ASSESSMENT OF GROUNDWATER QUALITY IN GAZA CITY (SOUTH OF PALESTINE) DURING THE PERIOD (1994-2004)

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ABSTRACT

Groundwater is the main source for public water supply in Gaza Strip. The surface water resources and other resources are very limited. In Eastern Mediterranean countries including Palestine, the demand on water is growing very rapidly due to the rapid population growth; urbanization and socio-economic development.

Gaza Strip located in the southwestern part of the Palestinian Coastal Plain in arid to semi arid area. The rainfall in the area ranges between 450 mm/y in the north to about 300 mm/y in Gaza City and 200 mm/y in the south. Gaza Strip characterized by densely population (1.3 millions inhabitants) lives in small area (365 square kilometers), with the highest population density rate in the world (3198 inhabitants per square kilometers). As a result to the population level; the increase of agriculture activities; the over pumping of the groundwater; the seawater intrusion and the limitation of the rainfall, quality and quantity of groundwater in Gaza Strip is deteriorated rapidly.

To detect the trend of changes in the chemical characteristics and the groundwater quality in the study area, some of 18 municipal wells samples were collected and analyzed during the last ten years (1994-2004). The samples were evaluated for domestic use by applying the WHO Standards. The comparison shows significant decreasing and fluctuation in water quality for the study area. This change in groundwater quality in Gaza City is attributed to the previous mentioned factors and to the fluctuation in the annual rainfall of the area.

INTRODUCTION

Gaza Strip is located in the southwestern part of the Palestinian Coastal Plain in arid to semi arid area. It is 45 Km Long and width ranges from 5 to 12 Km with total area of about 365 Km^2 (Figure 1).

Groundwater is the main source as water resources in Gaza Strip for supplying both agriculture, domestic and industrial purposes. The surface water is very limited or almost neglected and represented by some wadi. The main wadi is Ghazza Wadi which is almost dry as results to the Israel dams built on the upper stream and before the Gaza Strip political border.

In Gaza Strip there are more than 4000 water wells distributed in all the area. Most of the Gaza Strip wells (about 3760 wells) are agriculture wells and registered in Ministry of Agriculture (MOA) and Ministry of Palestinian Water Authority (PWA). Some of 39 of the total wells are piezometer wells drilled for aquifer exploration and depth monitoring. About 100 municipal well are existed and distributed all over the Gaza Strip (Figure 2) to serve about 1.3 million inhabitants in an area of one of the highest population densities in the world, (PCBS [1].

Monitoring wells in Gaza Strip is coordinated by the Palestinian Water Authority (PWA) and conducted by different ministries (Ministry of Agriculture, Ministry of Health and Ministry of planning) and local municipalities, but all the data on water monitoring are transferred to the PWA.

The average daily mean temperature ranges from 25^{o}C in summer to 13^{o}C in winter. The daily relative humidity fluctuates between 65% in the daytime and 85% at nigh in summer, and decreases to about 60% and 80% respectively in winter. The average annual rainfall varies from 450 mm/y in the north to 300 mm/y in central Gaza Strip and 200 mm/y in the south.

The present study is planned to detect and trace the trend of changes in municipal Gaza city wells in both the chemical characteristics and the quality of this water during the last ten years (1994-2004). Three assemblages of groundwater samples (1994, 1999 and 2004) for 18 municipal wells in Gaza city were collected and analyzed in the Public Health Laboratory, Ministry of Health. A comparison study done for the eighteen drinking water wells to evaluate and asses the water quality by applying the WHO standard [2] . Three chemical indicators (TDS, Nitrate and Chloride) have been chosen in the comparison for three years (1994, 1999, and 2004).

The year 1994 is the year for establishing the Palestinian National Authority to Palestinian land as a result of OSLO agreement. Therefore, from this year, the published numbers considered as a Palestinian numbers. The previous decades before 1994 have been studied and evaluated for irrigation and domestic purposes by some authors (El-Nakhal [3], Ashour [4], Abu Heen [5], El-Nakhal et al. [6] and PWA[7] and [8] The results of the evaluation show that the chemical characteristics and the water quality samples of the periods 1964 and 1994 is better than that of 1984, and the concentration of NO_3 increases rapidly through the time. The results also shows that only 25% of the water wells are suitable for domestic use in 1964, decreases to 5% in 1984 and 18% in 1994.

