ground loading affects nitrate leaching.

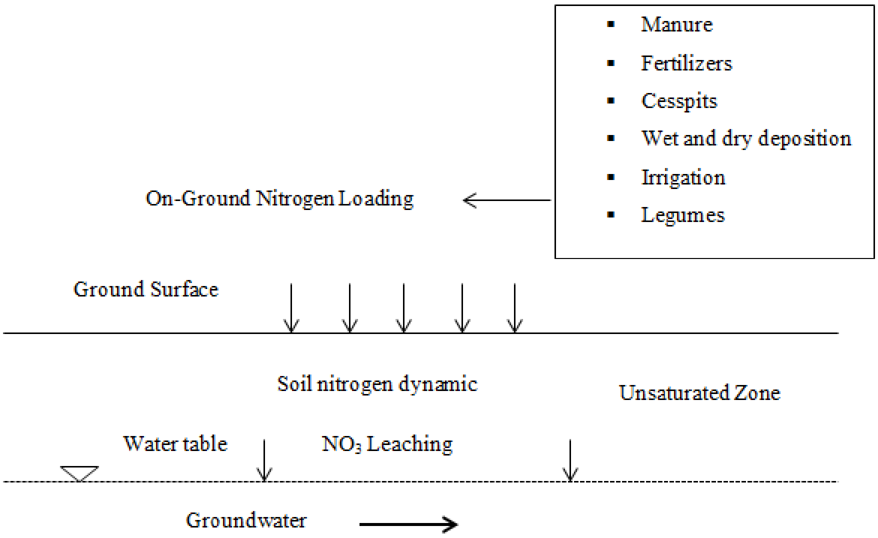

Figure 16: Schematic describing the process of groundwater nitrate contamination[5]

[5] Adapted from Almasri & Kaluarachchi, Multi-criteria decision analysis for the optimal management of nitrate contamination of aquifers, 2005.

Degradation of groundwater quality due to nitrate pollution and the related effects on human health have motivated the adoption of mitigation measures that can keep the nitrate concentrations below the MCL depending on the nitrate sources. The main goal of management options is to minimize the nitrate contamination problem and to keep nitrate concentrations below the MCL. In addition, management options are essential to provide land use planners and decision makers with proposed mitigation measures that ought to be carried out to minimize the problem of nitrate pollution.

This chapter highlights selected proposed management options in order to control the nitrate contamination in both the EA and the WAB. Figure 13 depicts a flow chart describing the general management options framework elements.

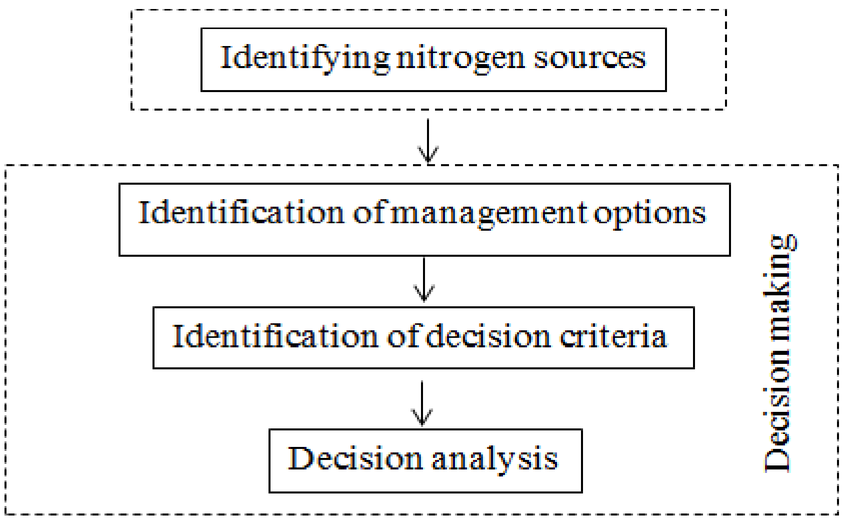

Figure 17: Flow chart depicting the general management framework elements for decision making

3.2 Management Options

The managemnt options entail the control of potentail sources due to the human activites on the ground surface. Each management option can address a specisic source that is not addressed by another mangenet option (Almasri, 2007).

