College of Graduate Studies

Science in Natural Resources and its Sustainable Management

Evaluating spring water quality in Hebron District (Halhoul and Dura town)

By:

Tha'er Baker "Ahmad Mousa" Abu-Arqob

Supervisor:

Associate Prof. Dr. Yousof Amr

Co-supervisore: Prof. Dr. Ayed Salama

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This thesis was successfully defended and approved on July 10th ,2023

by:

Examination Committee:		**Signature**
Associate prof. Dr. Yousof Amr	Main Supervisor	
Prof. Dr. Ayed Salama	Co-supervisor	
Dr. Hazem Bakeer	Internal examiner	
Dr. Ali Abu-Ayyash	External examiner	

DEDICATION

I would like to dedicate this thesis to people whom I love, my mother, my father, my family and my wife. With love.

ACKNOWLEDGMENT

I would like to express my heartfelt appreciation and gratitude to my supervisor Associate Prof. Dr. Yousof Amr and Prof. Dr. Ayed Salama for their devoted supervision and guidance.

Also, with all my heart I would like to thank my parent whose grow me up and made me the person who I am now. Additionally, I would like to thank my wife for her patience and sympathy.

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Finally, my gratitude to Hebron University that embraces a complementary competency and well-equipped facilities that provide the students with a comfortable condition for education and innovation.

For all of you … thank you.

Tha'er Abu-Arqob.

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List of Abbreviations:

CFU	Colony forming unit
EC	Electrical Conductivity
EDTA	Ethylene diaminetetraacetic acid.
MCM/yr	Mean monthly discharge/year
MENA regions	Middle East/North Africa
meq/l	Milliequivalents per litre
mg/l	Milligrams per liter
mm/yr	Millimetre per year
PLO	Palestinian liberation organisation
PSI	Palestinian standard institution
PWA	Palestinian Water Authority
ppm	Part per million
pH	Potential Hydrogen.
SAR	Sodium Absorption Ratio
SSP	Soluble Sodium Percent
TDS	Total Dissolved solids.
TWW	Treated wastewater
WHO	World health organization
WMO	World Meteorological Organization

Abstract

The scarcity of fresh water in the West Bank creates a severe challenge for the Palestinians on many levels. Investigating the quality of the spring's water is crucial step for promoting their use. Groundwater is considered to be the main source of water in the West Bank, so, it is essential to protect its quality from deterioration and contamination.

This study was conducted in 2018/2019 on 22 springs located in two towns at Heron District, mainly 11 springs in Halhoul in the north of Hebron district and 11springs in Dura in the south west of Hebron district. The two areas include many springs that used for both domestic and agricultural purposes. A biological (total coliform and fecal coliform) and physiochemical (Total hardness, pH, TDS, TS, EC, Cl^-, NO_3^-, SO_4^{-2}, Ca^{+2}, Mg^{+2}, K^+, Na^+, HCO_3^-, P, PO_4^{-3}, B, SAR and SSP) tests were used to evaluate the water quality.

Generally, the results revealed high biological contamination in the tested springs in Halhul and Dura especially in the wet season. On the other hand, for the physiochemical parameters the pH, EC, Cl^-, NO_3^-, Ca^{+2}, Mg^{+2}, K^+, Na^+ TDS, NO_3^- and B revealed generally results within the accepted limits, but the, SO_4^{-2}, HCO_3^-, Ca^{+2}, P and PO_4^{-3} were higher than the acceptable limits according to the Palestinian and WHO standards. All of the tested springs are not suitable for drinking due to the fact that they don't meet the drinking quality standards and for that more efforts must be spent to worn the people in the study area to avoid using these springs for drinking. But they are able to be used for plant irrigation and precisely trees.

Key Words: spring quality; Contamination; wastewater; irrigation water; micro-properties of water; chemical properties of water; West Bank.

Chapter One

1. Introduction

Water is the key word for the life on our earth. Universally, the civilizations were established and thrived nearby the water resources. Nowadays, the world testifies a global warming, drought periods and rain shortage due to climate change. One of the major causes of the climate change that affect air, soil and water is the human activities that led directly or indirectly to the environmental pollution.

The water status in Palestine has been also influenced by the global climate change and water contamination, not only that, also the water status in Palestine is highly influenced by the Israeli occupation restrictions that control the access of the Palestinians to their water resources.

Groundwater in West bank is an important source of potable, agricultural and industrial uses (Qannam, 2003). Groundwater in the West Bank considered the major source of water (Ikhlil, 2009) so, it is essential to protect its quality from deterioration and contamination. For that it is of great necessity to evaluate and preserve this valuable resource for the Palestinian communities.

Springs discharging systems provide domestic and irrigation water for a group of Palestinian villages in Hebron. Springs are either jointly or communally owned. Some have no clear ownership right, which invariably leads to poor maintenance and management (FAO, 2009).

Spring water contamination with bacteria and chemical pollutants is a real danger for the water from the springs. Most of the targeted springs in our study were located either close to the cultivated land or to the houses which may cause pollution due to the waste water or the chemicals that used in agriculture such as fertilizer, pesticides and herbicides.

The springs in the study area still did not receive enough attention from the standpoint of conserving the sources of water, its quality and the uses of the water from these springs (Abed Rabbo, et al. 1998).

Many studies have been conducted to evaluate water springs in Palestine. The researchers tested the biological and chemical parameters to evaluate the water quality all-around the West Bank and they concluded that there are many springs were not suitable for drinking purposes and that the source of pollutants could be the sewage and/or fertilizations and pesticides (Ikhlil, 2009; Sawad, 2009; Daghara et al., 2019).

Groundwater in the West Bank is located in the mountain basins that is subdivided into three basins, which are almost completely controlled by the Israeli occupation (Daghara et al., 2019). These basins are the western, eastern and north eastern basins as shown in figure (1) (Mahmoud et al., 2022).

This study focused on the quality of the spring water in Dura and Halhul in Hebron governorate and its suitability for domestic and agricultural uses. Analysis of water samples from about 22 springs in October 2018 and April 2019 for the aim of evaluating the suitability of the tested springs for either domestic or agricultural uses based on internationally accepted chemical and biological standards. In addition, surveying the possible sources of pollution for each spring.

Objectives of the study:

- Evaluate the suitability of the tested springs for domestic and agricultural uses in Dura and Halhul.
- Determine the chemical, physical and biological properties of springs.
- Determine the types & levels of pollutants.
- Investigate the possible sources of pollution.
- Impact of watershed on spring water quality.

Chapter Two

2. Literature Review:

2.1. Water Resources in Palestine

The geographical location of Palestine contributed significantly to the spatial and temporal variations of water resources. Its location between an intersecting point of three continents has attracted different parties to occupy the region and force sovereignty over water resources, which affected the industrial and agricultural development of the country over years (Daghara et al., 2019). In general, there are three water resources in Palestine including rainfall, surface water and groundwater (PWA, 2012; Judeh et al., 2017). From a natural perspective and independently from human control over resources, there is an interconnected relationship between the three resources. Rainfall is the aqua-heart that bumps into the surface water and groundwater. Subsequently, an aberration in the amount of rainfall in a certain year can affect the volume of available water in groundwater and other resources. The temporal variation of rainfall in the past ten years cannot be neglected. While the annual average rainfall in the West Bank is 450 mm/y, the average rainfall in 2012 was higher (518 mm/y) (SRWOR, 2012), After 10 years, the World Meteorological Organization (WMO) reported an average rainfall of 521.9 mm/y. Although the average rainfall shows an increase compared with previous years, it is in an imbalance due to climate change. In addition, the amount of water that can be used is declining due to the increase in polluted air (Hejaz et al., 2020).

Despite the fact that Palestine is rich with water resources, the Israeli occupation has limited the Palestinian accessibility to these resources to one major source, which is groundwater. According to the sixth sustainable development goal, getting access to a clean water source is an essential and non-negotiable part of the development process (Gain et al., 2016). The Jordanian River is considered one of the most biodiverse and longest rivers in the area, which lies between Palestine, Syria and Jordan (Hillel et al., 2015). It originates from Mount Hermon between Lebanon and Syria crossing the lake of Tabaria from the south and spilling into the lowest area on earth (the Dead Sea) (Gafny et al., 2010). However, water flow in the lower part of the Jordan river has changed drastically and the Palestinian share of water decreased from 1400 monthly discharge/year (MCM/yr) to 200 MCM/yr and the quality of water got worse (UN-ESCWA and BGR, 2013). The cause of the reduction in water flows is the overuse of water in the upper areas including Syria and Israeli occupation through building dams near the river's main tributary (Gafny et al., 2010; Hillel et al., 2015). Subsequently, Groundwater including springs and wells became the main source of water for Palestinians.

Groundwater accounts for 90% of Palestinian water consumption, making it the vein of life in Palestine (Daghara et al., 2019). There are three basins in the West Bank (figure 1): Western Basin, North-eastern Basin and Eastern Basin; and one in Gaza: The Coastal (PWA, 2012). Its renewable water is mainly due to the accumulated rainfall from the mountains. These three resources might discharge their content to the surface due to the imbalance in the hydraulic pressure of water in groundwater in comparison with the land surface creating Springs (Kresic & Stevanovic, 2009). Among the three basins, the western one is the most important. It includes the upper and lower Cenomanian aquifers systems. Moreover, this basin yields about 360-520 MCM/y, yet, Palestinians got about 28 MCM (Jebreen et al., 2017). Meanwhile, the North-eastern basin, this aquifer yields about 100-145 MCM/y, which is mostly recharged from the boundaries of the West Bank and includes the upper and lower Cenomanian aquifers, in addition to the shallow

Eocene aquifer. However, the Palestinian yearly consumption from this basin is about 23 MCM/y from the shallow Eocene aquifer, which means that the majority of the preserved water in this basin is heavily consumed by the Israeli occupation (103 MCM/y) (Jebreen et al., 2017). Finally, The Eastern basin is composed of three sub-aquifers, the Mountainous Heights, North-eastern Tip, and Jordan Valley. Its yearly yield is about 145-185 MCM. However, the Israelis utilize about 50 MCM/y in addition to 100 MCM/y from the springs of the dead sea. As usual, the Palestinians consumed about 50% less than the Israeli (about 53 MCM/y) from this basin (Jebreen et al., 2017).

There are two groups of springs on the West Bank: Jordan River Basin Springs and Dead Sea Basin Springs. Jordan River Basin Springs include 42 main springs (e.g Bardala, Far'a, Fasail, Diouk, Nou'meh Ein Sultan and Qil). Meanwhile, the Dead Sea Basin Springs include 21 main springs (e.g Fashkha springs and Ein Gedi), however, its water is salty (brack water) (PWA, 2014).

Besides the mentioned conventional water resources, there are other non-conventional water resources, which include: treated water (wastewater reuse) like Al Bireh plant with an annual discharge of 0.5 MCM/yr, desalinated water to transfer brackish water into drinkable water and finally purchased water. There are 39 licensed wells in the Occupied Palestinian Territories, which is considered a small fraction of the number of wells used inside the green line (500 wells) (PWA, 2012). The imbalance between the water recharge rate and abstraction in these wells cause water deficit and insufficiency in most regions.

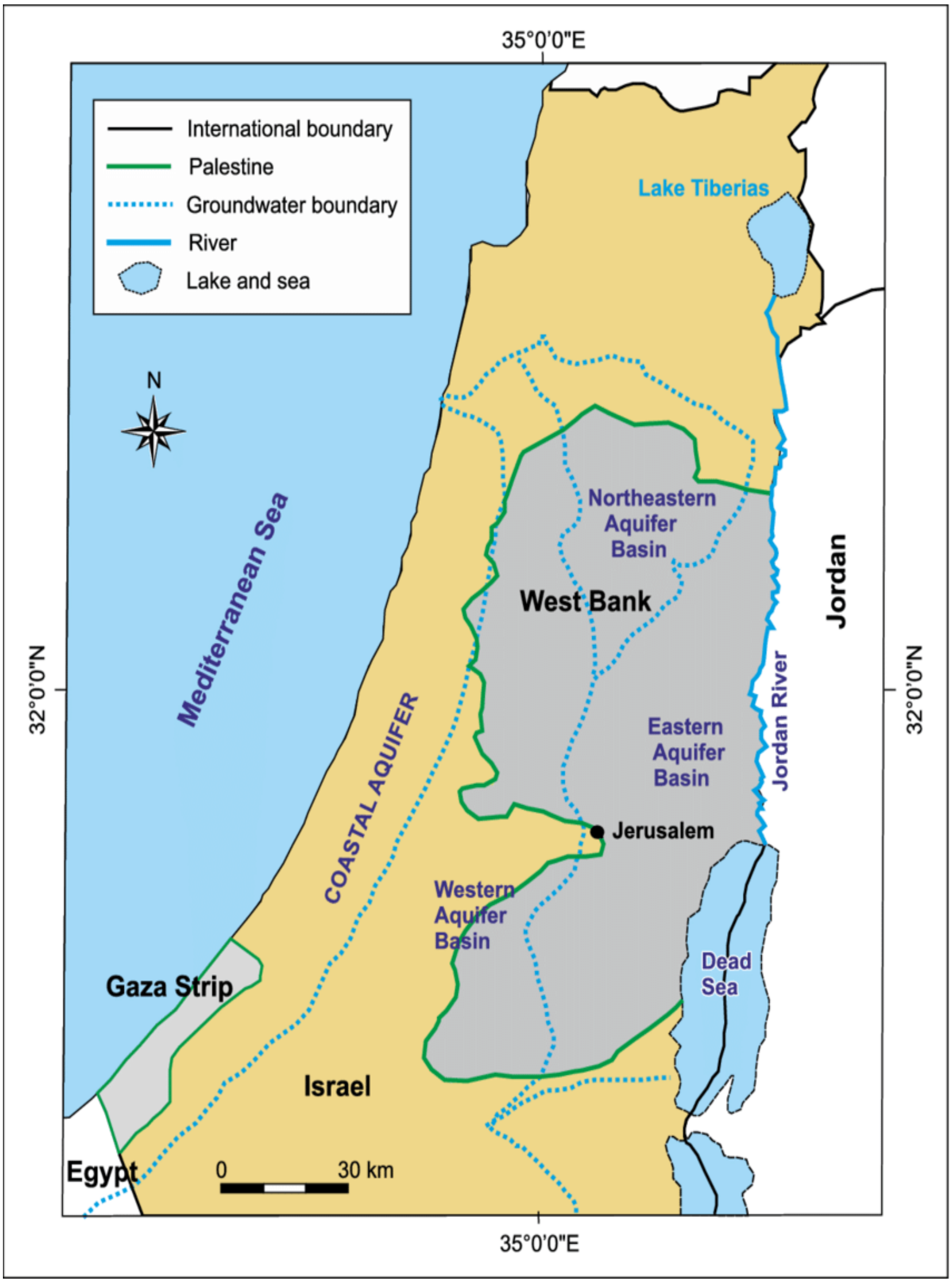


Figure 1: The main three water basins in the West Bank and Gaza according to Jebreen et al., 2017

2.1.1. Geology of the study area:

Palestine is located on the north western part of the Arabian Shield. During its history, this shield separated from the great Afro-Arabian shield along the Red-Sea line. A branch of this breakage extended along the line of Aqaba, Wadi A'raba, the Dead Sea and the Jordan Valley, and continued northwards to Lebanon, Syria and Turkey. The West Bank of Jordan occupies the western part of this branch, known as the Jordan Rift Valley (Rofe and Raffety 1965, 1963).