DESCRIPTION OF GAZA STRIP AQUIFER

The Costal Aquifer is belonging to Pleistocene age and consists primarily of Kurkar Group deposits that include calcareous sandstone, silt, clay, unconsolidated sands and conglomerates. From the coast eastward, the clays extend about 2-5 km inland, and the layer divided into sub aquifers A, B1, B2 and C (Figure 3). Clay pinch out eastwards and the aquifer believed to be unconfined system.

Saqiya Group is the top base of the coastal aquifer (aquitard) and consists of thick sequences of marls, claystones and shale which belong to the Post- Eocene age. The total saturated thickness of Kurkar Group ranges between 60 to 70 in southeast of Gaza Strip, decreases to about few meters in the northeast and about 100 m along the shore southwards increases to 180 m in Gaza City and in the north of Gaza Strip. The total rainfall recharge to the aquifer is estimated to be approximately 45 MCM/y (PWA, 2000). The lateral inflow to the aquifer is estimated between 10-15 MCM/y. Some of about 2 MCM are extraction from the surface water of the wadi to the aquifer. So the total freshwater recharge at present is about 60 MCM/y.

The Coastal Aquifer of Gaza Strip holds approximately 5000 MCM of groundwater of different quality. Only 30% of the aquifer is fresh water with chloride content of less than 500 mg/l and 70% of the aquifer (1400 MCM) are classified as brackish or saline water (Qahman and Larabi [9].

DRINKING WATER STATUS IN GAZA STRIP:

Groundwater is the main source of water in Gaza strip where about 95% of the residents receive drinking water services and supplied by municipal wells after disinfecting water with chlorine. The groundwater in Gaza Strip originated from the mountain of Hebron (West Bank), which constitute the catchment for the aquifer. During the infiltration and travel of water from the catchment area to Gaza aquifer, different physical and chemical processes affect its quality. In general, groundwater quality in the area is very poor for many reasons.

The three most common causes of unacceptable groundwater quality are anthropogenic pollution, saline intrusion and naturally occurring quality problems. A fourth and sadly cause of water quality problems is inadequate design, construction, operation and maintenance of wells themselves.

The anthropogenic pollution represented in impacts of urbanization and agriculture. They took place with the tremendous increase in population with highly intensive irrigated agriculture and various domestic and uncontrolled land use activities. The principal problems of uncontrolled and excessive use of chemical fertilizers and pesticides in agriculture are the leaching of nitrates and pesticides compounds, together with increasing salinity. The absence of proper sewer system (septic tanks and cesspools) and inappropriate design of wastewater treatment plants leads to the wastewater infiltration to the groundwater. The quantity of groundwater that can be sustainable pumped from aquifers has been exceeded the aquifer recharge and therefore, water shortages have developed. This over-pumping of the groundwater leads to continuous lowering of regional water levels and cause sea water intrusion and up coning of deep brine fossil water. Artificial pollution of groundwater may rise from either point source or non point source pollution. Water losses in the networks are very highly where it ranges from 35 to 50%.

Gaza municipality has one hundred drinking wells. Water quality in Gaza city deteriorated rapidly in the recent ten years according to (WHO) standards and 67% of the wells unfit for drinking (MOH, 2003). Ministry of health implementing water quality monitoring program for drinking water resources and networks, in the co-operation with municipalities and public health laboratory.

In this paper a comparison study has been done for eighteen drinking water wells used in Gaza city to evaluate and asses the water quality and the changes trends in three periods (1994, 1999 and 2004). Total dissolved solids (TDS), Nitrate and Chloride are the most famous three chemical indicators usually used to give indications for water quality. These indicators have been analyzed in the Public Health Laboratory, Ministry of Health, and comparison has been achieved for the selected three periods.

The analysis results of the three parameters indicate a positive correlation between the time and concentration in the most of the eighteen wells in the study area. Results of the study will be presented and discussed below.

Total Dissolved Solids

Total solids is the term applied to the material residue left in the vessel after evaporation of sample and its subsequent drying in an oven at a defined temperature. One part of the total solids is total dissolved solid which can be done by drying the water sample in drying oven at 105 C for at least one hour.
Total dissolved solids considered as indicators for the water salinity, the WHO standard is (1500) mg per liter.

Eighteen municipal well samples were collected and analyzed in 1994, 1999 and 2004. The raw data has been taken from the Palestinian Water Authority (PWA) and analyzed in the Public Health Laboratory, Ministry of Health. The results is quoted in Table (1) and graphically presented in Figure (4). Both Table (1) and Figure (4) show that in 1994 water samples about 33% of the water wells (6 wells) are above the WHO standard and unsuitable as a source for drinking water supplies. In 1999 the ratio increased to about 44% (8 wells) and rapidly increased to about 67% in the year 2004, which means two third of the municipal water wells in Gaza City are unsuitable as a source for drinking water. Total Dissolved Solids (T.D.S) increased rapidly by time.

