

Groundwater Pollution Assessment In Tulkarem Area, Palestine

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Abstract

A hydrochemical study was conducted for the north western part of the Auja Tamaseeh basin in Tulkarem area. It acts as an evaluation study of the human effect activities on the quality of the groundwater. The groundwater type is of an earth alkaline with increased portions of alkalis with prevailing bicarbonate.

The mineral phases of calcite, dolomite and aragonite are the main constituents of the lithological formations in the recharge basin area. A spatial analysis was performed to correlate the polluted groundwater wells with the natural and anthropological activities using GIS. The polluted wells are located within populated areas and in high to moderate sensitive areas in close to the agricultural activities.

Key Notes: Groundwater pollution, Tulkarem, West Bank, Nitrate, Chlorite.

1 Introduction

Groundwater acts as the main source of water in the West Bank, so, it is essential to preserve its quality from deterioration and contamination especially when it is subjected to human activities. Population, pollution and other natural factors like droughts have contributed to the problem of water scarcity [1]. The Western West Bank Aquifer is flowing toward the Mediterranean Sea with a replenishment capacity of approximately 362 million Cubic meters (MCM) per year [2]. Groundwater in Tulkarm area is being utilized through 10 domestic and 53

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irrigation wells with total discharge of 21.3 MCM per year [2]. The Tulkarm area is considered to be a highly sensitive area because of the existing shallow aquifer system where the pollutants are being increased into the groundwater system through various human activities and natural processes [3]. Groundwater quality is influenced considerably by the quality of the recharge source. Variations in natural and human activities reflect spatial variations as well as the petrological aspects of the aquifer and the hydro chemical parameters of the groundwater. Pollution sources are classified as point sources and diffuse sources. Point sources are sources that can be clearly identified and pinpointed (such as landfill leachate). Diffuse sources cannot be pinpointed and are distributed over a large surface area (application of fertilizers and pesticides in agriculture: (nitrates and pesticides) infiltrate into the soil over an extensive surface area). There are several activities that are harmful to the groundwater quality in Tulkarm area. Approximately 58.5 tons of pesticides were used in Tulkarm Area in the years of 1993/1994 growing season; about 25% of the total cultivated areas in the area are treated with pesticides [4]. About 70% of houses dispose their wastewater using cesspits which is one of the main pollution sources to groundwater. Most of these cesspits are emptied by vacuum tankers and disposed into wadis or to improper dumping sites. There are approximately 12 known dumping sites in Tulkarm area [4]. These dumping sites are located in agricultural lands and their sites were selected randomly without any consideration to the soil characteristics, topography and climate as well as groundwater. As none of the existing dumping sites is designed to collect leachate from solid waste degradation, the leachate always finds its way through the soil to the groundwater, increasing nitrate concentration and other pollutants to the water. The pollutants pose the aquifer system leads to increase the number of soluble chemicals from urban, agricultural and industrial activities. These chemicals are not completely removed by filtration as groundwater passes through the aquifer and some pose a threat to human health. The removal of pollutants from aquifers is an extremely costly and protracted operation and in

some cases the aquifers may be irreversibly damaged. Pollution is detected in many springs and wells in the West Bank; it was found that the Qilt springs in the Jordan Valley were contaminated with fecal coliforms, which indicate the infiltration of pollutants in the recharge area of the springs [5]. In Groundwater pollution study [6] Concentrations of Pb and Cr in some of the groundwater wells in Tulkarem area complied with the WHO guideline; while nitrate (NO₃) and potassium (K) concentrations exceeded the permissible concentrations. A combination of physical, chemical, and isotopic analyses was used to describe the hydrogeological system and the recharge trends of water and salts to the aquifers. The results indicate that intensive irrigation and fertilization substantially affected the quantity and quality of groundwater recharge; while two main contamination processes were identified, both linked to human activity: salinization due to circulation of dissolved salts in the irrigation water itself, mainly chloride, sulfate, sodium and calcium, and of direct input of nitrate and potassium mainly from fertilizers [7]. Recharge is a critical issue for water management and the recharge assessment and the factors affecting recharge are of scientific and practical importance [8]. The main objective of this research is to study the groundwater hydrochemistry of the groundwater in Tulkarem area in order to detect whether there is a pollution of natural origin or man-made ones.