The stratigraphy of the study area ranges between Lower Beit Kahel and Alluvium Formations which extend by the age from Lower Cenomanian to the end of the Recent age (Abed and Wishahi, 1999). The characteristics of these geological formations in the area (Figure 2) are as follows:

2.1.1.1. Lower Beit Kahel Formation

This Formation consists of hard crystalline mottled dolomitic limestone with some shales and chalk. The presence of well-jointed dolomitic limestone made this Formation to be a good aquifer. The thickness of this formation ranges between 92 and 180 m (Baida and Zukerman, 1992).

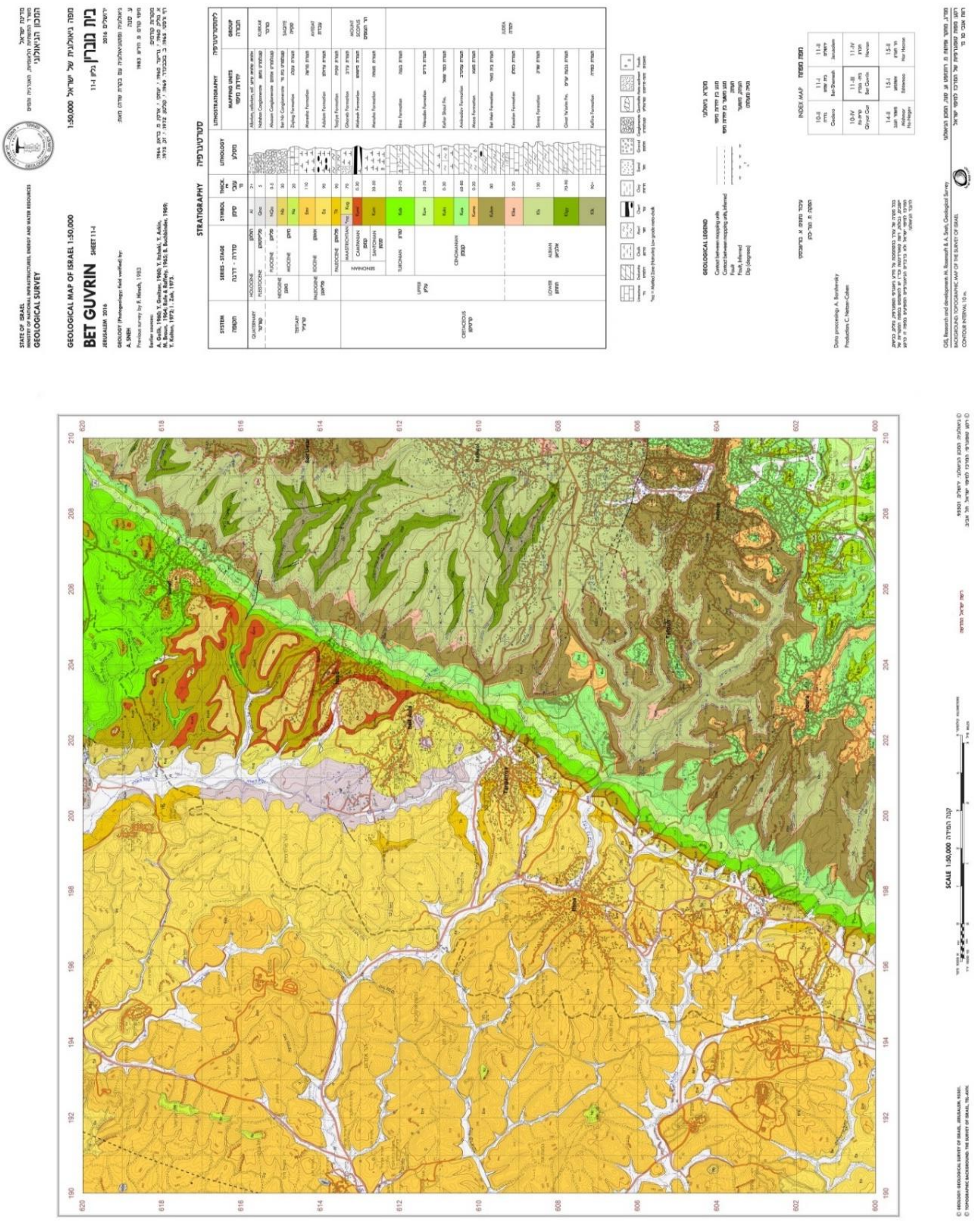
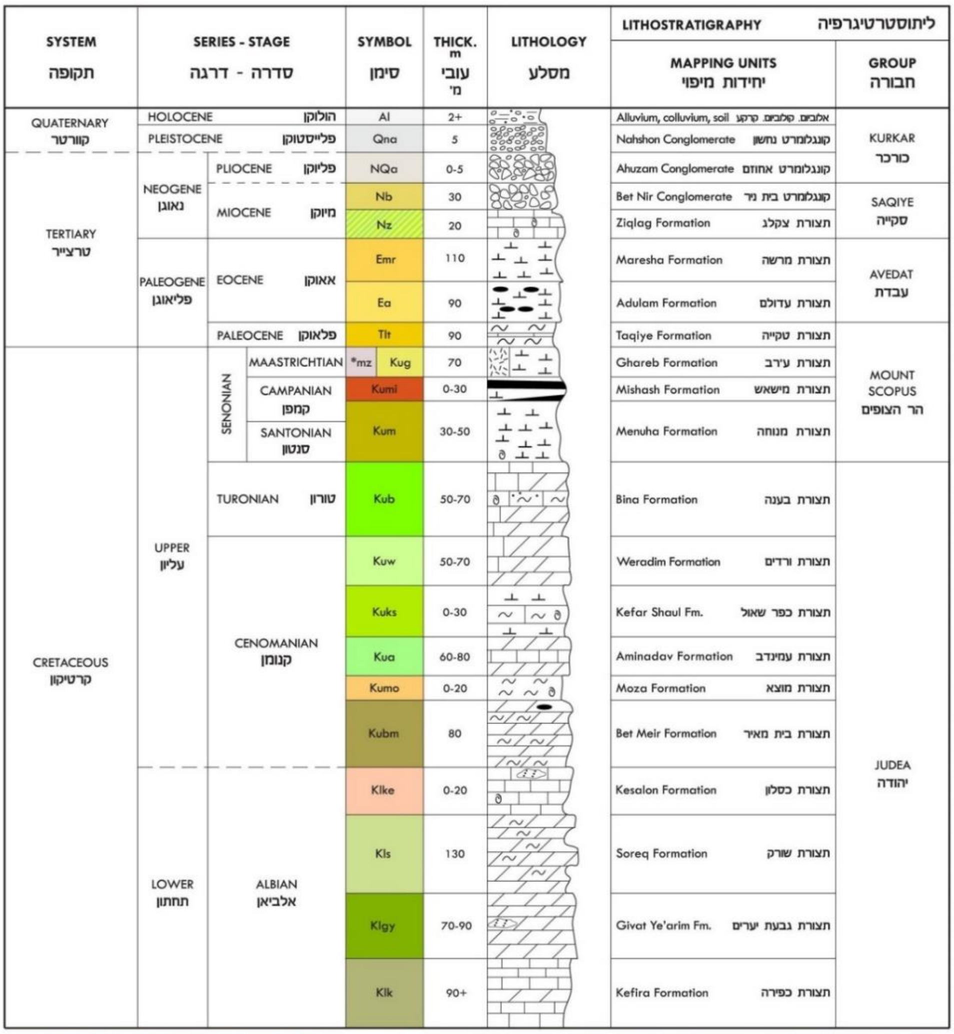


Figure 2: The characteristics of these geological formations in the area



STRATIGRAPHY סטרטיגרפיה

SYSTEM תקופה	SERIES - STAGE סדרה - דרגה		SYMBOL סימן	THICK. m עובי מ'	LITHOLOGY מסלע	LITHOSTRATIGRAPHY ליתוסטרטיגרפיה: MAPPING UNITS יחידות מיפוי	GROUP חבורה
QUATERNARY קוורטר	HOLOCENE הולוקן		Al	2+		Alluvium, colluvium, soil אלוביום, קולוביום, קרקע	KURKAR כורכר
	PLEISTOCENE פלייסטוקן		Qna	5		Nahshon Conglomerate קונגלומרט נחשון	
TERTIARY טרציאר	NEOGENE נאוגן	PLIOCENE פליוקן	NQa	0-5		Ahuzam Conglomerate קונגלומרט אחוזם	
		MIOCENE מיוקן	Nb	30		Bet Nir Conglomerate קונגלומרט בית ניר	SAQIYE סקייה
			Nz	20		Ziqlag Formation תצורת צקלג	
	PALEOGENE פליאוגן	EOCENE אאוקן	Emr	110		Maresha Formation תצורת מרשה	AVEDAT עבדת
			Ea	90		Adulam Formation תצורת עדולם	
		PALEOCENE פלאוקן	Tlt	90		Taqiye Formation תצורת טקייה	MOUNT SCOPUS הר הצופים
CRETACEOUS קרטיקון	UPPER עליון	SENONIAN: MAASTRICHTIAN	*mz Kug	70		Ghareb Formation תצורת ע'רב	
		SENONIAN: CAMPANIAN קמפן	Kumi	0-30		Mishash Formation תצורת מישאש	
		SENONIAN: SANTONIAN סנטון	Kum	30-50		Menuha Formation תצורת מנוחה	
		TURONIAN טורון	Kub	50-70		Bina Formation תצורת בענה	JUDEA יהודה
		CENOMANIAN קנומן	Kuw	50-70		Weradim Formation תצורת ורדים	
			Kuks	0-30		Kefar Shaul Fm. תצורת כפר שאול	
			Kua	60-80		Aminadav Formation תצורת עמינדב	
			Kumo	0-20		Moza Formation תצורת מוצא	
			Kubm	80		Bet Meir Formation תצורת בית מאיר	
	LOWER תחתון	ALBIAN אלביאן	Klke	0-20		Kesalon Formation תצורת כסלון	
			Kls	130		Soreq Formation תצורת שורק	
			Klgy	70-90		Givat Ye'arim Fm. תצורת גבעת יערים	
			Klk	90+		Kefira Formation תצורת כפירה	

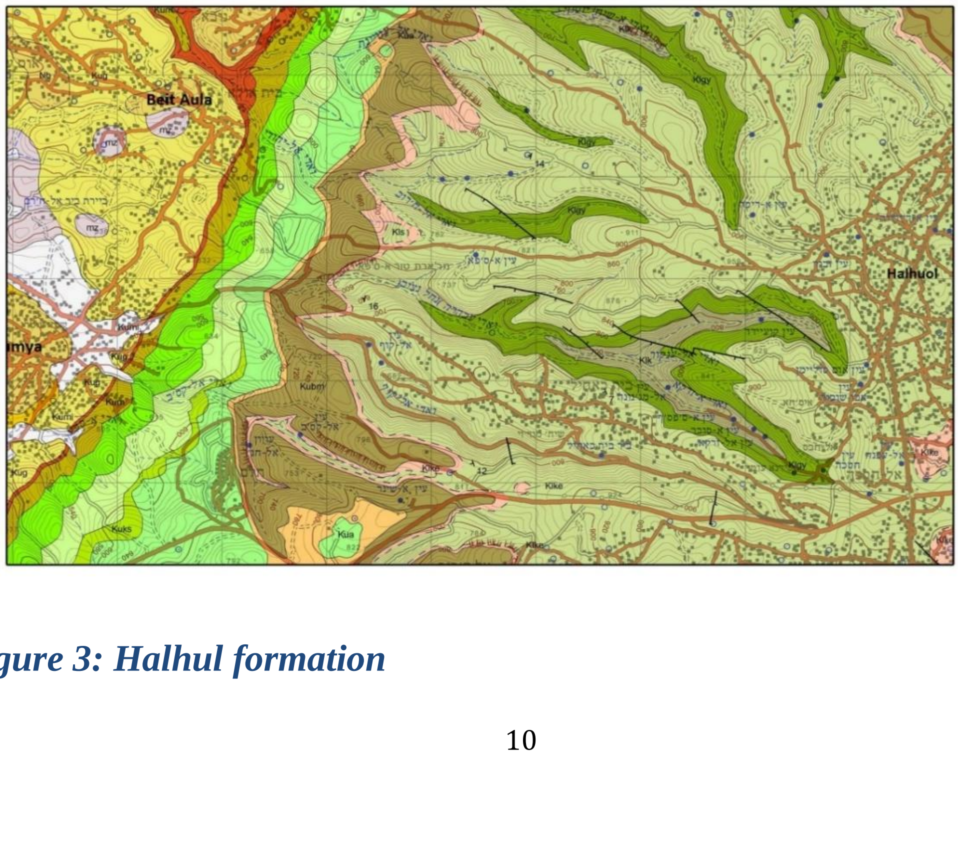
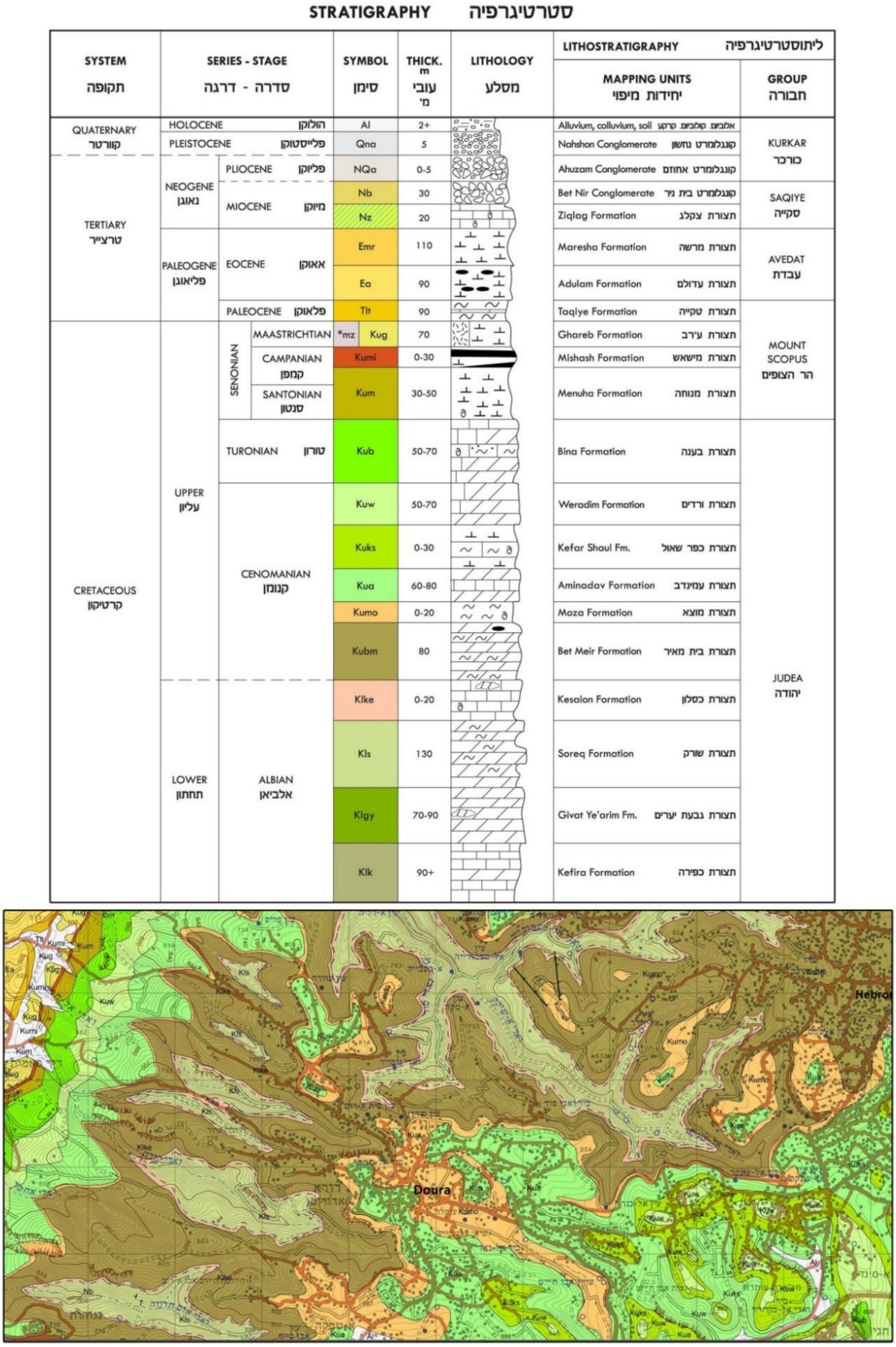