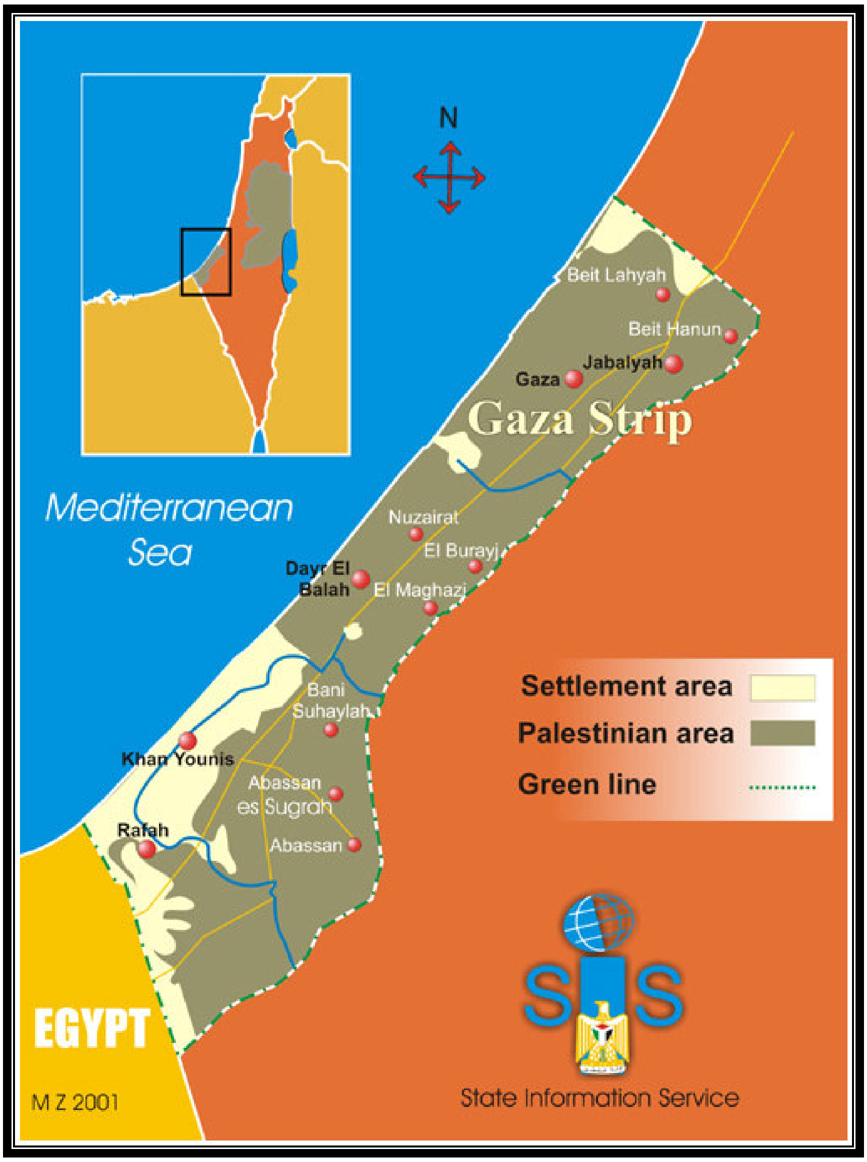

Figure (1): Location map for Gaza Strip

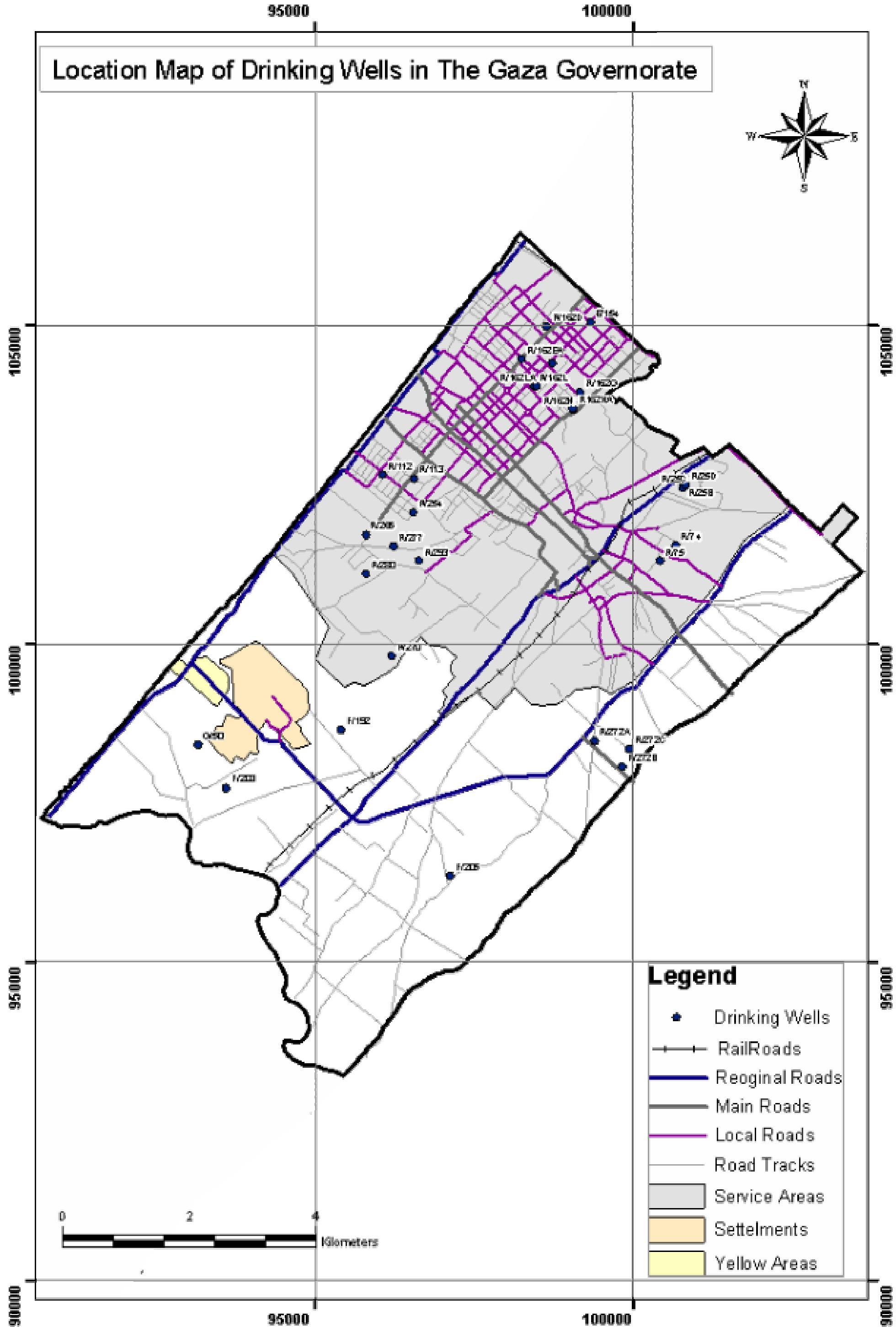

Figure (2): Location map of municipal drinking water wells in Gaza City

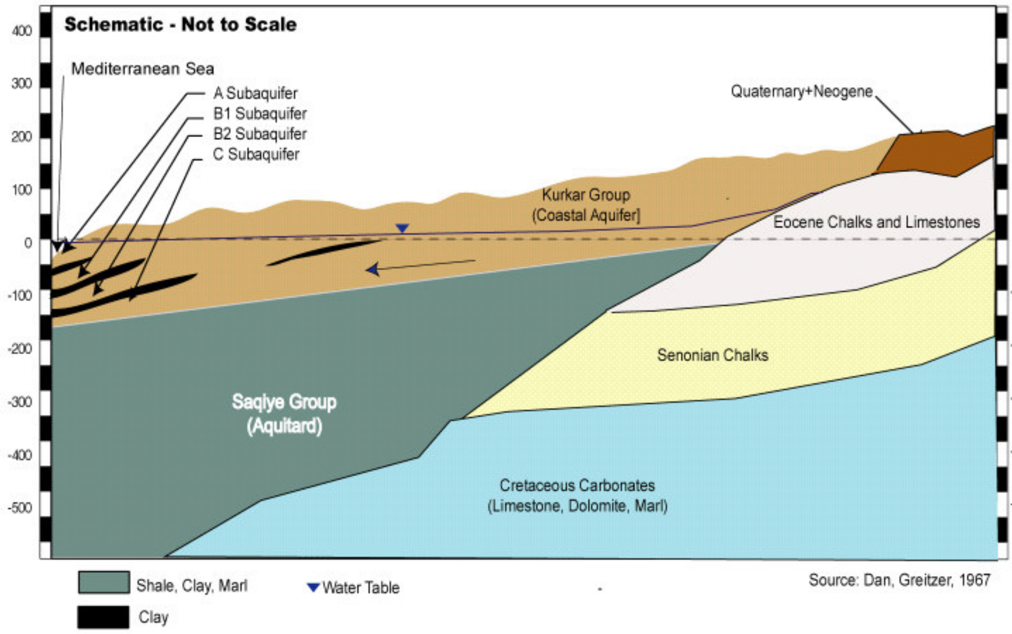

Figure (3): Hydrogeological cross section of the Gaza Strip aquifer

Table (1): TDS concentration (mg/l) for the study area

Well name	Well code	1994	1999	2004
Sheikh Radwan-1	R-162-L	1160	1200	2071
Sheikh Radwan-2	R-162-E	1105	1229	2337
Sheikh Radwan-3	R-162-B	1653	1830	2182
Sheikh Radwan-4	R-162-C	652	817	942
Sheikh Radwan-5	R-162-D	1450	1630	1864
Sheikh Radwan-7	R-162-H	1653	1706	1693
Sheikh Radwan-8	E-154	549	900	2468
Sheikh Radwan-9	E-157	612	783	787
Sheikh Radwan-10	D-68	546	583	673
Sheikh Radwan-11	D-69	481	510	627
Sheikh Radwan-12	D-70	560	673	307
Sheikh Radwan-13	R-162-G	1380	1330	1705
Safa-1	R-25-B	1966	1830	1866
Safa-2	R-25-A	1472	1569	1761
Safa-3	R-25-C	2653	2417	2820
Safa-4	R-25-D	1873	2000	2300
Sheikh Ejlein- 1	R-112	1586	1450	1492
Sheikh Ejlein-2	R-245	1500	1590	1851

Nitrate:

