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Water Quality in the Gaza Strip: The Present Scenario

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ABSTRACT

The Gaza Strip is one of the most densely populated areas in the world, 4505 people per km^2 and the only source of water is represent by groundwater. The water quality in Gaza is very poor and the groundwater is affected by many different contaminants sources including soil/water interaction in the unsaturated zone due to recharge and return flows, mobilization of deep brines, sea water intrusion or upcoming and disposal of domestic and industrial wastes into the aquifer. Previous reports on the water quality in Gaza discussed the high levels of major ions (especially of chloride, nitrate and fluoride) in the drinking water. Moreover, little or no information is available for trace elements in the groundwater of the Gaza Strip. The sources of trace elements in groundwater could be natural and anthropogenic. 58 wells were sampled during July 2010, and were analyzed major ions and trace elements to check if the water quality is improving from the previous report. This study has revealed that no groundwater in Gaza Strip meets all WHO drinking water standards. The contaminants which affected the Gaza Strip are of different types and they originate from different sources. The environmental conditions are no safe for the population and some actions to improve the groundwater conditions are necessary to safeguard the population.

Keywords: Gaza; Drinking Water; Trace Elements; Population Safety; Food Security

1. Introduction

A constant monitoring of groundwater in Gaza Strip is crucial: the groundwater is the only source of water in this area. Municipal groundwater wells are currently being used for drinking and domestic purposes while private wells are being used for irrigation and its should be sampled 2 - 4 times a year for the analysis of anions, cations, trace elements and pesticides [1]. The water quality in Gaza is affected by many different water sources including soil/water interaction in the unsaturated zone due to recharge and return flows, mobilization of deep brines, sea water intrusion or upcoming and disposal of domestic and industrial wastes into the aquifer [2]. Previous reports on the water quality in Gaza [1,4] discussed the high levels of major ions (especially of chloride, nitrate and fluoride) in the drinking water. Moreover, little or no information is available for trace elements in the groundwater of the Gaza Strip. The sources of trace elements in groundwater could be natural and anthropogenic. The distribution of trace elements in groundwater is continuously reset by complex geochemical processes (e.g., equilibrium and non-equilibrium water/solid interactions, advection, dispersion, absorption, precipitation, co-precipitation, chelation, colloidal interaction) and biological processes [3]).

This paper study the composition of the groundwater few years after the war events (2006-2008/2009) that affected years after the war events (2006-2008/2009) that affected the Gaza Strip. The results were compared to the last published studies regarding the drinkable of groundwater [1,4]. In 2002 Shomar [1] analyzed the waters of 71 municipal and 21 private wells used for drinking and domestic purposes. The results show that the 89% of water wells are not considered usable for drinking purposes, especially for the worrisome concentrations of chlorine, fluoride and nitrates that exceed the guidelines of the World Health Organization (WHO) [5]. As for trace elements results show high concentrations of zinc, lead, arsenic and cadmium.

Shomar [1] proposed interventions ranged from frequent monitoring wells and implementation of studies, on the correlation between the incidence of some diseases and pollutants, the development of a strategy for disposal of waste that would prevent contamination of groundwater.

The aim of this paper is to check the quality of stream

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water in the Gaza Strip after 2002 and identify the possible source of contaminants. Analysis of trace waters contribute to implement the knowledge of the geochemical and biological process involved the water resource of Gaza Strip, and also determine if any of trace elements threats human health in Gaza Strip.

2. Study Area

The Gaza Strip is one of the most densely populated areas in the world, 4505 people per km^2 [6]. For administrative purposes, the area has been divided into five regions: North, Gaza, Middle, Khan Younis and Rafah, **Figure 1**.

Approximately 85% of the population of the Gaza Strip drinks from municipal groundwater wells and 15%, mostly in agricultural areas, use private wells to supply their drinking water [4].