2 Study areas

Tulkarem area is located in the north western part of the West Bank (Figure 1). The total area of Tulkarem is about 246 km² and its current population is estimated at 166,832 people, representing 12.4% of the total population of the West Bank [9]. The number of people living in the rural areas is representing 55% of its total population. The population density in Tulkarm area is about 678.2 persons/km² [9]. The majorities of Tulkarm rocks are composed of carbonate rocks such as limestone, dolomite, marl and chalk ranges from Cretaceous to Quaternary age [10]. The lithology is characterized mainly by well jointed

limestone and dolomite with chalk and marl. The main aquifer systems in the study area are:

- Upper Cenomanian-Turonian Aquifer system, where the majority of Palestinian wells are tapped and it is composed of limestone, dolomite and marl with joints and karsts that give its aquifer properties.
- Lower Cenomanian Aquifer, which underlies the upper Cenomanian Aquifer. A small number of Palestinian wells are tapping this aquifer.
- Eocene Aquifer of the Tertiary chert, which consists of limestone and sandstone.

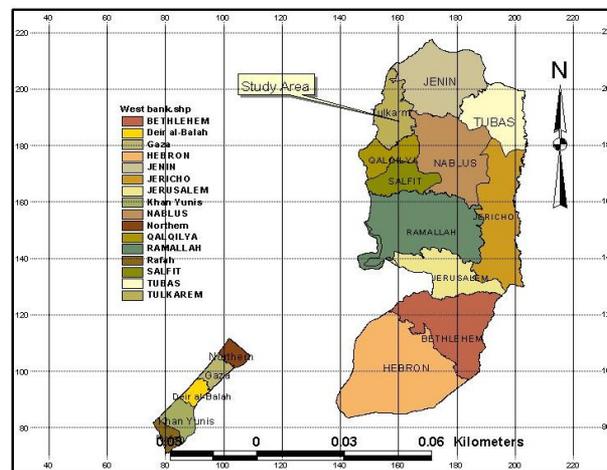


Figure 1: The location map of the study area

3 Materials and methods

The sampling campaigns were carried out in two successive years of 2003 and 2004; a total of 22 samples were collected from the groundwater wells in Tulkarem area. The water samples were collected in one-liter polyethylene bottles and refrigerated in the laboratory at 2°C. Onsite tests for pH and Temperature (T) were carried out for each site using Hanna field multimode meter. The samples were analyzed at the PWA labs in Ramallah for the major ions (in mg/L) of HCO_3^- , Cl^- , SO_4^{2-} , NO_3^- , Ca^{2+} , Mg^{2+} , Na^+ and K^+ . Perkin –Elmer Optima 3000

ICP-OEA was used to determine calcium, magnesium, sodium and potassium. HP 8453 Diode Array Spectrophotometer was used to determine nitrate and sulfate concentrations. Metrohm 716 titrator used to determine chloride and bicarbonate concentrations.

4 Results

4.1 Hydrochemical data and water type classification

The major ions (in mg/L) of HCO_3^- , Cl^- , SO_4^{2-} , NO_3^- , Ca^{2+} , Mg^{2+} , Na^+ and K^+ as well as for the Physical parameters of pH and Temperature are listed in Table 1.

Table 1: Water Quality for Selected Wells in Tulkarem area

Well ID	Spring - 2003									
	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	HCO_3^- (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH	T (°C)
15-19/041	122	16	49	1.3	241	101	28.39	92	7.36	23.5
15-19/021	139	22	69	2.32	246	139	31.6	215	7.6	--
15-19/035	90	11	39.4	2.6	278	71.7	25	72	7.29	--
15-19/036	84	10	51.4	5.7	282	45.6	21	72	7.32	24
15-19/031	77	36	51	2.4	280	97.8	19.5	29	7.32	--
15-19/030	71	24	21	1.4	185	71.7	17	43	7.46	24.5
15-19/017	103	35	49	22	311	137	27	80	7.25	23.5
15-19/018	80	28	55.7	23	291	124	35.4	53	7.17	23
15-19/028	66	26	15.39	1.71	198	45.6	18	23.6	7.52	24.5
15-19/046	85	26	48.6	8.1	298	97.8	35	57	7.4	23
15-19/019	135	56	277.5	5.4	318	454	170	21	7.25	--
Well ID	Spring - 2004									
	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	HCO_3^- (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	NO_3^- (mg/L)	pH	T (°C)
15-19/041	86	26	46	3.8	205	132	21	63	7.52	24
15-19/021	116	25	61	6.6	250	113	28	149	7.2	24.5
15-19/035	89	24	38	2.8	250	82	20	61	7.36	24
15-19/036	83	11	35	2	265	59	21	46	7.5	23.5
15-19/031	80	28	44	4.8	261	75	17	32	7.56	25
15-19/030	61	20	24	1.8	157	34	19	52	7.42	23
15-19/017	94	36	49	22	239	121	31	66	6.99	22.5
15-19/018	91	34	63	22	253	117	31	60	7.01	23
15-19/028	53	26	20	0.8	161	35	18	28	7.52	22
15-19/046	87	39	64	9	272	95	32	59	7.4	22.5
15-19/019	89	69	254	4.6	350	489	90	23	7.17	24.5