Nitrate ion (NO_3) is naturally occurring as a part of the nitrogen cycle. It is derived from the oxidation of ammonia. Such oxidation may occur in wastewater treatment plants, water distribution systems, and in natural waters. Nitrate ion is the stable form of combined nitrogen for oxygenated systems. Although chemically inactive, it can be reduced by microbial action. Nitrate is used in inorganic fertilizers. It also used as an oxidation agent and in the production of explosives and purified potassium nitrate. The nitrate is taken up by plants during their growth and used in the synthesis of organic nitrogenous compounds where surplus nitrate readily moves with groundwater. The uptake of nitrate by plants however is responsible for most of the nitrate reduction in surface water. The presence of high or low water tables, the amount of rainwater, the presence of other organic materials, and other physiochemical proprieties are also important in determining the rate of nitrate in soil, in surface water nitrification and gentrification may also occur depending on the pH and temperature.

WHO standard for Nitrate concentration is 50mg/l. In some countries, it is well documented that water supplies containing high levels of Nitrate have been responsible for case of infantile methemoglobinaemia and death. Abu Naser [10] found relationship between Nitrate contamination of the groundwater and metheomoglobin level among infant in Jabalia, Gaza and Khanyounis in Gaza Strip. It has been recommended that water supplies containing high levels of Nitrate (more than 100 mg/l) should not be used for the preparation of infant food. This problem does not arise in adults.

Determination of nitrate is very difficult because of the relatively complex procedures required, the high probability that interfering constituents, and limited concentration range of the various techniques. An ultraviolet spectrophotometric method (UV) technique that measures the absorbance in wave length 220nm is the most suitable one. The results are quoted in Table (2) and presented in Figure 5).

Statistical analysis of both Table (2) and Figure (5) show that about 67% of the water wells (12 wells) are above the WHO standard in 1994 and all the wells in 1999 and 2004 are above the standard and unsuitable (100% of the wells). Nitrate concentration is also increases rapidly with time.