On the other hand, same pollution source can be controlled through different management options based on the reqiuired levels of effectivness and cost. Worldwide, and in many cases, a lot of researchers studied the implementation of management options to control the problem of nitrate pollution in groundwater. A number of management practices to control manure loading into groundwater were identified. Some of these management options such as treatment[6] of manure require large investment in equipment and maintenance. On the other hand, composting is good alternative since it helps in the reduction of both volume and nitrogen up to 50% (Davis, et al., 1999). Nitrogen-based fertilizer application rate in agricultural areas has been considered the main non-point source of nitrate contamiantion of groundwater, therfore reduction in application rate will be an efficient option (Yadav & Wall, 1998). However, the reduction of the fertilizer application is considerd a serious economic concern for farmers as it will affect the crop yield. Management options which are considered in this analysis are as follows; restriction on the use of nitrogen-based fertilizers, rehabilitation of wastewater collection networks, irrigation

[6] One of these treatment methods is Lagoon structure which designed to treat manure by bacterial degradation (Davis et al., 1999).

method and scheduling, and the control of the use of cesspits. Table 2 summarizes the set of proposed management options to manage the problem of nitrate contamination in the studied areas.

Table 4: Summary describing the proposed management options related to nitrate contamination problem in the studied areas

ID	Management option	Description	Where to apply?
1	Restriction on the use of nitrogen-based fertilizer	To manage the amount, method of application, and timing of N application.	Deir AlGhusun, Attil, Illar,‘Arrbbuna, Al Jalma, ‘Arrana, Deir Ghazala, Faqqu’a, Kafr Dan, Aljameelat, Beit Qad, Jenin, Jenin camp, Jalbun, ‘Aba, Deir Abu Da’if, Umm at Tut, Ash Shuhada, Jalqamus, Al Mughayyir, Bir Albasha, Qabatiya, Raba, Misliya, Al Jarba, Az Zababida, , Al Kufeir, Sir, ‘Anza, Sanur, Meithalun, Al Jadida, Salhab, ‘Aqqaba, Ras al Far’a, El far’a camp, Talluza.
2	Irrigation method and scheduling	Use high efficiency irrigation system to avoid runoff and deep percolation[7]. Scheduling involves how much and when to irrigate depending on plants needs and soil moisture to avoid runoff and high leaching potential.	Deir AlGhusun, Attil, Illar,‘Arrbbuna, Al Jalma, ‘Arrana, Deir Ghazala, Faqqu’a, Kafr Dan, Aljameelat, Beit Qad, Jenin, Jenin camp, Jalbun, ‘Aba, Deir Abu Da’if, Umm at Tut, Ash Shuhada, Jalqamus, Al Mughayyir, Bir Albasha, Qabatiya, Raba, Misliya, Al Jarba, Az Zababida, , Al Kufeir, Sir, ‘Anza, Sanur, Meithalun, Al Jadida, Salhab, ‘Aqqaba, Ras al Far’a, El far’a camp, Talluza.
4	Control the use of cesspits	Proper insulation, frequent disposal, and proper disposal.	Deir AlGhusun, Attil, Zeita, Illar, Baqa ash Sharqiya, Qaffin, Annazla ash Sharqiya, Arrbbuna, Al Jalma, ‘Arrana, Deir Ghazala, Faqqu’a, Kafr Dan, Aljameelat, Beit Qad, Jenin, Jenin camp, Jalbun, ‘Aba, Deir Abu Da’if, Wad ad Dabi’, Umm at Tut, Ash Shuhada, Jalqamus, Al Mughayyir, Al Mutilla, Bir Albasha, Tannin, Qabatiya, Telfit,Raba, Misliya, Al Jarba, Az Zababida, , Al Kufeir, Sir, ‘Anza, Sanur, Meithalun, Al Jadida, Siris, Salhab, ‘Aqqaba, Ras al Far’a, El far’a camp, Yasid, Al Badan, ‘Asira ash Shamaliya, Talluza.

[7] High efficiency irrigation system can be sprinkler or drip.

In general, management options entail different properties and conflicting objectives, therfore there applicabilty has to be well evaluated probably and perfectly using the multi criteria decisin analysis (MCDA) (Almasri M. , 2007).

3.3 A review of Multi-Criteria Decision Analysis

A number of proposed management options to protect the groundwater quality from nitrate contamination are evaluated through the MCDA. In general, MCDA evaluates a set of proposed management options in terms of multi criteria in order to provide decision makers with most effective option. This type of analysis is considered useful for diverse priorities and conflict objectives and yield a decision based on different goals such as economic and environmental. A criterion is a characteristic of management option that the decision maker considered important (Almasri & Kaluarachchi, 2005).