The Hydrowin software was used to perform the chemical analysis and the graphical representation of the hydrochemical parameters. The investigated wells are located within the two hydrological sub-basins in Tulkarem area; Iskandaron and Alkhadodera drainage sub basins. The groundwater water type in the area is of the earth alkaline water type with increased alkalis and with prevailing bicarbonate with less observable change between the years of 2003 and 2004 (Figure 2). Some of groundwater samples are located in the fields where HCO_3^- and Ca^{2+} are the dominant anions, in association with dolomite which is presumed if Mg is significant. The other samples are located in the field where no dominant cation or anion, indicates water exhibiting simple dissolution, which agrees with Piper diagram classifications.

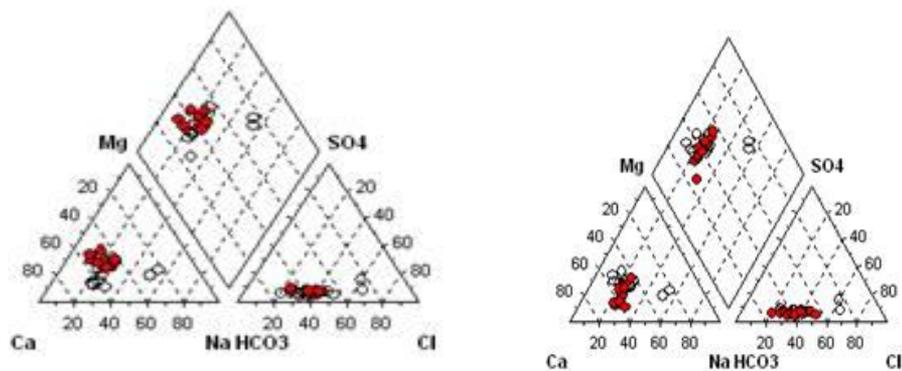


Figure 2: Piper diagrams for Alkhodera (left) and Iskandaron (right) wells

4.2 Water genesis & saturation indices

Saturation index is used to define the amounts of an assemblage of pure phases that can react reversibly with the aqueous phase. As groundwater moves underground it tends to develop a chemical equilibrium by chemical reactions with its environment. Average values of SI for Anhydrite (CaSO_4), Aragonite (CaCO_3), Calcite (CaCO_3), Dolomite ($\text{CaMg}(\text{CO}_3)_2$) and Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)

and Magnesite (Mg CO_3), were calculated using the Hydrowin software. The results indicate that no significant variance was observed between the year of 2003 and 2004. Also the results show that $\text{SI} < 0$ for Anhydrite, Gypsum and Magnesite. On the other hand the $\text{SI} > 0$ for calcite, dolomite and aragonite. The saturation indices indicate that the groundwater is over saturated with aragonite, calcite and dolomite which are three dominant mineral phases affecting the water composition through its transformation from rainwater to groundwater in the recharge area of the watershed. Referring to the water type classification, most of the samples have a water type of earth alkaline water with increased alkalis and with prevailing bicarbonate according to Piper plot. It is shown that dominant ions for the samples are ($\text{Ca} \ \& \ \text{HCO}_3$) for the years of 2003 and 2004 and they are originating from the recharging water in limestone aquifer which is interrelated to the aquifer type as well as its lithology.