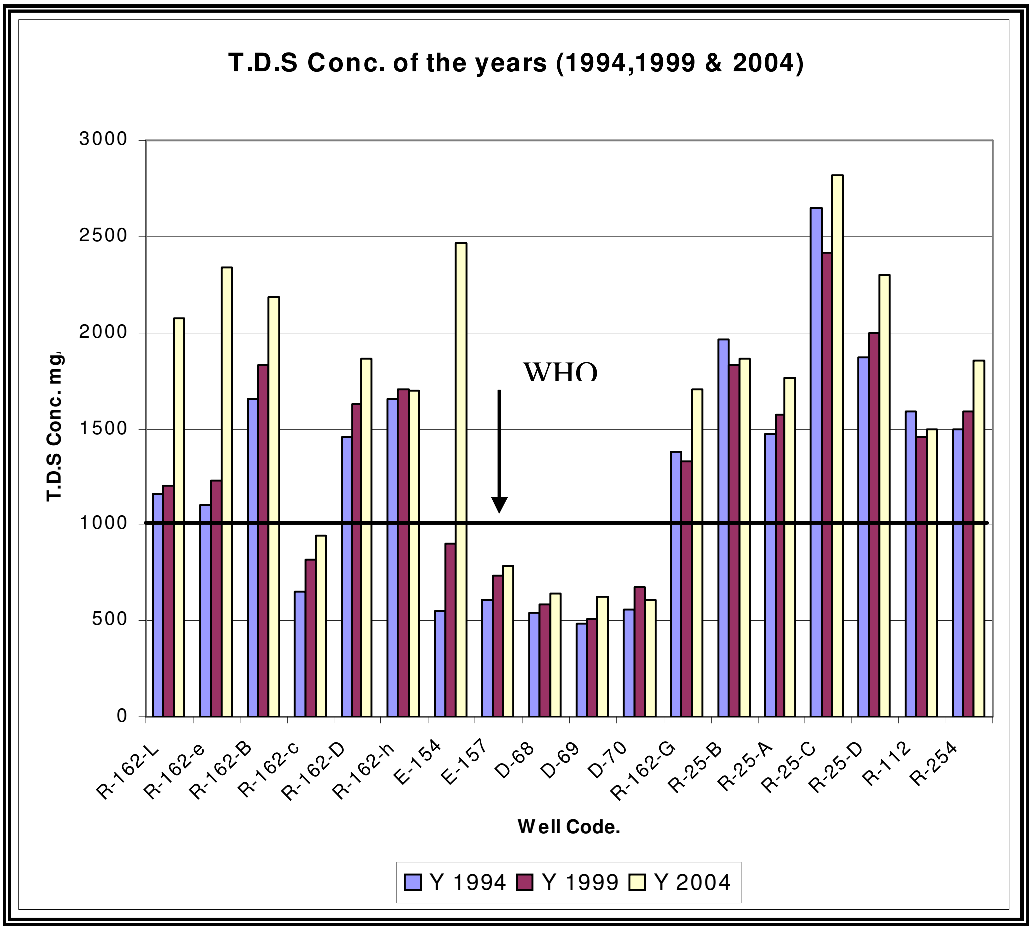

Figure (4): T.D.S concentration (mg/l) in the study area

Table (2): Nitrate Concentration (mg/l) in the study area.

Well name	Well code	1994	1999	2004
Sheikh Radwan-1	R-162-L	135	136	177
Sheikh Radwan-2	R-162-E	50	80	234
Sheikh Radwan-3	R-162-B	150	220	138
Sheikh Radwan-4	R-162-C	68	85	130
Sheikh Radwan-5	R-162-D	93	105	260
Sheikh Radwan-7	R-162-H	205	200	220
Sheikh Radwan-8	E-154	70	88	80
Sheikh Radwan-9	E-157	80	85	119
Sheikh Radwan-10	D-68	50	86	108
Sheikh Radwan-11	D-69	90	100	144
Sheikh Radwan-12	D-70	76	77	145
Sheikh Radwan-13	R-162-G	115	150	149
Safa-1	R-25-B	225	220	256
Safa-2	R-25-A	160	155	170
Safa-3	R-25-C	185	200	220
Safa-4	R-25-D	65	78	103
Sheikh Ejlein- 1	R-112	85	120	121
Sheikh Ejlein-2	R-245	65	65	63