Multi criteria decision analysis employs the approach of the importance order of criteria (IOC) [8] for the purpose of selection and ranking of alternatives. This method identifies the best and the worst management option based on the total utility of an alternative through the weighting and ranking for each decision criteria. The objective function is to maximize the total utility.

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[8] For more details see (Yakowitz, et al., 1993).

Therefore, the best option will be selected via the selection of the maximum total utility of proposed options as below:

$$Uj = \sum_{i=1}^{n} WiVij \quad (1)$$

Where n is the number of criteria of option j; W_i is the weight of criterion and V_{ij} is the value of option with respect to *i*th criteria. This objective function is subject to the following constraints:

$$W_1 \geq W_2 \geq \ldots \geq W_n \quad (2)$$

$$\sum_{i=0}^{n} Wi = 1 \quad (3)$$

$$W_i \geq 0 \quad (4)$$

The first constraint defines the ranking with respect to importance of each criterion. Second one is the scaling constraint while the third is the non-negativity constraint. In order to evaluate suggested management options, MCDA requires identification of decision criteria. The decision criteria could be either of environmental, economic and social concerns. Total cost is a criterion of economic objective, while farmer awareness and health hazards are considered as criterion of social objective. On the other hand, leaching of nitrate to groundwater is a criterion of environmental objective. Table 5 shows suggested MCDA analysis of proposed management options for nitrate pollution in the studied areas.

Table 5: Suggested multi criteria decision analysis of proposed management options for nitrate groundwater pollution

Criteria	**Wight**	**Management Options**			
		Do nothing (keep the current situation)	Restriction on the use of nitrogen-based fertilizers	Irrigation method & scheduling	Control the use of cesspits
Leaching of nitrate to groundwater	W_1	V_{11}	V_{12}	V_{13}	V_{14}
Farmer awareness	W2	V21	V22	V23	V24
Health hazardous	W3	V31	V32	V33	V34
Total cost of MO	W4	V41	V42	V43	V44
Total	$\sum_{i=1}^{n} Wi$	$\sum_{i=1}^{n} WiVi1$	$\sum_{i=1}^{n} WiVi2$	$\sum_{i=1}^{n} WiVi3$	$\sum_{i=1}^{n} WiVi4$

Chapter Four
Conclusions and Recommendations

4. Conclusions and Recommendations

4.1 Conclusions

The following are the main conclusions:

1) The areas of intense agricultural activities have the maximum values of nitrate concentrations exceeding the MCL.

2) The disposal of untreated wastewater is considered as a point source of nitrate contamination in the groundwater of Ash-Shaarawieh.

3) Nitrate concentration decreases as depth of sampling increases.

4) Water sampling and analysis were overwrought as some limitations regarding to reagent, stock of samples, well owner, and budget impacted the process of collection and measurement.

5) The implementation of the proposed management options will help in controlling the problem of nitrate contamination in the studied areas.

4.2 Recommendations

The following are the recommendations:

1. More frequent and well distributed sampling should be promoted. This should follow a well-developed strategy for groundwater monitoring.

2. Modeling should be utilized for the selection of proper management options to control nitrate occurrence in groundwater aquifers.

3. Proposed management options should be applied through regional development plan for groundwater quality.

4. The stakeholders and all involved parties should be involved in the discussion meeting for the selection of proper management options. This involvement is essential to come up with sound and realistic management options.

References

- Viers, J., Liptzin, D., Rosenstock, T., Jensen, V., Hollander, A., McNally, A., et al. (2012). **Nitrogen Sources and Loading to Groundwater**. Davis: Center for Watershed Sciences, University of California.

- Abu Maila, Y., El-Nahal, I., & Al-Agha, M. (2004). **Seasonal variation and mechanisms of groundwater nitrate pollution in the Gaza Strip.** Environmental Geology, 47, 84-90.

- Abusaada, M. J. (2011). **Flow Dynamics and Management Options in a Stressed Carbonate Aquifer System,The Western Aquifer Basin,Palestine.**

- Almasri, Kaluarachchi, J. J., Ghabayen, S., Jarrar, A., McKee, M., Jayyousi, A., et al. (2005). **Assessment of Groundwater Vulnerability to Nitrate Contamination in Gaza Strip, Palestine.** ASCE-EWRI.