4.3 Nitrate and chloride concentrations in Tulkarem

With reference to WHO standards for chloride concentration of 250mg/L and for nitrate concentration 45mg/L for drinking water and based on the analysis of the available water quality data [2] for 40 groundwater wells. The percentage of polluted wells by nitrate in this drainage basin is 55%, while the percentage of polluted well by nitrate is 4%. The concentrations of nitrate reach a high level up to 189 mg/L, with typical values in the range of 20-93 mg/L. The concentrations of chloride reach a level up to 489 mg/L, with typical values in the range of 34-139 mg/L; this range of concentrations is less than the WHO standards for drinking water quality of 250 mg/L. Five wells out of seven domestic wells in the area are polluted by nitrate, while the other polluted wells with nitrate are agricultural wells, with values exceeding WHO standards for drinking water.

It is shown that there is no pollution risk with respect to chloride in the area, while, it is clear that the high level of nitrate concentrations exceeds the WHO standards of 45 mg/L, in both agricultural and domestic wells (Figure 3). This can be

explained by many anthropogenic activities and agricultural practices that pose a great probability of nitrate pollution of groundwater in Tulkarm. These practices and activities include the lack or inadequate sewage disposal methods. Furthermore, the heavy cultivation of the agricultural land and the need to increase the production lead to excessive use of fertilizers, pesticides, herbicides, and soil fumigants, which have drastic effects on the water quality in the area.

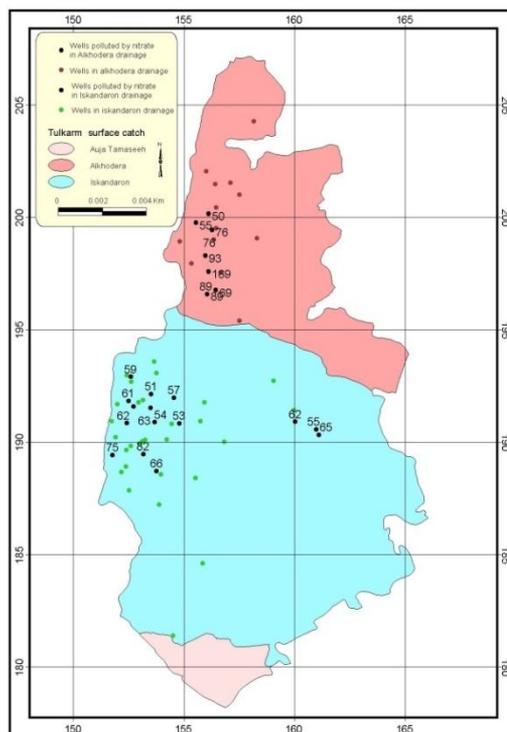


Figure 3: Nitrate Concentration for groundwater wells in Tulkarem area.

4.4 Trend Analysis

The ground water quality in Tulkarm area with respect to the nitrate and chloride concentrations is not static depending on many factors, like the pollution sources and the intensity of pollutant, the soil type and sensitivity of the aquifer. A graphical representation of the analyzed data and historical data of nitrate and chloride concentration was conducted for 20 groundwater wells in Tulkarm area.

The selected wells were polluted and unpolluted, the nitrate and chloride concentrations were plotted versus time per well. It was found that, there are two types of trends, steady state trend and significant increase trend. The steady state trend was defined for wells with small or no variation of nitrate and chloride concentrations with time series. The significant increase trend was defined for wells with increasing variations of concentrations with time. The main findings of that are (Total # of selected wells = 20):

% of wells with steady state increase trend of nitrate = $(5/20)*100\% = 25\%$

% of wells with significant increase trend of nitrate = $(15/20)*100\% = 75\%$

% of wells with steady state trend of chloride = $(6/20)*100\% = 30\%$

% of wells with significant increase trend of chloride = $(14/20)*100\% = 70\%$

From these results it is concluded that there is a significant increase in nitrate and chloride concentrations with time for the specified wells. This may be caused either by the accumulation of nitrates or chloride in the groundwater from continued land use practices or by changes in land use, such as changes to more intensive agricultural activities or increased rates of wastewater effluent application.