The study area is part of the coastal zone in a transitional area between a temperate Mediterranean climate to the east and north and an arid climate of the Negev and Sinai deserts to the east and south. As a result, the Gaza Strip has a characteristic semi-arid climate. The aquifer system in Gaza Strip is part of the larger Palestinian coastal plain hydrogeological system, which extends from Haifa City in the north to Sinai desert in the south and over an area of about 2000 km^2. The Palestinian coastal plain is characterized by flat relief, and is bounded to the east by the foothills of the West Bank mountain belt. This plain is narrow in the north and gets wider in the south. It has an average width of about 13 km. The main aquifer formation is composed of calcareous sandstone and gravel from the Pleistocene age and recent Holocene sand dunes. Some silts, clay, and conglomerate exist in the aquifer formation. Three main clay layers intercalate the aquifer and divide it into three main sub-aquifers in the west. These clay layers extend from the shore in the west to about 3 - 5 km inland. Thus, the aquifer is mainly unconfined in the eastern part and confined/unconfined in the western part. Aquifer thickness varies from a few meters in the east of Gaza Strip to about 170 m near the shoreline. The aquifer overlies thick impermeable marine clay of the Tertiary age called the Saqaya Formation [7].

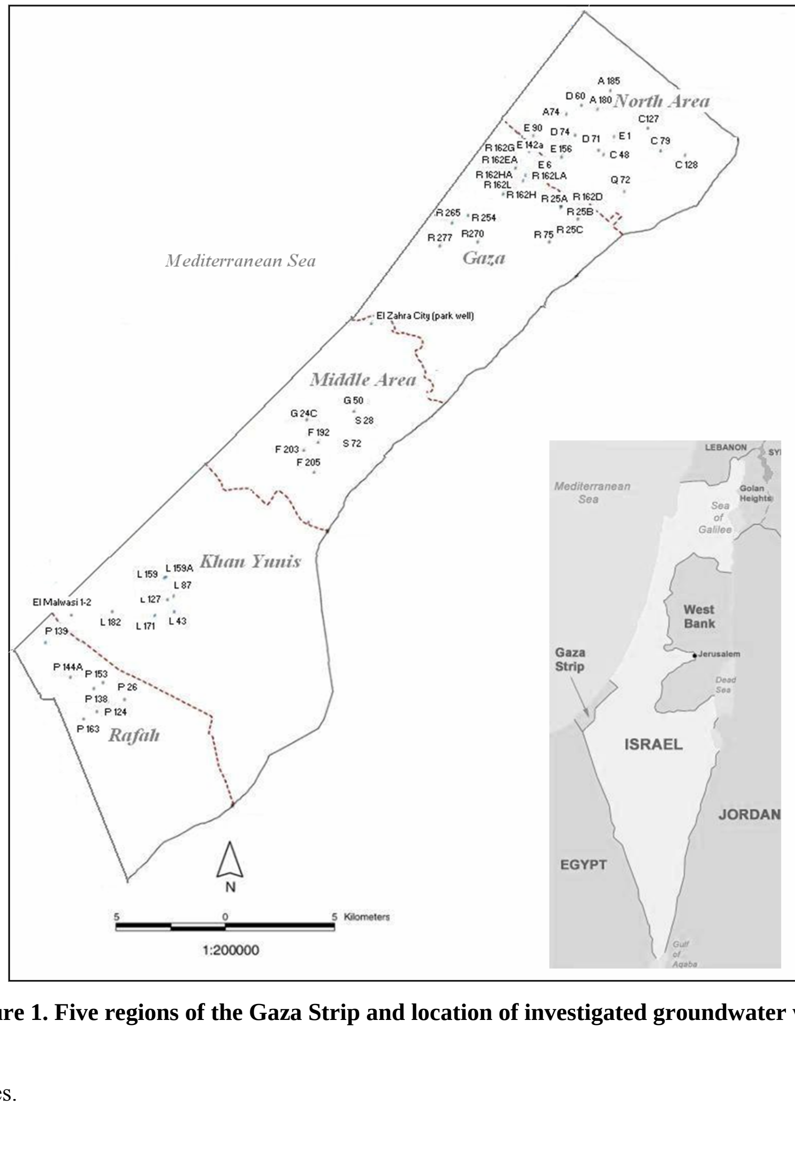

Figure 1. Five regions of the Gaza Strip and location of investigated groundwater wells.

Sampling and Analysis

58 Municipal wells were sampled by Gazzella ONLUS during July 2010 with the permission of the Ministry of Health Gaza-Palestine, **Table 1**.

Gazzella ONLUS is a nonprofit Organization. The principal aim of the Association is the aid, the care and the rehabilitation of the Palestinian children injured by weapons. Mostly the Association acts through the children sponsorship.