- Almasri, M. (2007). **Nitrate contamination of groundwater: A conceptual management framework.** Environmental Impact Assessment Review, 220-242.

- Almasri, M. (2007). **Nitrate contamination of groundwater: A conceptual management framework.** Environmental Impact Assessment Review, 27, 220-242.

- Almasri, M., & Kaluarachchi, J. (2004). I***mplications of on-ground nitrogen loading and soil transformation on groundwater quality management.*** **J Am Water Resour Assoc (JAWRA),** *40(1)*, 165–86.

- Almasri, M., & Kaluarachichi, J. (2004). ***Assessment and management of long-term nitrate pollution of ground water in agriculture-dominated watersheds.*** **Journal of Hydology,** 225-245.

- Almasri, N. M., & Kaluarachchi, J. J. (2005). ***Multi-criteria decision analysis for the optimal management of nitrate contamination of aquifers.*** **Journal of Environmental Management,** *74*, 365-381.

- Anayah, F., & Almasri, M. (2009). **Trends and occurrences of nitrate in the groundwater of the West Bank, Palestine.** Elsevier.

- ARIJ. (2015). Status of Environment in the Stat of Palestine. The Applied Research Institute-Jerusalem.

- Atekwana, E., & Geyer, C. (2018). **Spatial and temporal variations in the geochemistry of shallow groundwater contaminated with nitrate at a residential site.** Environmental Science and Pollution Research, 27155-27172.

- Authority, P. W. (2011). **Annual Status Report on water resources, water supply, and wastewater in the Occupied state of Palestine.** Ramallah: PWA.

- Birkinshaw, S. J., & Ewen, J. (2000). ***Nitrogen transformation component for SHETRAN catchment transport modelling.*** **Journal of Hydrology**, 1-17.

- Chowdary, V. M., Rao, N. H., & Sarma, P. S. (2005). **Decision Support Framework for Assessment of Non-point-source Pollution of Groundwater in Large Irrigation Projects**. ScienceDirect, 194-225.

- Davis, J., Koenig, R., & Flynn, R. (1999). **Manure Best Management Practices: A practical Guide For Dairies in Colorado, Utah and New Mexico**. U.S. Environmental Protection Agency and U.S. Department of Agriculture.

- Ducci, D., Morte, R. D., Mottola, A., Onorati, G., & Pugliano, G. (2019). **Nitrate trend in groundwater of the Campania region (southern Italy).** Environmental Science and Pollution Research, 26(3), 2120–2131.

- El-Fadel, Quba'a, R., El-Hougeiri, N., Hashisho, Z., & Jamali, D. (2001). **The Israeli Palestinian Mountain Aquifer : A Case Study in Groundwater Conflict Resolution.** Vol.30.

- Ghanem, M., & Samhan, N. (2012). ***Groundwater Pollution Assessment In Tulkarm Area, Palestine***. **Journal of Earth Sciences and Geotechnical Engineering**, *2*, 1-16.

- Ghanem, M., Samhan, S., Carlier, E., & Ali, W. (2011). ***Groundwater Pollution Due to Pesticides and Heavy Metals in North West Bank***. **Journal of Envrionmetal Protection,** *02*(04), 429-432.

- Goodchild, R. (1998). **EU policies for the reduction of nitrogen in water: the example of the nitrates directive**. Environmental Pollution, *102*(1), 737-740.

- Hajhamad, L., & Almasri, M. N. (2009). **Assessment of nitrate contamination of groundwater using lumped-parameter models.** ELSEVIER.

- Hall, M. D., Shaffer, M. J., Waskom, R. M., & Delgado, J. A. (2001). ***Regional nitrate leaching variability : What makes a difference in northeastern Colorado.*** **Journal of the American Water Resources Association**, *37(1)*.

- Jebreen, H., Wohnlich, S., Banning, A., Wisotzky, F., Niedermayr, A., & Ghanem, M. (2018). **Recharge, geochemical processes and water quality in karst aquifers:Central West Bank, Palestine.** Environmental Earth Sciences, *77*.

- Joosten, L., Buijze, S., & Jansen, D. (1998). **Nitrate in sources of drinking water? Dutch drinking water companies aim at prevention.** Envrionmental Pollution, *102*(1), 487-492.

- Kurunc, A., Ersahim, S., Sonmez, N. K., Kaman, H., Uz, I., UZ, B. Y., et al. (2016). **Seasonal changes of spatial variation of some groundwater quality variables in a large irrigated coastal Mediterranean region of Turkey**. Science of the Total Environment, 53-63.