4.5 Spatial Analysis Relations Using Arcview

Using Arcview GIS software, Spatial related layers were created in order to investigate and interpret the spatial distribution of the polluted wells in Tulkarm area with respect to aquifer sensitivity, geological formation of the aquifer system, soil description and built up areas. The polluted wells within the Iskandaron drainage sub-basin are located in the moderate to highly sensitive areas (Figure 4). Most of them are located in the Senonian geological formation with a lithology of chalk and chert, undifferentiated with basal conglomerate in parts (Fig. 5), while the others are located in the Upper aquifer with Turanian geological formation having a typical lithology of limestone and dolomite karstic, marly limestone, karstic. The nature of karstic aquifer explains the easily movement of pollutants

to the groundwater system in both drainage basins, especially when subjected to human activities and uncontrolled use of lands with respect to wastewater discharge, leakage from cesspits and agricultural fertilizers. The polluted wells in both Alkhodera and Iskandaron drainage sub-basins are located in the regions covered by Alluvial soil which is characterized by fine textural or Aeolian sediments, where the usage of this soil type for productions currently limited to cultivate wheat (Figure 6). The Terra Rossa soil acts the main soil cover in the area which is fertile and the cultivation of field crops mainly wheat, barley, vineyards, olive and fruit trees, particularly on valley shoulders, are the dominant land use pattern on these soils. It could be concluded that these fertile soils are subjected to excess use of fertilizer acts as a non point source of pollution for the groundwater because of the agricultural runoff especially when the polluted groundwater are located in the downstream of the area. The polluted wells are located within built-up areas and villages boundaries and are subjected to human activities such as wastewater, cesspits and fertilizers, especially in the absence of regulations to control these actions which is harmful to the groundwater quality (Figure 7). In addition, the wells are located in the populated areas have higher values of nitrate, which reveals the possibility of wastewater intrusion from sewer system and cesspits.