Figure 3: Halhul formation



STRATIGRAPHY סטרטיגרפיה

SYSTEM תקופה	SERIES - STAGE סדרה - דרגה	SYMBOL סימן	THICK. m עובי מ'	LITHOSTRATIGRAPHY ליתוסטרטיגרפיה: MAPPING UNITS יחידות מיפוי	GROUP חבורה
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		Nz	20	Ziqlag Formation תצורת צקלג	
	PALEOGENE פליאוגן – EOCENE אאוקן	Emr	110	Maresha Formation תצורת מרשה	AVEDAT עבדת
		Ea	90	Adulam Formation תצורת עדולם	
	PALEOCENE פלאוקן	Tlt	90	Taqiye Formation תצורת טקייה	MOUNT SCOPUS הר הצופים
CRETACEOUS קרטיקון	UPPER עליון – SENONIAN – MAASTRICHTIAN	*mz Kug	70	Ghareb Formation תצורת ע'רב	
	CAMPANIAN קמפן	Kumi	0-30	Mishash Formation תצורת מישאש	
	SANTONIAN סנטון	Kum	30-50	Menuha Formation תצורת מנוחה	
	TURONIAN טורון	Kub	50-70	Bina Formation תצורת בענה	JUDEA יהודה
	CENOMANIAN קנומן	Kuw	50-70	Weradim Formation תצורת ורדים	
		Kuks	0-30	Kefar Shaul Fm. תצורת כפר שאול	
		Kua	60-80	Aminadav Formation תצורת עמינדב	
		Kumo	0-20	Moza Formation תצורת מוצא	
		Kubm	80	Bet Meir Formation תצורת בית מאיר	
	LOWER תחתון – ALBIAN אלביאן	Klke	0-20	Kesalon Formation תצורת כסלון	
		Kls	130	Soreq Formation תצורת שורק	
		Klgy	70-90	Givat Ye'arim Fm. תצורת גבעת יערים	
		Klk	90+	Kefira Formation תצורת כפירה	

Figure 4:Dura formations

2.2. Hydrology:

2.2.1. Climate

The study area is classified as sub-humid (Halhul) and semi-arid (Dura) and they are highly influenced by the Mediterranean climate (Figure 5). Indeed, the hot, long dry summer and cool short rainy winter are the major characteristics of such a climate (Basheer-Salimia and Ward, 2014). Moreover, the majority of precipitation falls during the months of the winter and spring and rarely snows on the highlands, commonly between November and March. On the other hand, summer is entirely hot and dry. The climate is highly affected by the Negev and Arabian deserts, particularly during spring and early summer, when the hot dusty air blows in from the deserts (known as Khamaseen).

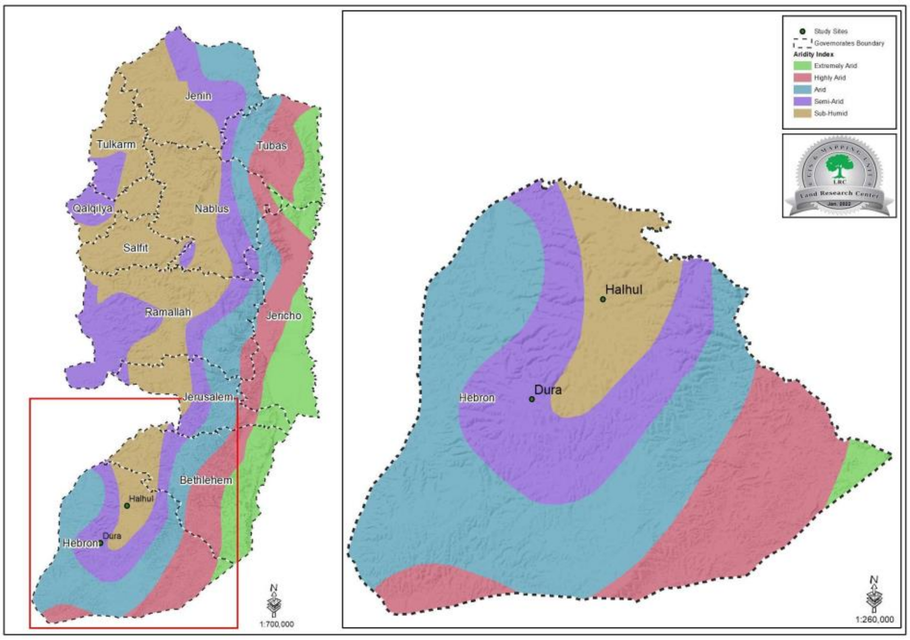

Figure 5:Aridity index map

2.2.2. Temperature

The mean monthly temperature in the targeted areas is 8°C during the winter, 26°C in summer, and 15°C as the average annual temperature. The maximum average monthly temperature is 38°C in (August) and the minimum temperature is -3°C in (January) (Hebron Climatic Station, 2020) (Figure 6). The temperature in Hebron during 2018/2019 is shown in (Figure 7).

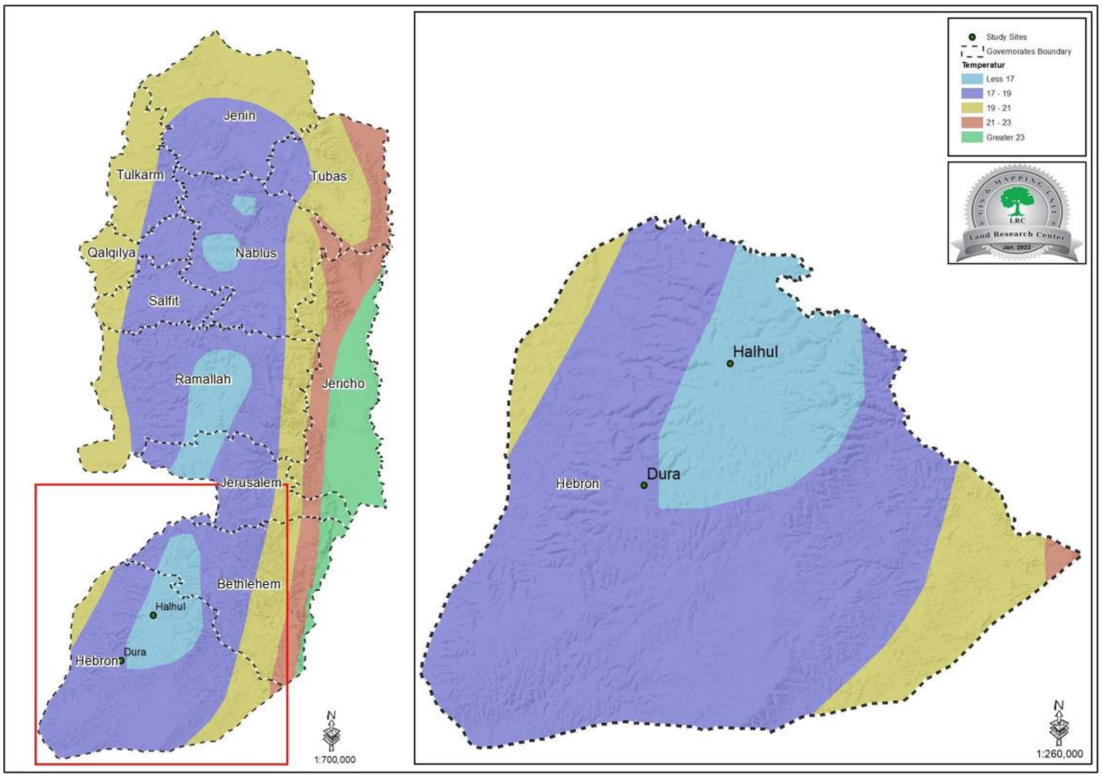

Figure 6:Temperature map in different areas in the West Bank on the lift with specificity to Dura and Halhul areas in Hebron

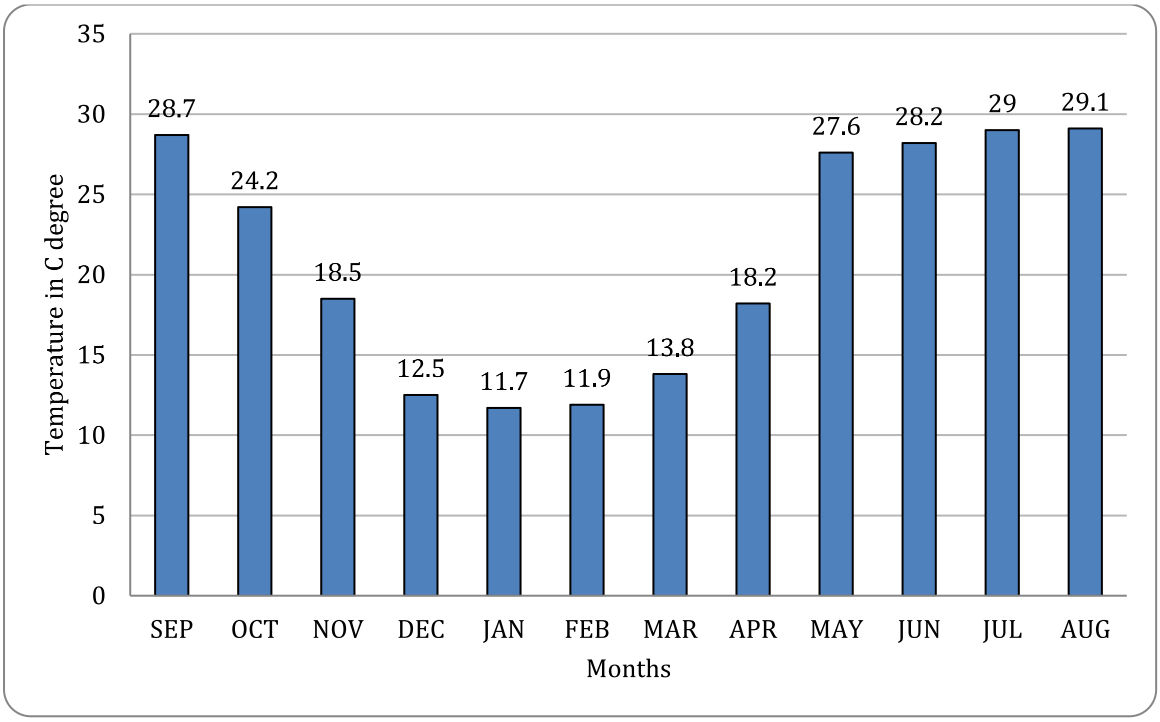

Figure 7:average temperature degrees from September 2018 - August 2019 in Hebron governorate.

2.2.3. Relative Humidity

The annual mean of relative humidity ranges from 55%-60% (Hebron Climatic Station, 2020) (Figure 8), where the study area is known to be a dry area in comparison with the northern part of the West Bank (Swaileh and Abdulkhaliq, 2012; Samara et al., 2019).