- Lee, Y. (1992). **Risk assessment and risk management for nitrate-contaminated groundwater supplies : Unpublished PhD dissertation. University of Nebraska.** Lincoln, Nebraska.

- PCBS. (2016). Retrieved from http://www.pcbs.gov.ps

- Postma, D., Kristiansen, H., Boesen, C., & Larsen, F. (1991). **Nitrate Reduction in an Uconfined Sandy Aquifer:Water Chemistry, Reduction Processes, and Geochemical Modeling**. Water Resources Research, 2027-2045.

- PWA. (2011). **Annual Status Report on water resources, Water Supply, and Wastewater in the Occupied State of Palestine**. Ramallah: Palestinian Water Authority.

- PWA. (2012). **Status Report of Water Resources in the Occuiped State of Palestine**. Palestinian Water Authority.

- PWA. (2013). **Transboundary Water Resources Strategy.** Ramallah: Palestinian Water Authority.

- Re, V., Sacchi, E., Kammoun , S., Tringali , C., Trabelsi , R., Zouari , K., et al. (2017). **Integrated socio-hydrogeological approach to tackle nitrate contamination in groundwater resources.** Science of The Total Environment, 664–676.

- Shadeed, S., Sawalha, M., & Haddad, M. (2016). ***Assessment of Groundwater Quality in the Faria Catchment, Palestine.*** **An-Najah Univ.J.Res**. (N.Sc.), 30(1).

- SUSMAQ. (2003). **Boundaries of the Western Aquifer Basin and the Eocene Aquifer in the Northeastern Aquifer Basin.**

- Tesoriero, A. J., Hugh, L., & Cox, S. (2000). **Mechanism and rate of denitrification in an agricultural watershed: Electron and mass balance along groundwater flow paths**. Water Resources Research, 36, 1545-1559.

- UNEP. (2003). **Desk Study on the Environment in the Occupied Palestinian Territories**. Nairobi,Kenya: United Nations Environment Programmer.

- UN-ESCWA, & BGR. (2013). **Inventory of Shared Water Resources in Western Asia.** Beirut: (United Nations Economic and Social Commission for Western Asia; Bundesanstalt für Geowissenschaften und Rohstoffe).

- US EPA, U. (2018). **Drinking Water Standards and Health Advisories.** Washington, DC: Office of Water.

- Wolfe, A., & Patz, J. (2002). **Reactive Nitrogen and Human Health:Acute and Long-term Implications.** AMBIO, 31(*2)*, 120-125.

- Yadav, S. N., & Wall, D. B. (1998, March). **Benefit-cost analysis of best managemnet practices implemented to control nitrate contamination of groundwater.** Water Resources Research, *34 (3),* 497-504.

- Yakowitz, D. S., Lane, L. J., & Dzidarovszky, F. (1993). **Multi-attribute decisiom-making: dominance with respect to an importance order of the attributes.** Applied Mathematics and Computation, 54(6), 167-181.

- Zhou, Z. (2015). **A Global Assessment of Nitate Contamination in Groundwater.** International Groundwater Resources Assessment Centre, WAGENINGEN University & Research.

Appendix I

The results of analysis for wells located in Qabatiya town in Jenin governorate in the Eocene aquifer.

ID	Well Name	Depth (m)	Water use	Nitrate concentration(mg/l)			
				Sep-18	Jan-19	Feb-19	Mar-19
1	Ahmad Zakarya Kmail	350	Domestic	1.1	4.87	-	0.48
2	Alaa Zakarneh	320	Domestic	1.4	6.6	7.2	16.65
3	Abu Anwar	310	Domestic	5.7	4.43	5.5	3.27
4	Abu Mostfa	300	Domestic	2.4	38.96	14.1	39.95
5	Abu Yaseen	300	Agricultural	7.6	12.39	33.2	-
6	Abu Naser	260	Agricultural	3.4	3.1	1.4	0.13

Appendix II

The results of analysis for wells that were considered in the study of the WAB.