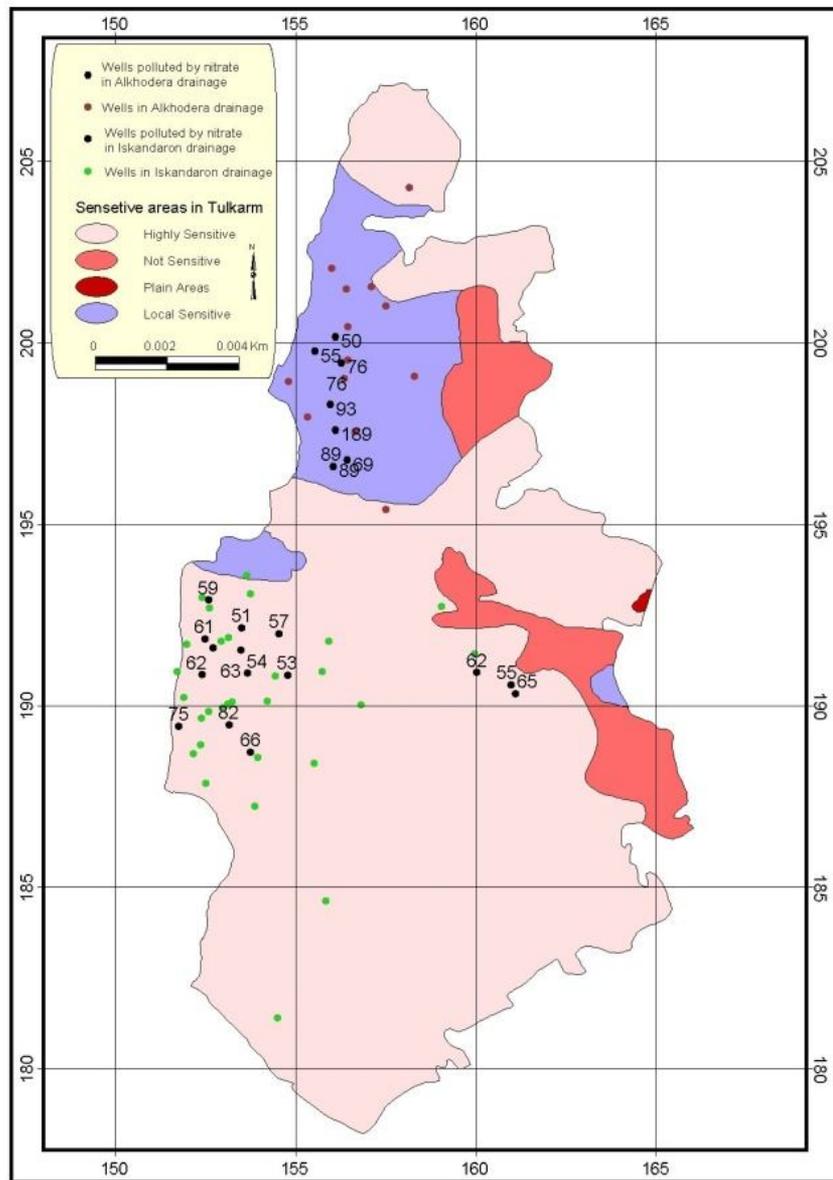


Figure 4: Polluted wells and Tulkarem sensitive areas

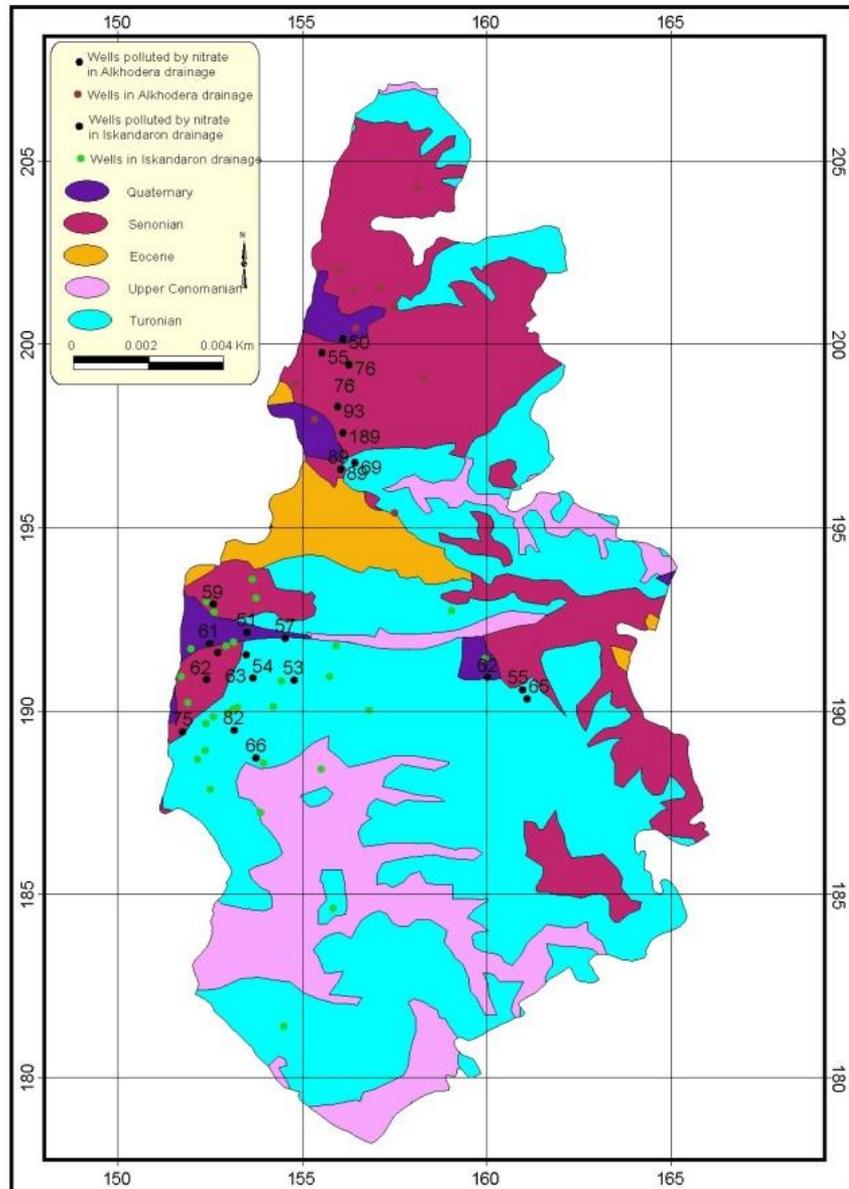


Figure 5: Polluted wells and Tulkarem geology

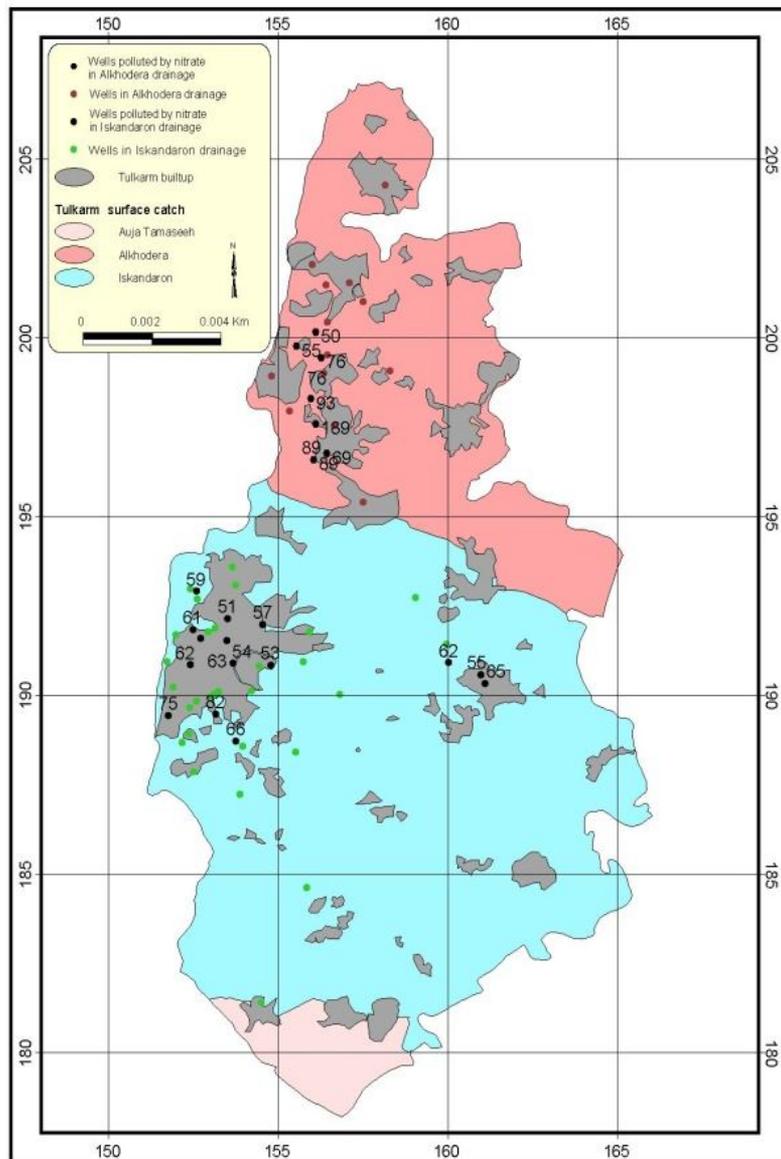


Figure 7: Polluted wells and builtup areas in Tulkarem

5 Conclusions

The hydrochemical study was conducted in Tulkarm Area and indicates that the water type for most of the wells is earth alkaline water with increased alkalis and with prevailing bicarbonate. Most of the samples are located in field where Ca^{2+} , HCO_3^- dominant anions, association with dolomite if Mg^{2+} is significant. These ions are originated from recharging water in limestone and dolomitic aquifer that is interrelated to aquifer type and its lithology. The saturation indices analysis revealed that water genesis is mainly originates from the recharge area of limestone and dolomitic limestone. The results showed that aragonite, calcite & dolomite are the three dominant mineral phases affecting the water composition through its transformation from rain water to groundwater. The hydrochemical analysis and graphical representation indicates that, the ions of Cl^- & NO_3^- are mainly coming from pollution causing activities such as intensive irrigation, sewage percolation & excessive land fertilization. Forty groundwater wells in Tulkarm area were investigated in terms of nitrate and chloride concentrations and represented spatially and interrelated to geological and anthropological factors. The results of pollution investigation for domestic and agricultural wells in Tulkarm area indicates that there are high levels percent of nitrate concentrations exceeds the WHO standards of 45mg/L for drinking water of 55%. There is no visible pollution risk with respect to chloride. The nitrate polluted wells are located within the irrigated complex cultivation and within the built up answered areas and village boundaries means that they are subjected to human activities which is harmful to groundwater quality.

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