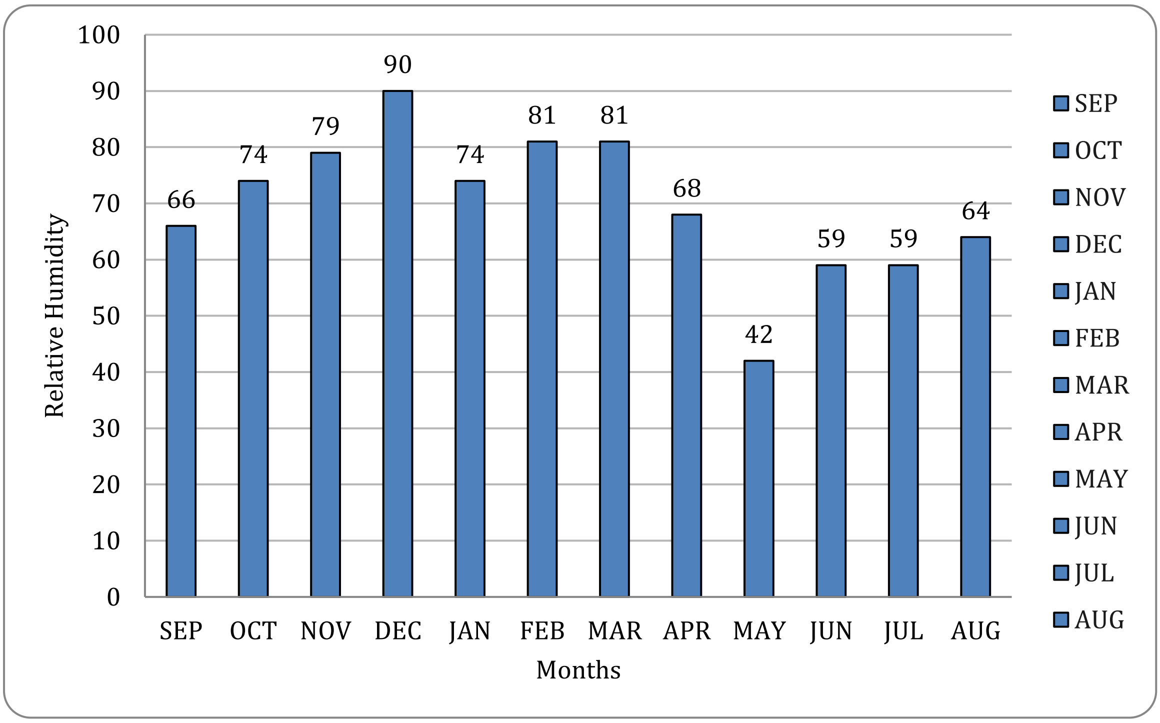

Figure 8:average relative humidity in Hebron governorate during the seasons 2018/2019.

2.2.4. Precipitation

Generally, Dura has a semi-arid, Mediterranean climate; where almost 70% of the yearly rainfall occurs between November and February. Also, the highest rainfall usually falls in January. The average annual rainfall in the study area varied from 450 mm to 507 mm (Hebron Climatic Station, 2020) (Figure 9). The precipitation of rainfall in Hebron, Dura, and Halhul in the wet and dry seasons of 2018/2019 is shown in Figure (10).

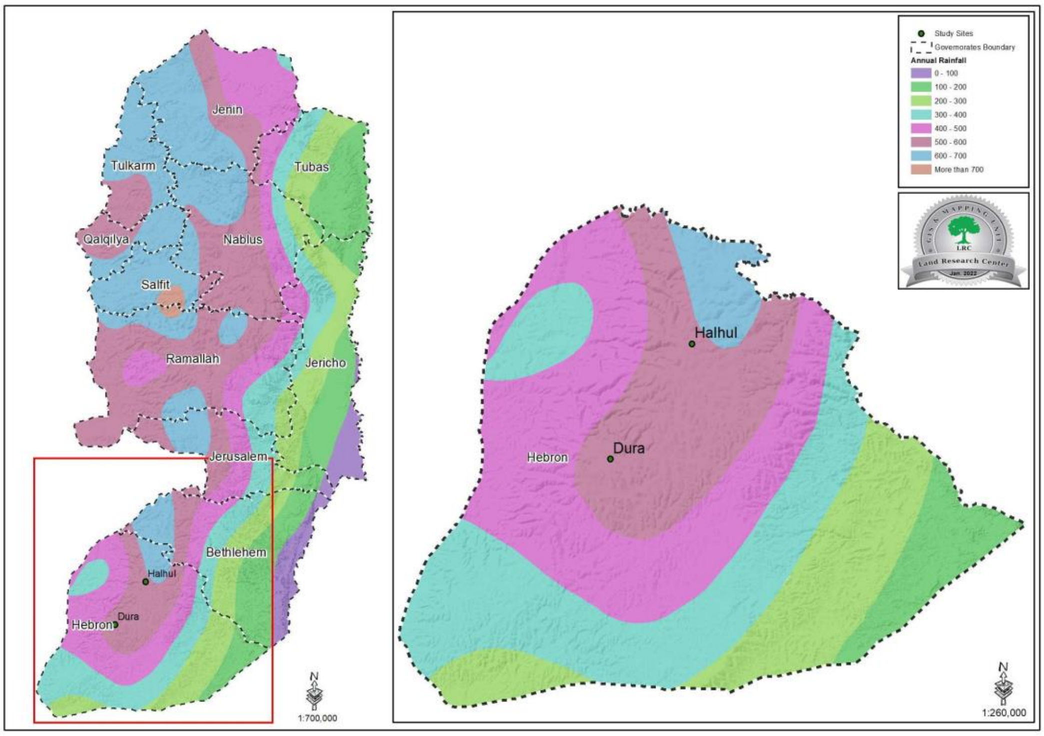

Figure 9:Annual rainfall map of different cities in the West Bank on the lift with specificity to Dura and Halhul areas in Hebron on the right.

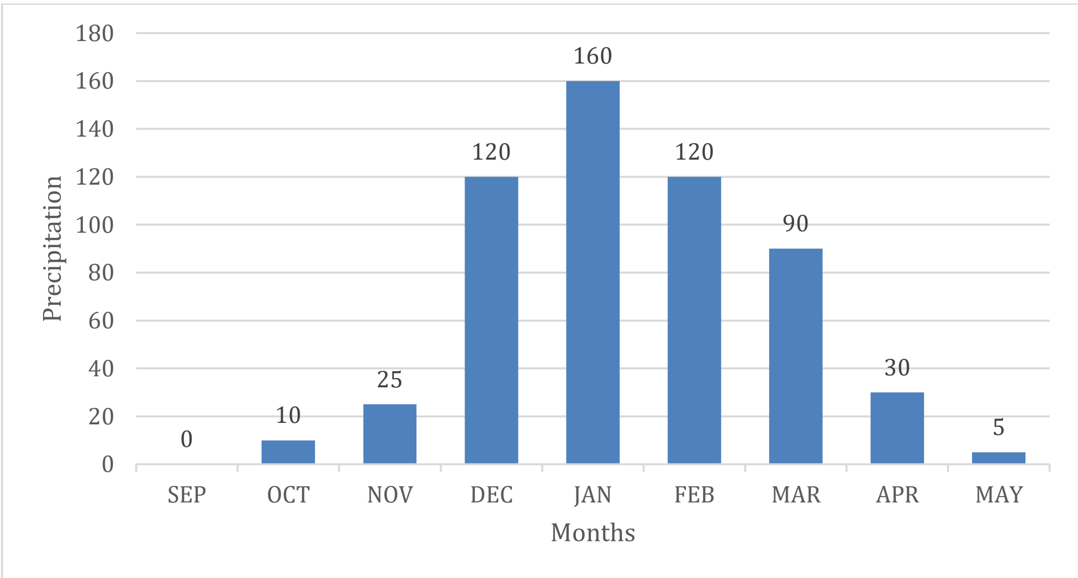

Figure 10:Monthly Precipitation (mm) in Hebron during September 2018 – April 2019

2.2.5. Evaporation

During the summer, the study area is characterized by high temperature and low humidity, which highly increase the evaporation rate (Al-Seekh and Mohammad, 2009). On the other hand, during the cold season, the evaporation rate is relatively lower when solar radiation is the lowest during the year (Hebron Climatic Station, 2020). The figure below shows evaporation in Hebron starting from September 2018 to April 2019. Evaporation levels in Hebron during 2018/2019 are shown in Figure (11).

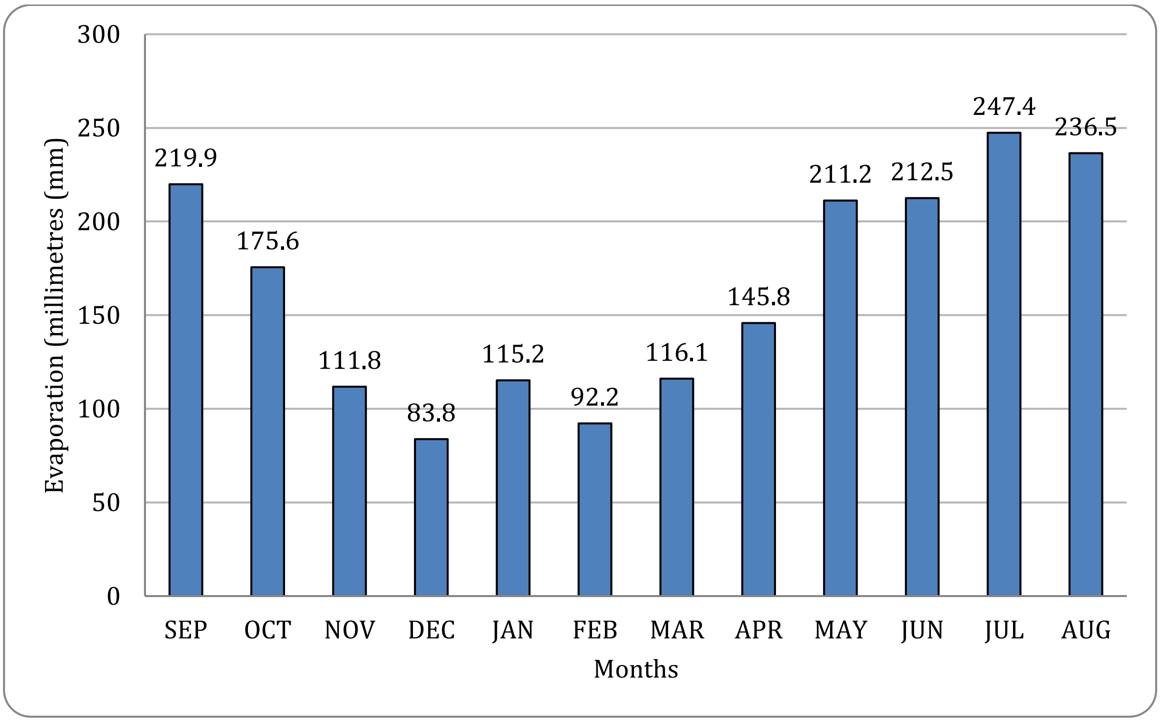

Figure 11:The amount of actual evaporation in Herbon during 2018/2019.

2.3. Water Consumption in Different Sectors:

Despite the richness of historical Palestine with water resources, the accumulative effect of the environmental and humanitarian factors on the availability of water led to a great gap between the available quantity of water and the rate of its consumption. Water is an essential part of industrial, agricultural, domestic, municipal and environmental sectors (Judeh et al., 2017).

Al-Khatib and Assaf (1994) predicted that by 2020 domestic and agricultural water demand will increase to 726 MCM and 500 MCM respectively. Although their prediction was a warning sign and a hint for Palestinians to start a water management and recycling plan, none of the previous steps were effective to prevent a water crisis from happening in 2022.

2.3.1. Agricultural Water Demand in Palestine:

The agricultural system in Palestine is structured in Arid to Semi-Arid areas, subsequently, the amount of water needed to grow crops varies between different regions and seasons of the year (Abu-Madi, 2004). Figure (12) demonstrates the variations in water consumption in different cities on the West Bank from 2008 until 2018. Generally speaking, arid areas require larger quantities of water and their agricultural needs are poorly satisfied by rainfall. Agriculture accounts for the major sector that consumes water globally and in the MENA regions. About 87% of water allocation goes to the agricultural sector compared with 13% to other industries (e.g Municipal and Industrial) (Abu-Madi, 2004; Hamdan, et al. 2022). Different factors including an increase in the population size, climate change and rises in temperature, and other political factors aligned together creating a great gap between crops' irrigation demand and the availability of water resources. According to the Ministry of Agriculture 2015 report, the supply-demand gap for irrigation approximately equals 47 million m3 (MoA, 2016). One of the suggested solutions is the use of wastewater instead of clear or filtered water. However, only 11% of Palestinian farmers use treated wastewater, meanwhile, 90% of farmers use groundwater for crop irrigation (Hamdan et al. 2022). There are multiple factors that contribute to farmers' willingness to use groundwater including its availability with cheap prices for framers, the lack of access to TWW, and psychological aversion including thoughts in regard to the cleanness of water (Hamdan et al. 2022). Although there are several recommendations to use TWW for agricultural purposes, some researchers argue that the quality of treated wastewater is relatively low and is not considered a healthy option for agricultural uses. Craddock et al. (2022) study showed that wastewater from domestic greywater contains different types of bacteria including E.coli, Klebsiella, and Enterobacteriaceae. In addition to various antibiotic-resistance bacteria like ampicillin, trimethoprim-sulfamethoxazole, tetracycline, cefazolin and multidrug-resistant. Among all these indicators, only the levels of E. coli violate water standards (Craddock et al., 2022). These findings suggest that although TWW can constitute a vital secondary source of water, many precautions should be taken into consideration and lots of efforts should be directed toward improving water treatment methods.

2.3.2. Municipal Water Demand in Palestine:

There are different resources for calculating water consumption in the municipal and domestic sectors in the West Bank and Gaza including statistics from the Industrial ministry and others. However, the numbers can vary among different resources since some of the statisticians combine industrial with either municipal or domestic consumption. In 2006, the total water consumption in the municipal and domestic water demand was estimated to approach 130 MCM/year including 75 MCM/year in the West Bank and 55 MCM/year in Gaza (Kanafani, 2020). The PWA estimated the industrial water demand in Palestine accounts for 8% of the municipal demand which approximately equals 8.3 MCM/year (Kanafani, 2020). Kanafani predicted future water needs in municipal and domestic sectors according to WHO average standards. From 2010 until 2020, It has been estimated that municipal water demand will reach 131 (L/c/d) in urban areas and 111 (L/c/d) in rural areas, or 268 MCM/year (Kanafani, 2020). Meanwhile, the industrial needs were estimated to reach 39 MCM/year by 2020 (WHO, 2017; Kanafani, 2020). In summary, irrigation is considered to account for the highest water demand compared with other sectors.