ID	Well Name	Well ID	LGU	Depth (m)	Water use	Nitrate concentration(mg/l)	
						Dec-18	Jan-19
1	Deir Al Ghusun Village Council	15-19/047A	Deir Al Ghusun	188	Domestic	26.12	19.92
2	Abed Al-Majeed Qasem	15-19/029	Deir Al Ghusun	200	Agriculture	51.80	65.08
3	As'ad Rabee' & Partners	15-19/035	Attil	190	Agriculture	38.96	38.96
4	Haseeb I'Mus	15-19/021	Attil	152	Agriculture	144.76	181.06
5	Attil Cooperative Society	15-19/036	Attil	310	Agriculture	32.32	30.99
6	Muhammad Nemer Barakat	15-19/041	Attil	202	Agriculture	61.09	48.25
7	Zeita Village Council	15-19/010	Zeita	262	Agriculture	31.43	28.78
8	Faris & Rushdee Abu Sabhah	15-19/031	Zaita	135	Agriculture	22.58	25.23
9	Muhammad 'Abed Al Razeq & Partners	15-19/042	Illar	200	Agriculture	37.19	22.58
10	Rasheed Samarah & Tahseen Shadeed	15-19/023	Illar	125	Agriculture	112.00	105.36
11	Abed Al Jabbar Samarah	15-19/011	Zeita	160	Agriculture	28.33	20.92
12	Muhammad Khalaf	15-20/001	Baqa ash Sharqiya	133	Agriculture	26.12	23.91
14	Qaffin Village Council	15-20/008	Qaffin	176	Agriculture	17.71	42.94
15	Awni 'Abd Al Hadi	15-20/007	Qaffin	180	Agriculture	31.43	13.28
16	Adeeb Kittanah	16-20/005	An Nazla ash Sharqiya	160	Agriculture	16.38	17.71

جامعة النجاح الوطنية

كلية الدراسات العليا

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بلسم تيسير الجندي

إشراف

د. محمد نهاد المصري

قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة المياه والبيئة، بكلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس – فلسطين.

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الملخص

تعتبر المياه الجوفية المصدر الرئيسي للمياه العذبة للفلسطينيين في الضفة الغربية وقطاع غزة. لذلك فإن تقييم جودتها و كميتها أمر ضروري. أشارت الدراسات الحديثة إلى وجود اتجاه متزايد في تلوث النترات في الحوض الأيوسيني والحوض الغربي. يُعزى تلوث النترات بشكل أساسي إلى الاستخدام المكثف للأسمدة، وتسرب المياه العادمة الناتجة عن الحفر الامتصاصية، وشبكات جمع مياه الصرف الصحي غير المناسبة. إن وجود تراكيز عالية من النترات في مياه الشرب قد تسبب مشاكل صحية مثل ميتهيموغلوبينية الدم عند الرضع وسرطان المعدة عند البالغين. يهدف هذا البحث إلى فهم التوزيع المكاني والعمودي للتلوث بالنترات في المياه الجوفية بالضفة الغربية من خلال أخذ الحوض الأيوسيني والحوض الغربي كحالات دراسية. تمت زيارة ما مجموعه 16 بئراً داخل الحوض الغربي تقع الى الشمال من محافظة طولكرم (الشعراوية) واختبارها لغرض التوزيع المكاني. تم النظر في ستة آبار متقاربة أخرى داخل حدود الحوض الأيوسيني تقع في منطقة قباطية لغرض التوزيع العمودي. تم إجراء هذه القياسات شهريًا بين الفترة من سبتمبر 2018 إلى مارس 2019. أوضحت النتائج وجود تركيزات مرتفعة من النترات تتجاوز الحد الأقصى المسموح في علار وعتيل. الآبار الموجودة في المناطق المروية تملك أقصى قيم من تركيز النترات. وهذا ناتج عن الأنشطة الزراعية المكثفة في هذه المناطق، أما الآبار داخل المناطق السكنية لديها ثاني أعلى قيم من تراكيز النترات. وهذا يعكس التخلص غير السليم من المياه العادمة التي تنتشر على نطاق واسع في هذه المناطق. أظهرت نتائج التحليل العمودي أن هناك علاقة عكسية بين عمق الآبار وتركيز النترات. أخيرًا، تم تحديد بعض خيارات الإدارة العملية للتحكم في مشكلة تلوث

النترات في مناطق الدراسة. لذلك، يجب استخدام النمذجة لاختيار خيارات الإدارة المناسبة للتحكم في حدوث النترات في المياه الجوفية. بالإضافة إلى ذلك، ينبغي أخذ عينات أكثر تواتراً وتوزيعاً جيداً من خلال خطة متطورة لرصد المياه الجوفية.