All samples were collected in laboratory certified clean bottles and labeled as to the well depth and location, date and time of sample collection, analyses to be performed, and field preservation performed, if any [8]. The measure of water temperature, electrical conductivity and pH value couldn't be possible to determine in the field. Only the electrical conductivity was measured in laboratory with a multi-parameter sensor (PCTSTest 35 EUTECH INSTR-UMENTS, reliability ±1%). Bicarbonate was determined by titration with 0.1 N HCl (reliability ±2%).

Water samples were filtered through cellulose filters (0.45 μm). Each sample was divided into two subsamples: the first had stored at 4˚C and been used to determine their major and minor constituents, with a Dionex DX-120 ion chromatograph (reliability ±2%). A Dionex CS-12 column was used for determining cations (Na, K, Mg, Ca), whereas a Dionex AS9-SC column was used for anions (F, Cl, NO_3, SO_4). The analytical accuracy of these methods ranged from 2% to 5%. The other was transferred to clean acid-washed polyetheylene bottles and acidified with concentrated nitric acid (Ultrapur, Merck, v/v) to pH < 2 and stored at 4˚C until analyses by inductively coupled plasma mass spectrometry, ICP-MS, reliability ±2%).

The analysis was carried out at the Geochemistry Laboratory of Sapienza University of Rome.

3. Results

In this session will only discuss the most environmentally significant data and those that exceed the WHO standards that pose risk for human or environmental health. The values of each well were averaged to provide the figures in this section. Our results were compared to the last published study about the groundwater of Gaza strip [1]. **Tables 2** and **3** summarized the measured variables, minimum and maximum value, standard deviations, average and median found in the wells of the five regions of Gaza Strip.

Table 1. Wells sampled during July 2010 in Gaza Strip. C48, G24C and P26 are agricultural wells; S28 is both agricultural and civilian. The other wells are civilian.

Region	No	Well number	Region	No	Well number	Region	No	Well number
North area	1	A185	Gaza	20	R162L	Middle area	39	S28
	2	A180		21	R162LA	Rafah	40	New well 2009 El Zoherat
	3	C79		22	R162D		41	P124
	4	C128		23	R162EA		42	P139
	5	C48		24	R277		43	P26
	6	C127		25	R254		44	P153
	7	E1		26	R265		45	P144A
	8	Q72		27	R270		46	P138
	9	E156		28	R75		47	P163
	10	D2		29	R25A		48	El Safa
	11	D60		30	R25B	Khan Yunis	49	L176
	12	E90		31	R25C		50	L182
	13	D71	Middle area	32	G24C		51	L127
	14	D74		33	G50		52	L43
Gaza	15	E142a		34	El Zahra City (Park Well)		53	L87
	16	E6		35	F203		54	L159
	17	R162H		36	F192		55	L159A
	18	R162HA		37	F205		56	El Mawasi1
	19	R162G		38	S72		58	El Mawasi2

Table 2. Results of quality: major ions (mg/L) and electrical conductivity (µS).

	North area (14 samples)					**Gaza** (17 samples)					**Middle area** (8 samples)					**Khan Yunis** (9 samples)					**Rafah** (9 samples)				
	Max	Min		Average	Median	Max	Min		Average	Median	Max	Min		Average	Median	Max	Min		Average	Median	Max	Min		Average	Median
E.C.	3400	927	675	1540	1334	20500	1002	4984	5135	3280	4600	1625	1165	3021	3215	4700	708	1482	2372	2300	4900	685	1397	2978	3200
TDS	3095	740	582	1560	1399	20573	1063	4713	4538	2855	4020	1570	920	2627	2703	4172	669	1189	2839	3302	4036	692	1369	2274	2269
Ca^{2+}	333	55	70	131	117	871	78	204	205	127	232	81	48	145	141	244	65	50	152	140	405	23	116	126	103
Mg^{2+}	233	50	48	109	95	829	80	204	225	149	163	72	34	123	128	277	42	69	162	174	276	20	87	121	141
Na^{+}	292	44	64	150	154	3625	91	902	894	512	929	211	275	519	495	921	66	290	487	498	915	108	297	405	352
K^{+}	19	3.6	4.8	8.4	7.7	56	0.5	15	14	7.3	14	0.4	4.4	5.0	3.6	17	3.6	4.0	7.6	6.0	30.4	2.64	9.7	11	7.3
Cl^{-}	1000	71	227	251	194	5405	114	1275	1182	662	1256	314	346	737	810	1353	136	386	676	705	1270	69	420	532	493
SO_4^{2-}	106	32	23	56	50	973	13	242	272	211	506	86	153	264	246	339	14	122	185	184	1245	18	398	307	123
HCO_3^{2-}	1098	366	228	729	690	12814	244	2905	1644	885	946	519	140	795	824	1281	244	330	919	946	915	287	268	654	824
Br^{-}	3.0	0	0.8	0.7	0.4	20	0.2	5.1	3.6	1.8	2.9	0.7	0.7	1.8	1.9	3.9	0	1.2	1.7	2.0	4.3	0.3	1.5	2.1	1.7
F^{-}	2.7	0.3	0.6	0.7	0.4	2.4	0.1	0.6	1.0	0.8	2.0	0.2	0.6	1.1	1.2	1.7	0.3	0.5	0.8	0.8	2.2	0.4	0.6	1.1	0.9
NO_2^{-}	30	0	9.3	4.8	0.2	110	0.1	30	47	48	46	1.7	18	19	11	184	0	73	56	14	122	0	40	16	1.5
NO_3^{-}	262	37	77	119	93	161	0	49	52	48	44	0	19	17	13	399	3	116	190	186	155	49	36	97	94