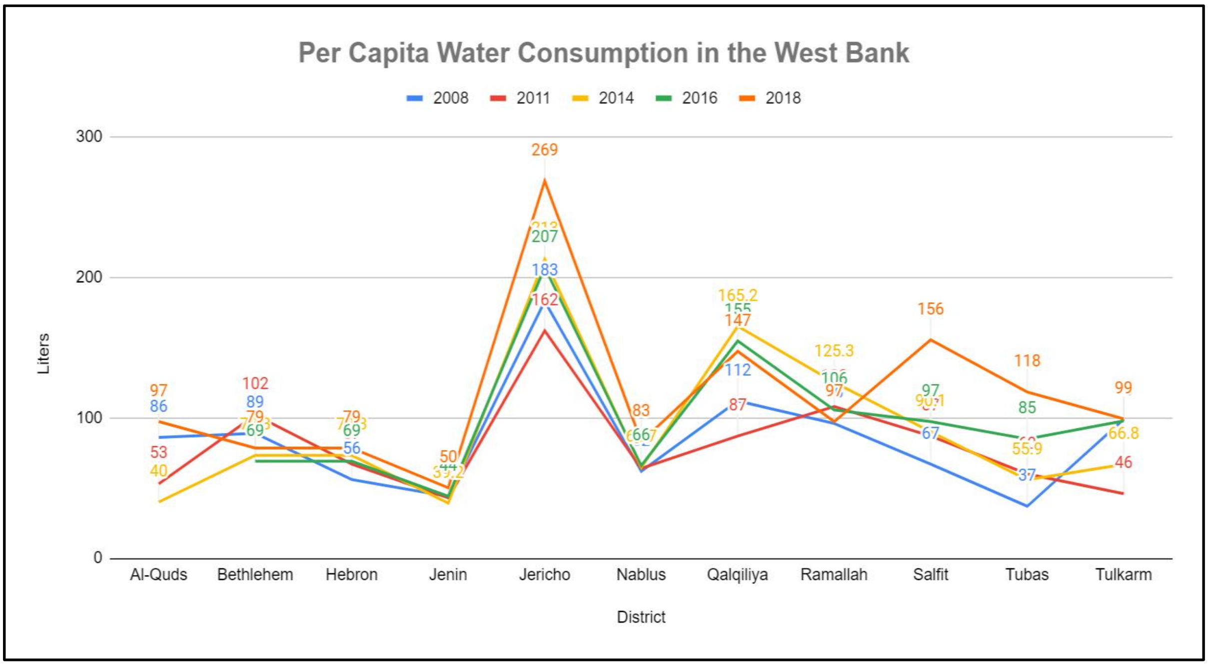

Figure 12: Average water consumption in different cities in the West Bank including, Al-Quds, Bethlehem, Hebron, Jenin, Jericho, Nablus, Qalqiliya, Ramallah, Salfit, Tubas and Tulkarm in five different years (2008, 2011, 2014, 2016 and 2018) (Source: State of Palestine, Water Authority Reports).

2.4. Water Insecurity in Palestine:

Palestine is located in the Northern hemisphere, at a latitude of 31.9522° N and a longitude of 35.2332° E (http://latitude.to:8080/map/ps/palestine). Many global climate circulation models predicted the severe effects of climate change including temperature and perception in that area. It is considered one of the newest and most urgent threats to water quality and quantity (McKee, 2012). Although Palestine is commonly known for a rainy cold winter and warm dry summer, climate change caused weather variability in different areas of the West Bank and Gaza (Barghouthi et al., 2017). The variations in topography between 400 meters below sea level and 1020 meters above sea level gave Palestine a relatively unique difference in temperature and precipitation percentages (Tubaile and Alkowni. 2001). Climate change has a direct and indirect effect on groundwater. During normal conditions, groundwater can be replenished from rain that diffuses to the earth's lower levels and water leakage from water on the surface. In extreme climates, the temperature can rise to levels higher than the yearly normal range causing droughts, at the same time, winter can get extremely cold with higher precipitation causing floods (Taylor et al., 2013). An increase in the evaporation levels of water due to the rise in temperature and the transpiration by plants can drain the moisture of the land leading to an increase in chloride percentages which prevents water from draining into the lower areas of groundwater (Taylor et al., 2013). With the accumulation of years, groundwater will turn into non-renewable sources. An indirect impact of climate change on groundwater is the human use of irrigation due to the lack of consistent and steady rainfall. The depletion of groundwater happens when humans exploit water for irrigation and shift their resources from surface water to lower layers (Taylor et al., 2013; Scanlon et al., 2006). All these factors will ultimately lead to worldwide water insecurity, however, the effect of climate change on Palestine will be tense when it is accompanied by other factors that cause water insecurity including the Israeli Occupation and the lack of water management and treatments of wastewater.

Barghouthi et al. (2017) argue that the effect of climate change in Palestine is magnified and its connection with the Israeli occupation constitutes a “Mosaic” and complex relation, he emphasizes the need for awareness campaigns about climate change and the need for long-term planning. Ragab and Prudhomme (2002), have estimated that after 20 years from now, the temperature will increase by two and a half Celsius degrees, moreover, the precipitation percentage will decrease up to 40% and these changes will last for the next thirty years. One of the ecologists at Tel Aviv University commented that according to this estimation the desert covering half of the country will slowly transcend to the northern parts of Palestine (Day and Caus, 2020). Regardless of this exponential tragedy affecting everyone living in historical Palestine, no one is really addressing the magnified effect of climate change on citizens living in the Occupied Palestinian Territory. Day and Caus (2020) has clearly criticized the convectional framework that the UN has been working on to solve this global issue and she moves forward naming it "Climate Apartheid". It was mentioned that: "Climate change is a universal problem. But its impact is not always equally felt". While Israel resides as the 32nd most equipped country to deal with climate change, the Occupied Palestinian Territory was not addressed in this equation. Subsequently, an unequal impact must be faced with unequal solutions.

2.5. The Effect of the Israeli Occupation on Water Insecurity

Different factors contribute to water insecurity in the West Bank and Gaza, including settler colonialism, climate change, and weak infrastructure management, including wastes from houses and factories. Al-Shalalfeh et al. (2017) argue that the main problem is not the availability of water resources but the lack of ownership of these resources due to the Israeli control of water accessibility. He suggests that equitable access to water resources between

Palestinians and Israelis will not solve water insecurity in Palestine. Subsequently, the only solution is to demolish the unjust colonial relationship and create equal ownership. The consequences of the Oslo agreement extended beyond five years and limited the Palestinian's accessibility to the north-eastern aquifer basin. The annual yield of water from this basin is estimated to be 100 - 145 MCM/yr, however, the illegal Israeli exploitation of its yield left 23 MCM/yr for Palestinians from wells and springs (Rouyer, 1999).

2.6. Water Quality in Palestine:

Water quality is defined as "the suitability of water to be used for different purposes in different sectors including domestic, agricultural, municipal and industrial sectors" (Boyd, 1999). In addition, surface water is considered an ecological home for different organisms (Boyd, 1999). Water quality can be measured using different physical, chemical and biological properties. Due to the importance of a guideline to measure water quality and its suitability for use in different sectors, the WHO organization structured a guideline for drinking water quality including all essential properties (WHO, 2017). Subsequently, any drift in the figures taken from certain indicators reflects warning signs and a signal for the authority of a certain country to take actions and precautions to protect the public health of its citizens. Water quality indicator parameters are defined as measurements that reflect information about the chemical status of groundwater or surface water (Al-Sulaiman, 2012). Physical properties are demonstrated by the level of pH; which indicates the concentration of metals and minerals dissolved in water from the surrounding rocks and soil (WHO, 2017). The suitable range of pH for irrigation is 6 to 9 (PSI, 2012) and between 6.5 and 9.5 (PSI, 2010) for domestic uses Meanwhile, chemical properties include the concentration of cations like Calcium (Ca^{+2}), Magnesium (Mg^{+2}), Potassium (K^{+}), and Sodium

(Na^+); and anions like Chloride (Cl^-), Nitrate (NO_3^-), Sulfate (SO_4^{-2}), Bicarbonate (HCO_3^-), and phosphate (PO_4^{-3}). Each element should not exceed the concentration set by the world health organization (WHO) (table 1). According to the fourth edition of WHO guidelines for drinking water quality, the range of Chloride, Sodium, and Potassium range between 200-300 mg/l. Generally speaking, once the concentration reaches 250 mg/l, the taste of the water starts to get saltier (World Health Organization, 2017). The normal range of Sulfate is between 250 mg/l and 1000 mg/l (WHO, 2017). The salinity of the water is measured using electrical conductivity which measures ion concentration in different types of salt. In general, EC measurements should not exceed 10% of the yield reduction. For drinking water, the preferred EC should not exceed 1.6 dS/m (Daghara et al. 2019). A measurement tool that correlates positively with water electrical conductivity is Total dissolved substances in water. Generally speaking, the higher TDS the higher the conductivity and the lower PH levels meaning that water tends to be more acidic (Islam et al., 2017). According to the Palestinian Water Quality Standards (PWA), the normal range of TDS in water should not exceed 1000 ppm (PSI, 2012). Another kind of measurement used to test water suitability for irrigation is the Sodium Absorption Ratio (SAR) (Ghanem et al., 2021). The SAR is measured by approximating the concentration of Sodium, Magnesium, and Calcium using a specified equation shown in figure (4) below. SSP also called the soluble Sodium percent is another measurement that determines the possibility of soil deterioration that affects plants' growth (Sarker et al., 2000). The deterioration of the soil happens due to the accumulation of soluble Sodium leading to the formation of crust and seal development (Sarker et al., 2000). According to (Davis, et.al, 2012; Eyankware et al., 2017) the formula used in measuring the SAR and SSP are:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \qquad \mathbf{SSP} = \frac{\mathbf{Na^{+}}}{\mathbf{Ca^{+2} + Mg^{+2} + Na^{+}}} * \mathbf{100}\%$$

Moreover, the microbiological factor considered the most critical factor that indicate the water quality. While chemical contamination impacts health after long exposure and the accumulation of these chemicals in the body, Biological contaminations have an immediate impact on health. Total Coliform including E. coli and Fecal Coliform are used as indicators to monitor and evaluate water quality. Total Coliform bacteria include a large number of bacteria types that originate from mammalian feces. Although these kinds of bacteria are not harmful in themselves, they are an indicator of the presence of other pathogens that grow from feces that can be pathogenic (Cohen and Shuval, 1973). The presence of E. coli in water does not always indicate contaminated water, however, specific strains like E. coli 0157:H7 can cause diseases (Cohen and Shuval, 1973). According to WHO standards, there should not be any type of coliform colony in drinking water (World Health Organization, 2011). Since the study area is within the Occupied Palestinian territories, each parameter has a normal range according to the Palestinian Standards of water quality shown in Table (2).

Table 1: Palestinian Standard concentration (PSI) and World Health Organization (WHO) standards for drinking water from springs, in addition

to the SAR, SSP, pH, electrical conductivity, and other mentioned parameters. (PSI, 2010; WHO, 2017)

Component	Unit	Palestinian standards institution	WHO
Potential Hydrogen (pH)	No Unit	6.5 - 8.5	6.5 - 8.5
TDS	mg/L	1500	1000
Sodium (Na)	mg/L	<200	<200
Potassium (K)	mg/L	<10	<10
Calcium (Ca)	mg/L	<100	<75
Magnesium (Mg)	mg/L	<100	<30
Bicarbonate (HCO_3)	mg/L	No limit	<100
Chloride (Cl)	mg/L	<250	<250
Nitrate (NO_3)	mg/L	<50	<45

Sulfate (SO_4)	mg/L	<200	<150
Phosphate	Ppm	3	3
Phosphorus	Ppm	3	3
Boron	Ppm	1	1
Total Coliform Bacteria	CFU	3	0
Fecal Coliform Bacteria	CFU	0	0

Chapter Three

3. Materials and Methodology

3.1. Study Area

This study was conducted in the season 2018/2019 on springs located in two towns at Hebron District, mainly in Halhoul in the north and Dura in the southwest.

Halhul is located in the northern part of Hebron governorate (6 km north of Hebron city) at an elevation of 1013 m above sea level. The average rainfall in Halhul town is about 583 mm/year (ARIJ GIS., 2009).

Dura is located in the southwest part of Hebron governorate (8 km southwest of Hebron city) at an elevation of 890 m above sea level. The average rainfall in Dura town is about 500 mm/year (ARIJ GIS., 2009).

In this study, 22 springs were the subject of water quality assessment (11 in Halhul and 11 in Dura) as shown in table (2). 60% of the economic activity in Halhul comes from Agriculture (ARIJ GIS., 2009). Most of the population in Dura and Halhul use these springs for Agricultural and domestic uses, making them a vital water source.

Table 2: the studied springs in Halhul and Dura

No.	Springs of Halhul	No.	Springs of Dura
1	Ain Aiub	12	Ain Kanar
2	Ain Al-Therwe	13	Ain Set-Alrom
3	Ain Zabood	14	Ain Fredis
4	Ain Al-Tenah	15	Ain Taha

No.	Springs of Halhul	No.	Springs of Dura
5	Ain Bagar	16	Ain Al-Shqya
6	Ain Qosbor	17	Ain Al-Dlbeh
7	Ain Al-Ewainat	18	Ain Dodeen
8	Ain Safa	19	Ain Zoqo
9	Ain Al-Set	20	Ain Aisa-Amer
10	Ain Al-Tahona	21	Ain Emtir
11	Ain Haska	22	Ain Jadow'

3.2. Springs Survey

For each spring, a descriptive survey was used to collect data about the name of the spring, its location, ownership, current status, geographical description, possible sources of pollution, and techniques used in water extraction.

3.3. Water Sampling:

Samples were collected at two different seasons around the years 2018 and 2019. The first sampling occurred in the dry season (October) when there is no rainfall for the six consecutive summer months. Meanwhile, the second sampling was carried out during the wet rainy season (April), when the area had received sufficient rainfall (Ameen, 2019).

Three replicates (bottles) per spring were taken during the morning from the 22 springs for the two seasons (April: 22*3replicates=66 samples, and October: 22*3replicates =66 samples). The presented results are the average of every three replicates.

Sampling bottles were sterilized, plastic, transparent and have a capacity of 1500ml/ bottle.

In the field, each bottle was:

- Washed internally with the spring water.
- Kept away from respiration to avoid biological pollution.
- Runneth over with spring water.
- Placed in a cold box until reached back to the soil and water laboratory at the College of Agriculture/ Hebron University.

3.4. Water Quality Assessment Parameters:

In order to evaluate water suitability for agricultural and domestic uses in Halhul and Dura areas, different physicochemical and microbiological parameters were used in the mentioned 22 springs. These tools were used to extract valid data and compare it with internationally accepted standards by WHO (Sawad, 2009). According to table (2) below, different methods and types of equipment were used to measure each parameter.

Table 3: Methods and pieces of equipment to measure different water quality indicators.