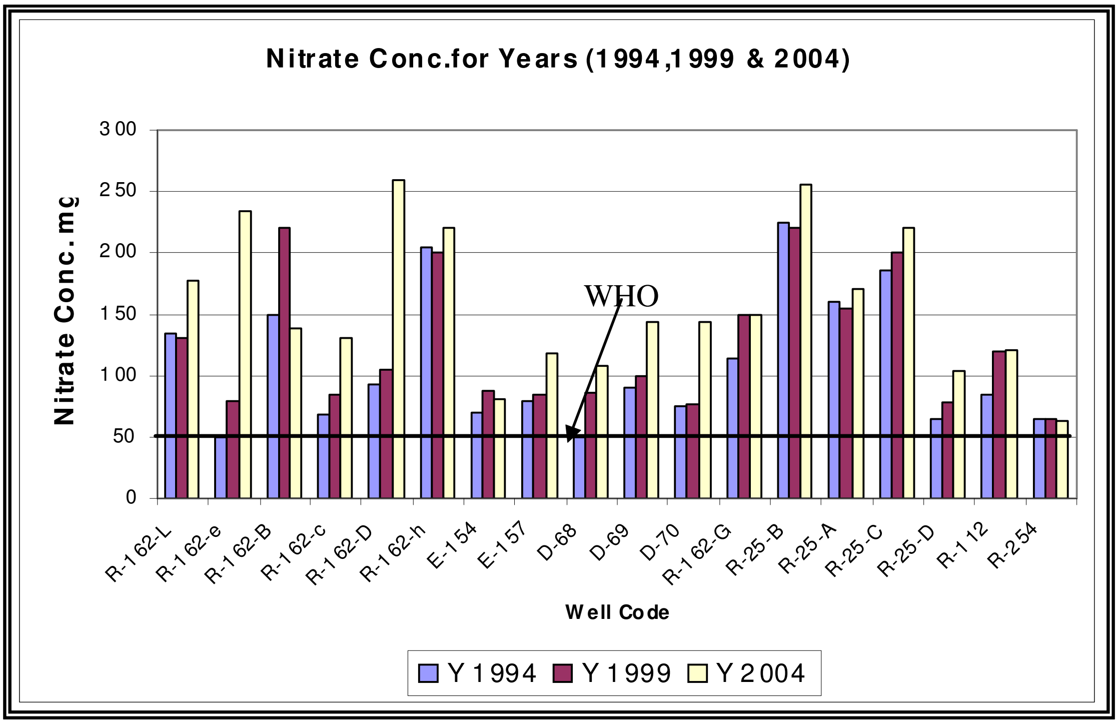

Figure (5): Nitrate Concentration (mg/l) in the study area

Chloride

Chloride is present in all natural waters at greatly varying concentration depending on the geochemical conditions. In general, the presence of Chloride in nature water can be attributed to dissolution of salt deposits, sewage discharge, oil-well operations, discharge of effluents of the chemical industries, irrigation drainage and seawater intrusion in coastal areas. The WHO standard of chloride concentration in drinking water is 250 mg/l.

Chloride ion is one of the major inorganic anions in water. In potable water the salty taste produced by chloride concentrations is depending on chemical composition of water. Some waters containing 250mg./l may have a detectable salty taste if the cation is sodium. On other hand the typical salty taste may absent in waters contain as much as 1000mg./l when the predominate cations are calcium and magnesium. Titration method with silver nitrate in the presence of potassium chromate as indicator was used to determine the chloride concentration in the present study. Results are presented in Table (3) and Figure (6).

It is shown from Table (3) and Figure (6) that 67% of the analyzed water wells (12 wells) are above the WHO standard in 1994 that increases to about 78% 1n 1999 (14 wells) and to about 83% in 2004 (15 wells). Chloride concentration for the study area is also increases by time.

Table (3): Chloride Concentration (mg/l) for the study area

Well name	Well code	1994	1999	2004
Sheikh Radwan-1	R-162-L	259	300	933
Sheikh Radwan-2	R-162-E	708	818	969
Sheikh Radwan-3	R-162-B	539	590	927
Sheikh Radwan-4	R-162-C	161	294	310
Sheikh Radwan-5	R-162-D	450	536	767
Sheikh Radwan-7	R-162-H	469	497	505
Sheikh Radwan-8	E-154	105	266	1302
Sheikh Radwan-9	E-157	105	161	184
Sheikh Radwan-10	D-68	91	119	142
Sheikh Radwan-11	D-69	72	70	136
Sheikh Radwan-12	D-70	74	88	112
Sheikh Radwan-13	R-162-G	399	435	594
Safa-1	R-25-B	497	490	556
Safa-2	R-25-A	399	490	508
Safa-3	R-25-C	812	929	1050
Safa-4	R-25-D	480	574	781
Sheikh Ejlein- 1	R-112	490	784	812
Sheikh Ejlein-2	R-245	315	342	395