Table 3. Results of trace elements.

	North area (14 samples)					**Gaza** (17 samples)					**Middle area** (8 samples)					**Khan Yunis** (9 samples)					**Rafah** (9 samples)				
g/l	Max	Min		Average	Median	Max	Min		Average	Median	Max	Min		Average	Median	Max	Min		Average	Median	Max	Min		Average	Median
Li	6.8	3.3	1.1	4.8	4.9	18	4.3	3.8	12	13	18	6.2	4.0	8.6	9.1	15	3.2	4.5	8.6	9.1	16	5.1	3.9	11.4	11.6
B	502	0.0	152	133	80	2449	35	639	830	708	1273	273	349	490	331	1251	168	388	490	331	977	61	314	506	446
Ba	3801	124	1147	870	301	2133	121	583	466	226	565	123	132	226	208	416	124	95	226	208	1512	142	436	391	241
Al	921	345	165	439	380	561	285	71	400	385	414	319	34	351	339	398	315	29	351	339	563	336	74	397	389
Cr	15	3.7	3.6	9.5	10	34	5.1	8.4	21	21	28	10	6.5	31	31	50	2.7	15.9	30.7	30.9	46	11	10	29	32
Mn	35	1.5	9.0	4.7	1.9	14	1.3	3.1	2.9	1.9	7.9	0.9	2.3	7.3	2.7	41	1.4	12.9	7.3	2.7	6.8	1.2	2.1	2.9	2.1
Fe	121	92	8	107	106	499	92	106	154	117	342	87	94	154	143	252	116	42	154	143	476	104	123	191	144
Cu	13	1.9	3.2	4.4	3.1	17	1.6	3.6	4.9	4.0	19	0.9	6.0	4.0	3.2	13	0.7	3.7	4.0	3.2	6.9	1.1	2.0	2.5	1.7
Zn	1312	75	346	400	264	800	141	212	324	211	624	173	159	356	329	623	241	111	356	329	712	244	136	384	353
Sr	3207	1249	492	1611	1438	12500	1365	2981	3133	1965	4827	982	1261	2051	2167	4187	457	1184	2051	2167	5386	2225	1031	3438	3315
Hg	4.2	0.3	1.1	1.2	0.8	1.4	0.0	0.4	0.3	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pb	13	0.5	3.5	2.5	1.1	2.9	0.3	0.7	1.1	0.8	2.8	0	0.9	0.8	0.4	2.4	0.2	0.7	0.8	0.4	3.8	0.3	1.2	1.2	0.7
U	4.2	1.9	0.7	2.9	2.8	8.6	2.4	1.6	5.6	5.7	10.3	3.5	2.4	3.2	3.2	5.5	0.7	1.9	3.2	3.2	8.2	1.8	1.9	4.0	3.7

3.1. General Physical-Chemical Parameters

Figure 2 shows the values of TDS in five region of the Gaza strip for each wells monitored during 2010. The lowest average values of TDS were measured in the North area (1560 mg/L), while the highest average value of TDS were estimated in Gaza area, 4538 mg/L, **Table 1**. This is in agreement with the findings of Shomar [1] about the general trend of TDS, but the values we measured in 2010 appear to be higher than those measured by Shomar [1]. Except for a few wells distributed in Gaza strip, the majority of wells exceed the WHO standards for TDS (1000 mg/L). R162D, situated in Gaza city, is the well is one in which has the highest level, more than 20,000 mg/L.