No.	Tests	Method
1	pH	pH-electrode meter
2	Total Dissolved Solids (TDS)	Equation TDS= EC*640.
3	Electrical Conductivity (EC)	Conductivity Meter
4	Chloride (Cl^-)	Titration with AgNO3 using potassium chromate Indicator

5	Nitrate (NO_3^-)	UV- Spectrophotometer method (λ=220nm)
6	Sulfate (SO_4^{-2})	Turbidimetric method, Spectrophotometer (λ=220nm)
7	Calcium (Ca^{+2})	Titration with disodium-EDTA using Murexide Indicator
8	Magnesium (Mg^{+2})	Titration with disodium -EDTA using Eriochrome black-T indicator.
9	Potassium (K^+)	Atomic absorption spectrophotometer.
10	Sodium (Na^+)	Flame Photometer.
11	$Ca(HCO_3)_2$	Titration with HCl using phenolphthalein and bromocresol-green indicators.
12	Phosphorus (P)	Atomic absorption spectrophotometer.
13	Phosphate ($PO4^{-3}$)	spectrophotometer
14	Boron (B)	spectrophotometer
15	Total Coliform.	Filter membrane method.
16	Fecal Coliform.	Filter membrane method.
17	SAR	$SAR = Na^+/ ((Ca^{+2} + Mg^{+2})/2)^{0.5}$
18	SSP	$SSP = ((Na^+) / (Ca^{+2} + Mg^{+2} + Na^+ + K^+))*100$
19	Total hardness	($CaCO3$) mg/L= 2.497Ca^{+2} + 4.115 Mg^{+2}. (Ca^{+2} and Mg^{+2} concentrations in mg/l)

Chapter Four

4. Results

4.1. Chemical properties of water:

Chemicals concentration in the 22 chosen springs were measured and the results were compared with WHO and the Palestinian standards.

4.1.1. Anions:

4.1.1.1. Calcium bicarbonate $Ca(HCO_3)_2$:

The results revealed higher values of Bicarbonate compared to the standard (200 mg/l) except Ain Safa and Ain Al-dlbeh that presented lower values than the standard in the two seasons, in addition to Ain Qosbor and Ain al-Ewainat that presented lower values in the dry season. Generally, the records in the wet season were higher than in the dry season.

Table 4: Mean Calcium Bicarbonate (mg/l) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	508.33	552.457	12	Ain Kanar	317.2	366.407
2	Ain Al-thrwe	370.067	377.997	13	Ain set-alrom	380.233	391.213
3	Ain Zabood	404.633	428.017	14	Ain fredis	274.5	296.257
4	Ain Al-tenah	335.5	289.14	15	Ain taha	286.7	320.047
5	Ain Bagar	237.9	254.167	16	Ain al-shqya	475.8	495.523
6	Ain Qosbor	189.1	244.61	17	Ain al-dlbeh	142.333	186.66
7	Ain Al-ewainat	187.067	207.603	18	Ain d.dodeen	366	397.11
8	Ain Safa	178.933	188.083	19	Ain zoqo	414.8	426.39

No.	Spring Name	Dry season	Wet season	No.	Spring Name	Dry season	Wet season
9	Ain Al-set	339.567	364.577	20	Ain aisa-amer	274.5	305.61
10	Ain Al-tahona	307.033	372.303	21	Ain emtir	284.667	305.407
11	Ain Haska	311.1	338.55	22	Ain jadow'	396.5	426.593

4.1.1.2. **Chloride (Cl^-):** Here, the results revealed that the chloride values were lower than the allowable value of the Palestinian and WHO standards (250 mg/l) except Ain Al-saqya and Ain Zoqo in Dura exceed the maximum level by 13% and 5.6% respectively during the wet season.

Table 5: Mean Chloride (Cl^-) (mg/l) values for the tested springs in the study area during dry and wet season							
Halhul				**Dura**			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	179.63	217.97	12	Ain Kanar	97.98	95.853
2	Ain Al-thrwe	171.82	146.143	13	Ain set-alrom	218.207	239.27
3	Ain Zabood	161.643	160.107	14	Ain fredis	180.933	181.88
4	Ain Al-tenah	88.87	78.103	15	Ain taha	159.753	143.54
5	Ain Bagar	139.99	70.41	16	Ain al-shqya	230.633	260.807
6	Ain Qosbor	105.2	71.95	17	Ain al-dlbeh	68.99	66.15
7	Ain Al-ewainat	74.553	54.79	18	Ain d.dodeen	159.987	213.713
8	Ain Safa	70.647	74.67	19	Ain zoqo	249.33	263.887
9	Ain Al-set	111.233	93.603	20	Ain aisa-amer	115.257	149.693
10	Ain Al-tahona	94.193	106.383	21	Ain emtir	126.263	136.793
11	Ain Haska	90.29	89.58	22	Ain jadow'	235.957	206.02

4.1.1.3. **Nitrate(NO_3^-):** The results of measuring Nitrate concentration in the evaluated springs showed lower nitrate values than the Palestinian and WHO standards (50 mg/l). In Halhul, 55% of the springs presented lower Nitrate values in the dry season. While 18% of the springs in Dura revealed lower nitrate values in the dry season.

Table 6: Mean Nitrate ($NO3^-$) (mg/l) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	18.847	21.46	12	Ain Kanar	10.12	11.67
2	Ain Al-thrwe	14.037	13.023	13	Ain set-alrom	37.18	38.653
3	Ain Zabood	17.82	21.04	14	Ain fredis	27.59	30.23
4	Ain Al-tenah	0.963	0.713	15	Ain taha	21.947	22.417
5	Ain Bagar	12.907	14.09	16	Ain al-shqya	26.047	28.18
6	Ain Qosbor	8.357	8.867	17	Ain al-dlbeh	3.47	3.147
7	Ain Al-ewainat	1.98	1.66	18	Ain d.dodeen	20.127	19.343
8	Ain Safa	4.217	4.66	19	Ain zoqo	22.837	23.76
9	Ain Al-set	9.53	8.683	20	Ain aisa-amer	16.693	17.837
10	Ain Al-tahona	8.743	9.357	21	Ain emtir	17.82	20.14
11	Ain Haska	7.73	7.293	22	Ain jadow'	29.353	30.353

4.1.1.4. **Sulphate (SO42-):** The results of Sulphate concentrations in the evaluated springs were mostly higher than the Palestinian and WHO standards 250 mg/l. Generally, the Sulphate concentrations in Halhul exceed the maximum allowable levels in all of the springs especially Ain Al-ewainat (1335.49 mg/l) and Ain Al-set (1079.21 mg/l). Also, the results of Sulphate concentrations in Halhul were mostly higher than Dura. On the other hand, in Dura 45.5% of the springs presented lower Sulphate values in the dry season and about 36% in the wet season when comparing to the accepted Sulphate concentration.

Table 7: Mean Sulphate (SO_4^{-2}) (mg/l) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	355.433	360.927	12	Ain Kanar	633.95	625.443
2	Ain Al-thrwe	306.817	310.66	13	Ain set-alrom	331.81	320.827
3	Ain Zabood	449.647	471.347	14	Ain fredis	386.197	414.353
4	Ain Al-tenah	335.16	366.37	15	Ain taha	202.71	170.437
5	Ain Bagar	549.63	505.133	16	Ain al-shqya	174.147	223.697
6	Ain Qosbor	462.83	488.653	17	Ain al-dlbeh	159.863	184.363
7	Ain Al-ewainat	1335.487	1210.233	18	Ain d.dodeen	246.66	265.34
8	Ain Safa	967.417	1006.42	19	Ain zoqo	252.15	257.92
9	Ain Al-set	1079.207	1191.007	20	Ain aisa-amer	143.38	140.5
10	Ain Al-tahona	676.533	632.307	21	Ain emtir	246.66	272.757
11	Ain Haska	705.37	766.35	22	Ain jadow'	274.68	292.393

4.1.1.5. **Phosphate and Phosphorus:** The results of measuring the Phosphate and Phosphorus concentrations in the 22 springs during the wet and dry seasons showed that only Ain Bagar, Ain Qosbor, Ain Al-ewainat, Ain Safa and Ain Haska showed normal concentrations (<3 mg/l) according to the Palestinian standards. Meanwhile, Ain Al-tenah and Ain Kanar showed higher concentrations in the wet and dry seasons respectively. Other springs showed higher concentrations of Phosphate and Phosphorus in both the wet and dry seasons.

Table 8: Mean Phosphate PO_4^{-3} (mg/l) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	37.87	42.443	12	Ain Kanar	3.313	1.627
2	Ain Al-thrwe	3.083	3.913	13	Ain set-alrom	27.88	42.167
3	Ain Zabood	125.657	165.227	14	Ain fredis	18.48	15.3
4	Ain Al-tenah	2.8	6.543	15	Ain taha	4.393	6.2
5	Ain Bagar	1.873	1.02	16	Ain al-shqya	23.453	33.43
6	Ain Qosbor	2.253	1.367	17	Ain al-dlbeh	5.16	5.43
7	Ain Al-ewainat	2.96	0.607	18	Ain d.dodeen	22.63	26.043
8	Ain Safa	2.883	1.667	19	Ain zoqo	6.823	11.783
9	Ain Al-set	3.723	3.21	20	Ain aisa-amer	6.257	5.593
10	Ain Al-tahona	6.083	4.92	21	Ain emtir	30.283	25.563
11	Ain Haska	2.93	0.677	22	Ain jadow'	8.02	19.47

Table 9: Mean Phosphorus P (mg/l) values for the tested springs in the study area during dry and wet season							
Halhul				**Dura**			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	12.347	13.837	12	Ain Kanar	1.08	0.53
2	Ain Al-thrwe	1.00	1.277	13	Ain set-alrom	9.09	13.747
3	Ain Zabood	40.963	53.863	14	Ain fredis	6.02	4.99
4	Ain Al-tenah	0.91	2.133	15	Ain taha	1.437	2.023
5	Ain Bagar	0.61	0.33	16	Ain al-shqya	7.647	10.9
6	Ain Qosbor	0.733	0.443	17	Ain al-dlbeh	1.683	1.773
7	Ain Al-ewainat	0.96	0.19	18	Ain d.dodeen	7.377	8.493
8	Ain Safa	0.937	0.543	19	Ain zoqo	2.227	3.84
9	Ain Al-set	1.21	1.047	20	Ain aisa-amer	2.04	1.823
10	Ain Al-tahona	1.987	1.603	21	Ain emtir	9.873	8.333
11	Ain Haska	0.957	0.223	22	Ain jadow'	2.613	6.347

4.1.2. Cations:

4.1.2.1. **Calcium (Ca^{+2}):** the results of measuring Calcium concentrations in the tested spring revealed that Calcium concentrations ranged from 44.2 to 172.8 mg/l. About 45.5% of the springs in both seasons exceed the maximum level (100 mg/L), and it was the same for all springs in the wet and dry seasons.

Table 10: Mean Calcium Ca^{+2}(mg/l) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	149	151.08	12	Ain Kanar	72.96	90
2	Ain Al-thrwe	127	139.2	13	Ain set-alrom	155.6	169.88
3	Ain Zabood	145.6	135	14	Ain fredis	179.6	198
4	Ain Al-tenah	71.6	80.96	15	Ain taha	121.2	157.2
5	Ain Bagar	80.88	88.4	16	Ain al-shqya	144.4	172.8
6	Ain Qosbor	60.4	72	17	Ain al-dlbeh	44.2	58.8
7	Ain Al-ewainat	73.68	88.8	18	Ain d.dodeen	122.88	138.4
8	Ain Safa	66	79.2	19	Ain zoqo	103.2	144.48
9	Ain Al-set	77.6	89.84	20	Ain aisa-amer	66.96	85.2
10	Ain Al-tahona	56.88	81.36	21	Ain emtir	110	123.6
11	Ain Haska	62.4	85.2	22	Ain jadow'	84.8	98.16

4.1.2.2. **Sodium (Na^+):** Here, the results of Sodium concentrations shown to be under the maximum level for the whole springs in Dura and Halhul according to the Palestinian and WHO standards (200mg/l).

Table 11: Mean Sodium Na^+(mg/l) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	20.673	43.067	12	Ain Kanar	54.767	33.547
2	Ain Al-thrwe	32.543	30.117	13	Ain set-alrom	51.333	48.773
3	Ain Zabood	26.093	36.4	14	Ain fredis	39.317	39.01
4	Ain Al-tenah	25.563	24.303	15	Ain taha	40.71	46.343
5	Ain Bagar	29.973	28.233	16	Ain al-shqya	50.557	50.937
6	Ain Qosbor	26.203	26.87	17	Ain al-dlbeh	36.1	24.607
7	Ain Al-ewainat	27.43	25.72	18	Ain d.dodeen	45.1	56.59
8	Ain Safa	26.593	27.463	19	Ain zoqo	40.453	46.71
9	Ain Al-set	50.133	34.58	20	Ain aisa-amer	51.01	36.8
10	Ain Al-tahona	48.587	33.24	21	Ain emtir	45.46	47.04
11	Ain Haska	32.467	35.127	22	Ain jadow'	39.923	44.983

4.1.2.3. **Magnesium (Mg^{+2}):** regarding the Magnesium concentration in the 22 springs for the wet and dry seasons, the results showed low concentrations except for Ain Set-Alrom (62.64 mg/l) and Ain Fredis (66.24 mg/l) in the wet season were Magnesium concentrations were lower than the Palestinian water quality standards (>100 mg/l) but higher than WHO recommended standard which is 60 mg/l.

Table 12: Mean Magnesium Mg^{+2} (mg/l) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	37.033	50.113	12	Ain Kanar	47.183	44.64
2	Ain Al-thrwe	40.44	50.16	13	Ain set-alrom	50.113	62.64
3	Ain Zabood	27.72	32.04	14	Ain fredis	37.68	66.24
4	Ain Al-tenah	39.36	50.063	15	Ain taha	31.44	42.817
5	Ain Bagar	56.473	51.24	16	Ain al-shqya	23.087	35.16
6	Ain Qosbor	43.2	52.56	17	Ain al-dlbeh	23.88	19.297
7	Ain Al-ewainat	12.313	20.497	18	Ain d.dodeen	19.873	24.577
8	Ain Safa	21.673	23.377	19	Ain zoqo	39.073	36.073
9	Ain Al-set	44.04	56.017	20	Ain aisa-amer	23.423	28.8
10	Ain Al-tahona	46.273	50.303	21	Ain emtir	41.04	52.56
11	Ain Haska	49.68	41.76	22	Ain jadow'	45.96	42.527

4.1.2.4. **Boron (B):** The results showed that most of the values that exceed the maximum level (1 mg/L) were in Dura (Ain Al-saqya, Ain Aisa-amter, and Ain Jadow' in the two seasons), in addition to (Ain Set-alrom and Ain Zoqo in the wet season). In Halhul only Ain Haska presented a higher value than the standard in the wet season. In general, the boron content during the wet season was higher than in the dry season except for Ain Al-thrwe, Ain Bagar and Ain Jadow' which were slightly higher in the wet season than the dry season.