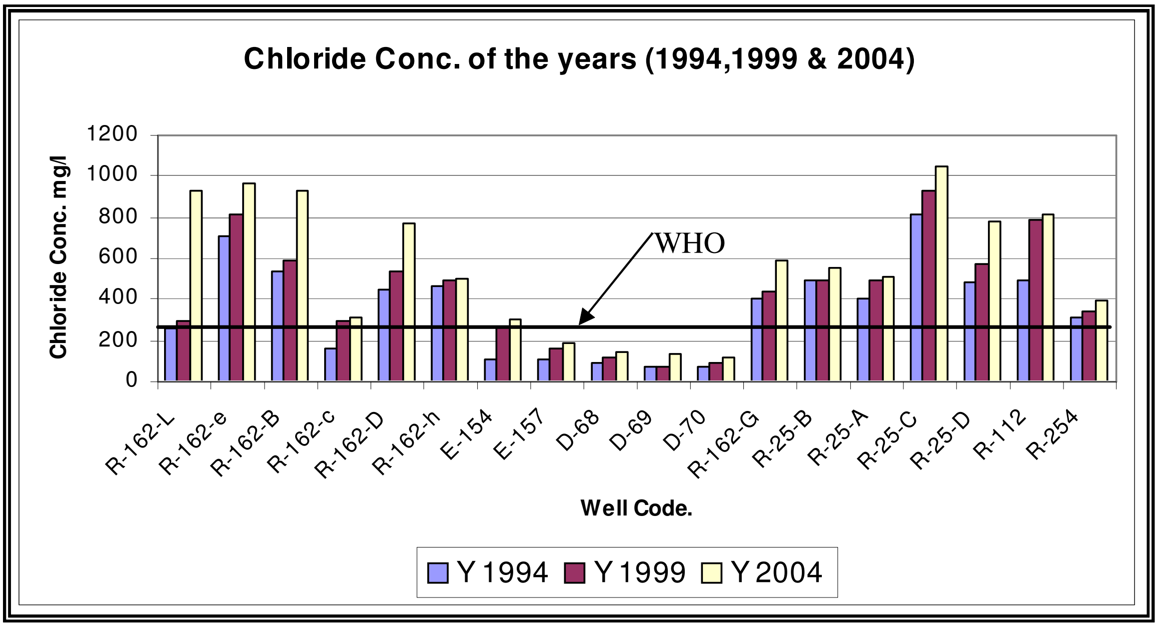

Figure (6): Chloride concentration (mg/l) in the study area

Table (4): Summary of evaluating the groundwater quality of Gaza city during the years 1994, 1999 and 2004

Water element	1994		1999		2004	
	suitable	unsuitable	suitable	unsuitable	suitable	unsuitable
T.D.S	67%	33%	56%	44%	33%	67%
Nitrate	33%	67%	0%	100%	0%	100%
Chloride	33%	67%	22%	78%	17%	83%

SUMMARY AND CONCLUSIONS

Eighteen municipal water wells representing the drinking water wells in Gaza city have been collected and chemically analyzes to the years 1994, 1999 and 2004. The chemical characteristics and the quality of the selected samples were evaluated to detect the trends of the changes in their prosperities according to WHO standard. Table (4) summarizes the results of evaluation and the following characteristics for the groundwater quality in Gaza city could be achieved:

1. Comparisons of the results of drinking water in Gaza city for the three years along more ten years (1994-2004) show rapidly deterioration for the water quality in the area.
2. Significant increase of the Total Dissolved Solids was achieved. The percentage of 33%, 44% and 67% for the years 1994, 1999 and 2004 respectively are calculated as unsuitable.
3. Nitrate concentration also showed serious deterioration. About 67% are unsuitable in 1994 that increased rapidly to 100% for the years 1996 and 2004.
4. Chloride concentration also deteriorated by time. About 67% of the study wells are unsuitable for drinking in 1994 that increased to about 78% and 83% for 1999 and 2004 respectively.
5. The change in the groundwater chemical characteristics and quality is attributed to many reasons. Uncontrolled and excessive use of chemical fertilizers and pesticides in agriculture, the absence of proper sewer system, the highest population density which lead to consume more water and over pumping and the change in the annual rainfall in the area are the most factors affected the groundwater characteristics in Gaza city.

RECOMMENDATIONS

According to rapidly deterioration's in the water quality for the main chemicals indicators, urgent action most be take place to stop the deterioration's in the water quality. It is recommended that:

- Remediation actions must be done for the drinking water distribution system and networks.
- Rehabilitation must be done for the drinking water resources and wastewater treatment plants

- Minimize the groundwater consumption in all uses.
- Carry out projects for artificial recharge using rain water
- Looking for deeper aquifer with better water quality.
- Minimize using fertilizers.
- Protect the aquifer in the coastal region from sea water intrusion.
- Apply developed methods in disposing solid wastes and liquids in such a way that they do not cause pollution of the groundwater aquifer.

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