Table 13: Mean Boron B (mg/l) values for the tested springs in the study area during dry and wet season

Halhul				**Dura**			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	0.977	0.987	12	Ain Kanar	0.767	0.937
2	Ain Al-thrwe	0.843	0.827	13	Ain set-alrom	0.98	1.02
3	Ain Zabood	0.897	0.913	14	Ain fredis	0.857	0.963
4	Ain Al-tenah	0.83	0.89	15	Ain taha	0.743	0.9
5	Ain Bagar	0.85	0.813	16	Ain al-shqya	1.01	1.06
6	Ain Qosbor	0.713	0.857	17	Ain al-dlbeh	0.687	0.95
7	Ain Al-ewainat	0.677	0.9	18	Ain d.dodeen	0.947	0.983
8	Ain Safa	0.653	0.92	19	Ain zoqo	0.92	1.073
9	Ain Al-set	0.9	0.967	20	Ain aisa-amer	1.073	1.017
10	Ain Al-tahona	0.833	0.94	21	Ain emtir	0.823	0.957
11	Ain Haska	0.8	1.023	22	Ain jadow'	1.11	1.02

4.1.2.5. **Potassium (K^+):** In general, the results of Potassium concentration showed lower values than the Palestinian standard (>10 mg/l) in the wet and dry seasons. Where the lowest value were recorded in Ain Al-ewainat (0.68 mg/l) during the wet season and Ain Safa (0.63 mg/l) during the dry season. Meanwhile, the highest results that went beyond the standard were recorded in Dura, where in the wet season Ain al-saqya presented the highest K value followed by Ain zoqo at the same season (25.3 and 24.9 mg/l respectively)

Table 14: Mean Potassium (K^+) (mg/l) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	10.58	21.68	12	Ain Kanar	0.957	0.74
2	Ain Al-thrwe	2.49	2.737	13	Ain set-alrom	9.15	10.893
3	Ain Zabood	8.967	15.203	14	Ain fredis	4.383	5.293
4	Ain Al-tenah	0.84	1.857	15	Ain taha	2.903	2.793
5	Ain Bagar	7.863	6.49	16	Ain al-shqya	10.753	25.303
6	Ain Qosbor	6.393	8.333	17	Ain al-dlbeh	12.61	2.03
7	Ain Al-ewainat	0.73	0.683	18	Ain d.dodeen	9.867	14.93
8	Ain Safa	0.633	0.707	19	Ain zoqo	7.64	24.997
9	Ain Al-set	5.11	5.637	20	Ain aisa-amer	4.91	5.81
10	Ain Al-tahona	5.217	5.637	21	Ain emtir	7.143	5.72
11	Ain Haska	2.517	2.29	22	Ain jadow'	11.227	16.05

4.1.3. Other chemical properties

4.1.3.1. Electrical Conductivity (EC):

Here, the results of EC showed lower values than the Palestinian drinking water standards (2500 µS/cm) that ranged from 582- 1966 µS/cm for all of the springs in the two seasons. However, the wet season presented generally higher EC values than the dry season and the results of Dura were mostly higher than Halhul. Moreover, three springs (Ain al-dlbeh, Ain Al-ewainat and Ain Safa) presented no restrictions for the agricultural use in the two seasons (<700 µS/cm). while the others are classified as slightly to moderately restricted (700-3000 µS/cm) and none of them reach the sever restriction (>3000 µS/cm).

Table 15: Mean electrical conductivity values (µS/cm) for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	1863	1964	12	Ain Kanar	1117	1085
2	Ain Al-thrwe	1367	1405	13	Ain set-alrom	2061	2291
3	Ain Zabood	1677	1740	14	Ain fredis	1771	1966
4	Ain Al-tenah	871	876	15	Ain taha	1458	1432
5	Ain Bagar	878	832	16	Ain al-shqya	2160	2270
6	Ain Qosbor	868	877	17	Ain al-dlbeh	590	582
7	Ain Al-ewainat	603	604	18	Ain d.dodeen	1606	1934
8	Ain Safa	678	668	19	Ain zoqo	2085	2210
9	Ain Al-set	1173	1062	20	Ain aisa-amer	1229	1505
10	Ain Al-tahona	1065	1221	21	Ain emtir	1321	1622
11	Ain Haska	1044	1023	22	Ain jadow'	2083	1853

4.1.3.2. Total dissolved solids (TDS):

Generally, the results of the TDS revealed lower values according to the PSI (1500 mg/l). Also, the values ranged between 372 in Ain al-dlbeh and 1466 in Ain set-alrom and both of them locate in Dura. Moreover, the average TDS records in Hahul (709) were lower than Dura (1054).

Table 16: Mean Total dissolved solids (TDS) (mg/l) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	Spring Name	Dry season	Wet season	No.	Spring Name	Dry season	Wet season
1	Ain Aiub	1192.32	1256.96	12	Ain Kanar	715.093	694.187
2	Ain Al-thrwe	874.88	898.987	13	Ain set-alrom	1319.04	1466.24
3	Ain Zabood	1073.067	1113.813	14	Ain fredis	1133.44	1258.453
4	Ain Al-tenah	557.653	560.853	15	Ain taha	932.907	916.267
5	Ain Bagar	562.133	532.267	16	Ain al-shqya	1382.4	1453.013
6	Ain Qosbor	555.307	561.067	17	Ain al-dlbeh	377.387	372.267
7	Ain Al-ewainat	385.707	386.347	18	Ain d.dodeen	1027.627	1237.973
8	Ain Safa	434.133	427.52	19	Ain zoqo	1334.4	1414.4
9	Ain Al-set	750.72	679.893	20	Ain aisa-amer	786.347	963.413
10	Ain Al-tahona	681.813	781.653	21	Ain emtir	845.653	1037.867
11	Ain Haska	667.947	654.72	22	Ain jadow'	1333.333	1185.707

4.1.3.3. **pH:** According to the Palestinian pH water quality standard, all of the tested springs were within the allowable pH limits (6-9) even in the two season. Also, a narrow range was recorded between the lowest and highest values (7.1-8.3).

Table 17: Mean pH values for the tested springs in the study area during dry and wet season							
Halhul				**Dura**			
No.	**Spring Name**	**dry season**	**wet season**	**No.**	**Spring Name**	**dry season**	**wet season**
1	Ain Aiub	7.4	7.3	12	Ain Kanar	7.8	7.3
2	Ain Al-thrwe	7.7	7.5	13	Ain set-alrom	7.6	7.5
3	Ain Zabood	7.3	7.6	14	Ain fredis	7.7	7.1
4	Ain Al-tenah	7.5	8.3	15	Ain taha	7.9	7.9
5	Ain Bagar	7.9	8.2	16	Ain al-shqya	7.6	7.1
6	Ain Qosbor	8.1	8.2	17	Ain al-dlbeh	8.3	8.1
7	Ain Al-ewainat	8.2	8.2	18	Ain d.dodeen	7.4	7.6
8	Ain Safa	8.1	8.2	19	Ain zoqo	7.3	8.2
9	Ain Al-set	7.5	7.4	20	Ain aisa-amer	7.4	7.1
10	Ain Al-tahona	7.6	7.5	21	Ain emtir	7.4	7.7
11	Ain Haska	7.7	7.8	22	Ain jadow'	7.3	7.3

4.1.3.4. The Sodium Adsorption Ratio (SAR):

The results of measuring the Sodium adsorption ratio for the examined springs in Halhul and Dura showed low SAR values (less than 10 meq/l). Moreover, the minimum result was recorded in Ain Aiub (0.32 meq/l) and the highest was in Ain aisa-amer (1.12 meq/l)

Table 18: Mean Sodium adsorption ratio (SAR) (meq/l) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	0.32	0.63	12	Ain Kanar	1.04	0.60
2	Ain Al-thrwe	0.52	0.46	13	Ain set-alrom	0.75	0.67
3	Ain Zabood	0.41	0.59	14	Ain fredis	0.56	0.50
4	Ain Al-tenah	0.51	0.44	15	Ain taha	0.69	0.68
5	Ain Bagar	0.53	0.50	16	Ain al-shqya	0.81	0.74
6	Ain Qosbor	0.54	0.50	17	Ain al-dlbeh	0.91	0.58
7	Ain Al-ewainat	0.62	0.51	18	Ain d.dodeen	0.79	0.92
8	Ain Safa	0.59	0.57	19	Ain zoqo	0.71	0.72
9	Ain Al-set	0.95	0.60	20	Ain aisa-amer	1.12	0.72
10	Ain Al-tahona	1.00	0.60	21	Ain emtir	0.77	0.74
11	Ain Haska	0.64	0.65	22	Ain jadow'	0.73	0.79

4.1.3.5. The Soluble Sodium Percent (SSP):

Generally, the tested water samples from the evaluated springs were classified as good for irrigation purposes. In Halhul there was 36% of the springs were excellent in the dry season, and the rest were good. The Same results were obtained in the wet season but with fluctuation among the springs that varied from excellent to good and vice versa.

In Dura, the results revealed reasonable classifications of springs except for Ain fredis, which showed excellent classification in the two seasons, and Ain taha, which turned from good in the dry season to excellent in the wet season. On the other hand, Ain al-dlbeh was Permissible in the dry season and turned to good in the wet season. Also, it was notable that 77% of the results in the dry season were higher than in the wet season.

Table 19: Mean Soluble Sodium Percent (SSP) (meq/l) values for the tested springs during dry and wet season

Halhul				Dura			
No.	**Spring Name**	**Dry season**	**Wet season**	**No.**	**Spring Name**	**Dry season**	**Wet season**
1	Ain Aiub	24.35	14.38	12	Ain Kanar	20.30	31.69
2	Ain Al-thrwe	14.78	17.30	13	Ain set-alrom	20.42	22.72
3	Ain Zabood	23.60	16.83	14	Ain fredis	14.36	16.74
4	Ain Al-tenah	16.64	19.22	15	Ain taha	19.72	22.22
5	Ain Bagar	19.91	21.60	16	Ain al-shqya	26.83	26.80
6	Ain Qosbor	22.03	23.93	17	Ain al-dlbeh	25.43	41.71
7	Ain Al-ewainat	19.46	24.67	18	Ain d.dodeen	30.50	27.80
8	Ain Safa	21.55	23.70	19	Ain zoqo	28.43	25.26
9	Ain Al-set	21.61	31.23	20	Ain aisa-amer	27.21	38.22
10	Ain Al-tahona	22.80	34.28	21	Ain emtir	23.05	25.83
11	Ain Haska	22.76	23.79	22	Ain jadow'	30.26	28.12

4.1.3.6. Total hardness:

The results of the total hardness revealed generally lower values than the PSI and WHO standards (500 mg/l). Also, the average total hardness concentrations during the dry season were lower than the wet season. And regarding the average results for the two localities, the springs of Dura presented higher results than Halhul.

Table 20: Mean Total hardness (mg/l)values for the tested springs in the study area during dry and wet season

Halhul				**Dura**			
No.	**Spring Name**	**dry season**	**wet season**	**No.**	**Spring Name**	**dry season**	**wet season**
1	Ain Aiub	524.44	583.46	12	Ain Kanar	376.34	408.42
2	Ain Al-thrwe	483.53	553.99	13	Ain set-alrom	594.75	681.95
3	Ain Zabood	477.63	468.94	14	Ain fredis	603.51	766.98
4	Ain Al-tenah	340.75	408.17	15	Ain taha	432.01	568.72
5	Ain Bagar	434.34	431.59	16	Ain al-shqya	455.57	576.17
6	Ain Qosbor	328.59	396.07	17	Ain al-dlbeh	208.63	226.23
7	Ain Al-ewainat	234.65	306.08	18	Ain d.dodeen	388.61	446.72
8	Ain Safa	253.99	293.96	19	Ain zoqo	418.48	509.21
9	Ain Al-set	374.99	454.84	20	Ain aisa-amer	263.58	331.26
10	Ain Al-tahona	332.44	410.15	21	Ain emtir	443.55	524.91
11	Ain Haska	360.25	384.59	22	Ain jadow'	400.87	420.10

4.2. Microbiological Properties of Water:

The results of testing the 22 springs for the presence and number of total Coliform and Fecal Coliform Bacteria showed that all springs were contaminated with both types of Bacteria.

Table 21: Mean Total Coliform (CFU/100 ml) values for the tested springs in the study area during dry and wet season

Halhul				Dura			
No.	Spring Name	Dry season	Wet season	No.	Spring Name	Dry season	Wet season
1	Ain Aiub	1223	1132	12	Ain Kanar	259	78
2	Ain Al-thrwe	115	131	13	Ain set-alrom	137	203
3	Ain Zabood	6790	7281	14	Ain fredis	3647	4189
4	Ain Al-tenah	313	477	15	Ain taha	183	236
5	Ain Bagar	908	1253	16	Ain al-shqya	1327	2827
6	Ain Qosbor	413	501	17	Ain al-dlbeh	11	24
7	Ain Al-ewainat	447	1040	18	Ain d.dodeen	127	376
8	Ain Safa	0	15	19	Ain zoqo	163	145
9	Ain Al-set	323	244	20	Ain aisa-amer	515	780
10	Ain Al-tahona	1989	387	21	Ain emtir	496	847
11	Ain Haska	133	183	22	Ain jadow'	253	833

Table 22: Mean Fecal Coliform (CFU/100 ml) values for the tested springs in the study area during dry and wet season							
Halhul				Dura			
No.	Spring Name	Dry season	Wet season	No.	Spring Name	Dry season	Wet season
1	Ain Aiub	692	411	12	Ain Kanar	163	28
2	Ain Al-thrwe	88	85	13	Ain set-alrom	80	93
3	Ain Zabood	3982	4447	14	Ain fredis	2389	2960
4	Ain Al-tenah	84	139	15	Ain taha	16	51
5	Ain Bagar	563	618	16	Ain al-shqya	843	864
6	Ain Qosbor	304	381	17	Ain al-dlbeh	5	16
7	Ain Al-ewainat	329	476	18	Ain d.dodeen	55	203
8	Ain Safa	0	3	19	Ain zoqo	53	88
9	Ain Al-set	248	145	20	Ain aisa-amer	309	420
10	Ain Al-tahona	1463	220	21	Ain emtir	331	353
11	Ain Haska	84	64	22	Ain jadow'	103	127

4.3. Springs Survey

The extracted data using the spring survey provided an overall scanning of the location, ownership, status, geographical description, possible sources of pollution, techniques of water extraction, and uses of water extracted from the 22 springs in this study.

The results showed that 41% of the springs are located near arable lands and living Areas (Table 21). More than half of the springs are owned by families and located near valleys. 81% of the springs are rehabilitated. Wastewater Cesspits and Agricultural Activities constitute 68% of the possible pollution sources. Finally, most of the springs are used for plant irrigation with only 13% used for drinking alongside other uses.

Table 23: Percentage of springs location, ownership, status, etc provided by the survey.

Survey Information	**Percentage**
Location	
Near Arable lands	31.82%
Near Arable Lands and Living Areas	40.91%
Near Living Areas	22.73%
Near Living Area, Chemicals Factory and Arable Lands	4.55%
Ownership	
Family	54.55%
Public	45.45%
Status	
Neglected	18.18%
Rehabilitated	81.82%
Geographical description	
In the Valley	54.55%
Inside Cave	4.55%
Foothill	40.91%
Possible sources of pollution	
Agricultural Activities	27.27%
Wastewater Cesspits	4.55%
Wastewater Cesspits and Agricultural Activities	68.18%
Techniques of Water Extraction	
By Electrical Pumps	50.00%

By Flow	50.00%
Springs Uses	
Domestic, Drinking and Agricultural Use/ Plants Irrigation and Animal Watering	9.09%
Plants Irrigation	86.36%
Agricultural Plant and Drinking	4.55%

Chapter Five

5. Discussion

It is well known that water is the key factor for life and civilization throughout the human history and wherever water exist the humanity were thriving and developing. For that, measuring water quality is critical to evaluate its suitability for agricultural, domestic or drinking purposes in order to assure high quality life and sustainability in all of the aspects of our life.Temperature, relative humidity, precipitation, and evaporation reflected the major impact of the weather in these areas on the quality of water in the 22 tested springs.

The highest temperature was scored during July and August 2019 (around 29 C̊), meanwhile, January 2019 showed the lowest temperature among the dry and wet seasons. This pattern resamples the normal pattern of temperature in the Mediterranean areas (Basheer-Salimia & Ward. 2014). Higher temperatures degrees affect the percentage of dissolved Oxygen inside water, which controls the survival of certain organisms inside springs. However, temperature degrees were normal and did not have any effect on the quality of water. Similar trends were documented by Daghara et al. (2019).

Moreover, pH results were within the normal range and did not have any major impact on the quality of water in the 22 springs. The electrical conductivity of the 22 springs showed that only three springs were below the standard concentration (Ain Al-ewainat, Ain Safa and Ain al-dlbeh), which means that these springs can be used for agricultural purposes with no restrictions because the number of dissolved salts and ions will not affect plants.

There are many reasons for up normal concentrations of anions and cation0s in water. For example, an increase in Potassium and Sodium concentrations indicates the overuse of artificial fertilizers and pesticides in agricultural areas

(Daghara et al., 2019). Meanwhile, increased Chloride concentrations can happen when industrial liquid wastes reach clean water resources (WHO, 2017; Daghara et al., 2019).

Some of the anions like sulphate can increase bowel movement and act as a laxative for drinkers who are not familiar with high sulphate percentages in their drinking water.

5.1. Ca^{+2}, Mg^{+2}, Total hardness and bicarbonate:

Calcium and Magnesium are highly related to the total hardness and bicarbonate concentration in the groundwater (Zohud and Alam, 2022). The high concentrations of Magnesium in irrigation water could negatively influence the soil structure (Adimalla and Venkatayogi, 2018). Limestone and dolomite are the main rock formation of these aquifers and considered the main source of Calcium and Magnesium (Ikhlil, 2009) in the springs of Dura and Halhul. Where it was notable that the calcium concentrations were higher in Dura, which could be related the nature of the limestone aquifer that is rich in Calcium. On the other hand, the magnesium concentrations were higher in Halhul, which may related to the dolomite rocks there (Sawad, 2009). Moreover, the higher results in the wet season compared to the dry season, might be attributed to the infiltrated rain water that dissolves the Calcium and Magnesium ions and drain them to the groundwater (Ikhlil, 2009).

The total hardness is directly proportional to Calcium and Magnesium contents (Jan et al, 2021). High hardness values (>500 mg/l) could cause negative impact on human health (Daghara et al, 2019), domestic uses such as cleaning practices (Jaglarz, 2020) and industry (Jan et al, 2021). This could be related to the calcium contents that exceed the maximum level (100 mg/l) in the vast majority of the tested springs particularly in Dura.

5.2. Sodium adsorption ratio (SAR), Soluble Sodium Percentage (SSP) and Sodium:

Water quality for agricultural purposes is highly influenced by Sodium concentration in the arid regions where water salinity increased. Consequently, this affects the agriculture in such areas and causes crops toxicity and make the farmers change their agricultural pattern toward salinity tolerant crops that could be expensive or less profitable (Zaman et al., 2018).

SAR and SSP is directly influenced by the sodium (Na^{+}), calcium (Ca^{+2}), magnesium (Mg^{+2}) soluble salts concentrations in the water (Sawad 2009; Zaman et al., 2018).

Sodium ions could contaminate the ground water through the heavy utilization of fertilizers and pesticides (Ghanem et al., 2021) or by the salty surface sea water that infiltrate through the rock layers (Zaman et al., 2018). Actually, the research area is far from the coastal areas, which may explain the low sodium, SAR and SSP values in the tested springs. This also indicates that these springs are suitable for the agricultural purposes due to the fact that all of the springs have lower values compared to the extent permitted by the Palestinian standards institution (PSI, 2012).

5.3. Boron:

It is one of the microelements that plants need tiny amounts of it in order to have ideal growth and the range between its deficiency and toxicity is slim. Also, Boron crops toxicity could appear if the crops were irrigated by water that contains Boron concentrations that exceed the permitted extent (1mg/l). Furthermore, Boron has higher ability to accumulate than other salts, which means that even with low concentrations of Boron in the irrigation water could efficiently accumulated and cause toxicity to crops in the arid and semiarid areas and particularly for the sensitive crops such as deciduous and citrus trees and strawberries (Nikolaou et al., 2020). The possible explanation for the records that exceed the permitted level could be related to the accumulation of the Boron that originated from the irrigation water and the intensive use of fertilizers in the limit exceeded springs (e.g. Ain jadow', Ain aisa-amer and Ain al-shqya).

Moreover, the deeper aquifer of Dura could also interpret the higher Boron concentration in Dura springs compared to Halhul (Ikhlil, 2009). Whereas similar results were obtained by Sankar et al. (2019) who found higher Boron concentrations in the deeper aquifer, where the ground water last longer and accumulate more of it. Another possible reason for these higher records in Dura could be due to its calcium-rich limestone rocks formations (Ikhlil, 2009), where Boron is incorporated to the Calcium carbonate and enrich the Boron concentration in the ground water (Kobayashi et al., 2020). Besides, the sewage waste disposal could be another probable reason for the high Boron concentrations (Rehman and Cheema, 2017) where most of the Boron contaminated springs locate near the populated areas, where people dispose the waste water in non-isolated holes, which allow the waste water to penetrate toward the groundwater.

5.4. Chloride (Cl^-):

Chloride in the ground water could be originated from rainwater that include atmospheric chloride (Gordon, 2013), sewage waste (Sekha, 2017), chloride salts that are found in the soil, rocks and sea water such as NaCl, KCl, MgCl2, and CaCl2 (Li et al., 2020). However, the reason behind the low chloride concentrations in the study area could be related to the long distance from the coastal regions (Li et al., 2020). On the other hand, the records that exceed the permitted level of Chloride could be related to the sewage waste, chemical fertilizers and/or organic fertilizers (Ikhlil, 2009).

5.5. Nitrate (NO_3^-):

The source of Nitrogen in the chemical fertilizer in the study area include many products like Ammonium sulphate or animal manure such as sheep, poultry and cow manures. The nitrogen in this fertilizer may subjected to dissolution and nitrification and transformed to nitrate (Ii et al., 2003 cited). Later, the fate of nitrate is determined by many factors like soil moisture, soil aeration, soil pH, soil texture, temperature and the nitrifying organisms, where it could be absorbed by the plants, accumulated in the soil, denitrificated or leached into the ground water (Foth, 1990). Here, the possible explanation for the low Nitrate contents in the tested springs could be related to the fact that the vast majority of the study area is classified as semi-arid, which reduces the leaching opportunities and gives way to denitrification and other nitrogen loosing routs to take place. Worth mention, that high Nitrate concentrations in drinking water which exceed the allowable limits may cause harmful effects on human and animals health (Ii et al., 2003).

5.6. Sulphate (SO_4^-):

Sulphate in groundwater originated as a result of mineral dissolution, atmospheric precipitation and other possible resources like fertilizers. A significant contributor to the high levels of sulphate in many aquifers of Palestine are minerals that contain Sulphate include Magnesium Sulphate, sodium Sulphate, and calcium Sulphate (gypsum) (Sharma and Kumar, 2020). By way of water through the Sulphate containing soil and rock layers, part of the Sulphate dissolves and leached to the groundwater. The high sulphate content in Halhul could be related to the Dolomite Calcite, Aragonite that represent the major rocks formation in that area (Ikhlil, 2009; Sharma and Kumar, 2020)

5.7. Phosphate (PO_4^{-3}):

Phosphorus is vital for the vast majority of plants and organisms. The phosphate combined in the ecosystem, where compounds like ADP, ATP, DNA, and RNA are vital compounds for the life that depend mainly on the presence of Phosphorus. Generally, Phosphorus occurs as organic bound phosphate, condensed phosphates or Orthophosphate, which commonly known by its formula (PO_4^{-3}). The main sources of Phosphate to the groundwater include soil, dissolution minerals that contain phosphate, fertilizer, animal waste and infiltration of wastewater (Welch et al., 2010; Ouakouak et al., 2017). At low levels Phosphates are not toxic to people or animals. However, digestive problems may arise from high phosphate concentrations (Isiuku and Enyoh, 2020). On the other hand, plants and algae under aerobic conditions and excessive phosphate content become welling to grow and thrive faster than usual (Ouakouak et al., 2017). The high content of phosphate in the springs could be attributed to the sewage water and chemical fertilizers that are used in the arable areas around the springs. Also, the higher phosphate content in Halhul compared to Dura could be related to the shallower depth of Halhul springs (Ikhlil, 2009).

5.8. Electrical conductivity (EC):

It is an important indicator for water quality that indicate the presence of ions of inorganic substances that dissolved in the water. The differences between the two areas could be related to the variation in the spatial distribution of the springs in different geological formations (Daghara et al. 2019). Also, the different agricultural activities that related to fertilization and irrigation could influence the EC measurements. on the other hand, the higher records of the wet season might be related to the rain water infiltration that dissolves the ions during its drainage to the groundwater (Zaman et al., 2018).

5.9. Total dissolved solids (TDS):

The quantity of organic and inorganic materials, like salts, minerals, and ions that dissolve in identified volume of water determine the TDS. Furthermore, The TDS depend mainly on the concentration of main ions like Ca^{+2}, Mg^{+2}, Na, K^{+}, HCO_3^{-}, Cl^{-}, and SO_4^{-2} (Selvakumar et al., 2014). Based on that, the general low TDS records probably related to the low concentration of the above-mentioned ions.

5.10. pH:

Regarding the pH values, the results revealed that the water samples varied from neutral to slightly alkaline. Similar results were obtain by Daghara et al. 2019 and it was related to the alkaline nature of the rocks formations of these springs.

5.11. Total Coliform and Fecal Coliform:

Bacteria that are initiated in the soil, surface water and human or animal waste are total coliforms. While the set of the total coliforms that are considered to be present specifically in the gut and feces of animals are fecal coliforms. The presence of fecal coliform bacteria in the groundwater indicates that the water has been contaminated with the fecal material of humans mainly by sewage water or other animals especially when manure is used to fertilize the agricultural areas. A probable health risk could occur in the presence of total coliform or fecal coliform for individuals who use this contaminated water sources (Aram et al., 2021). Regarding the high records for the total coliform and fecal coliform in Dura and Halhul, the main source for that contamination might be the sewage water and the animal manure that is used for the agricultural purposes (Ikhlil, 2009; Sawad, 2009; Aram et al., 2021). This also indicates that all of the springs that exceed the allowable level are not suitable for drinking purposes.

Chapter Six

6. Conclusion

1- All of the tested springs are suitable for plant irrigation purposes.

2- All of the tested springs are not suitable for drinking, unless it treated.

3- Springs must be regularly tested to evaluate their quality over time.

4- Put up a noticeboard near the springs which mention the use suitability (drinking or agricultural) and some major indicators like total coliform and salinity in addition to the date of the last measurements.

5- More and periodic evaluation must be implemented on regular base to monitor the spring water quality.

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Abstract in Arabic

الملخص باللغة العربية

تقييم جودة مياه الينابيع في محافظة الخليل (دورا و حلحول)

تشكل ندرة المياه العذبة في الضفة الغربية تحديًا خطيرًا للفلسطينيين على عدة مستويات. يعد فحص جودة مياه الينابيع خطوة حاسمة لتعزيز استخدامها. تعتبر المياه الجوفية المصدر الرئيسي للمياه في الضفة الغربية ، لذلك من الضروري حماية جودتها من التدهور والتلوث.

أجريت هذه الدراسة في عام 2019/2018 على 22 ينبوعًا تقع في بلدتين بمحافظة الخليل، و هما حلحول (11) في الشمال ودورا (11) في الجنوب الغربي. تضم المنطقتان العديد من الينابيع المستخدمة للأغراض المنزلية والزراعية. تم إجراء اختبارات بيولوجية (القولونية الكلية والقولونية البرازية) والكيميائية الفيزيائية (pH ، TDS، TS، EC، Cl^-، NO^{3-}، $SO_4{}^{2-}$، Ca^{2+}، Mg^{2+}، K^+، Na^+، HCO_3^-، P، PO_4^{3-}، B) وهي معايير تستخدم لتقييم جودة المياه.

بشكل عام ، أظهرت النتائج ارتفاع التلوث البيولوجي في الينابيع المفحوصة في حلحول و دورا خاصة في موسم الأمطار، مما يعني ان مياه هذه العيون غير صالحة للشرب. من ناحية أخرى ، بالنسبة للمعلمات الفيزيوكيميائية ، تبين ان الحموضة و Cl^-، NO^{3-}، Ca^{2+}، Mg^{2+}، K^+، TDS, Na^+ ، NO_3^- و B بشكل عام عن نتائج ضمن الحدود المقبولة ، ولكن ، SO_4^{2-}، HCO_3^-، Ca^{2+}، P و PO_4^{3-}