3.2. Major Anions and Cations

Except for a few wells in North Area region, all wells sampled showed high to very high concentration of the major ions, **Table 2**. The Piper diagram, **Figure 3**, shows that the wells' groundwater fall into two different idro-geochemical facies: North area has Ca-HCO_3 waters typical of shallow fresh groundwater and the other region have sodium-chlorine waters indicating that the Gaza Strip aquifer suffer a mixing between fresh water and seawater.

The 60% of the wells sampled showed nitrate levels above the WHO standard of 50 mg/L, **Table 4** and **Figure 4**. The average concentrations of NO_3 are 189, 118, 97, 52 and 17 in the Khan Yunis, North area, Rafah,

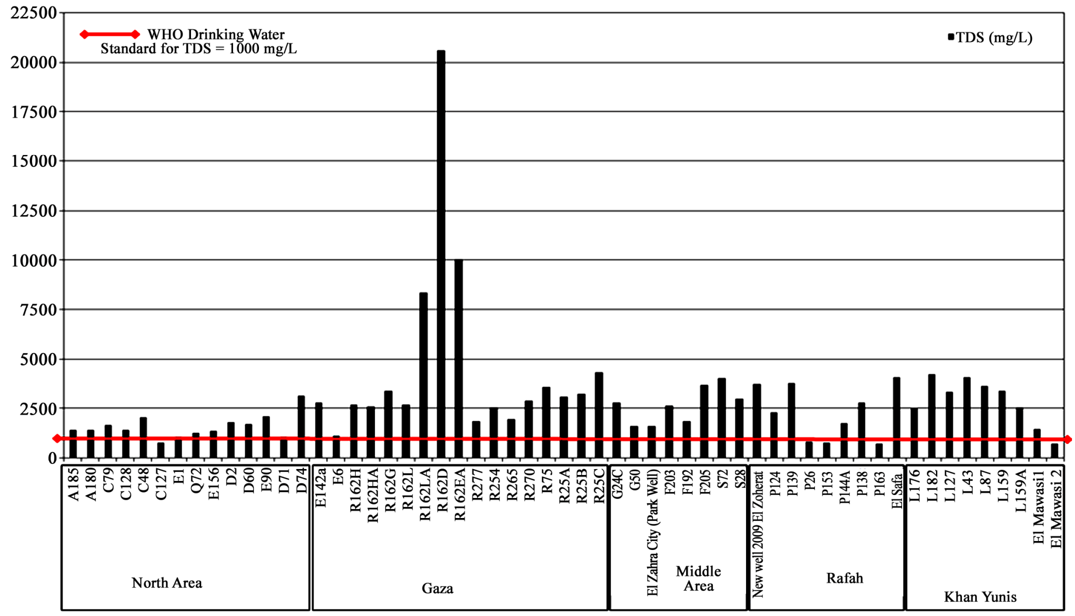

Figure 2. Variation of TDS concentrations in the groundwater wells of the Gaza Strip.

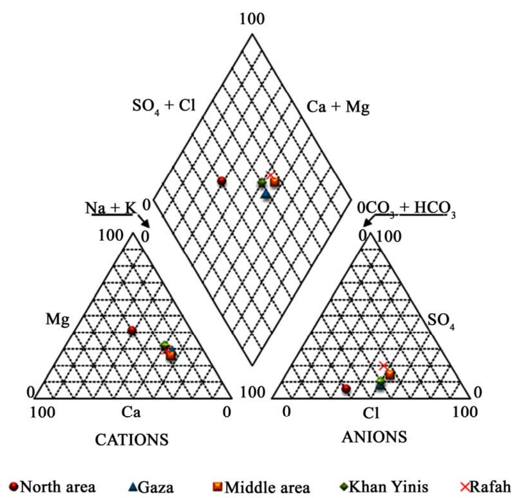

Figure 3. Piper plot showing the average composition of Gaza Strip groundwater.

Table 4. Percentage of wells which has major ions above WHO standards. Comparison between 2010 and 2002.

Parameter	WHO (mg/l)	Above WHO (%)	
		2010	2002[a]
TDS	1000	88	63
Na	200	67	53
Cl	250	71	54
SO_4	250	28	14
F	1.05	17	20
NO_2	3	59	n.a.
NO_3	50	60	90

[a]Shomar 2006 [1].

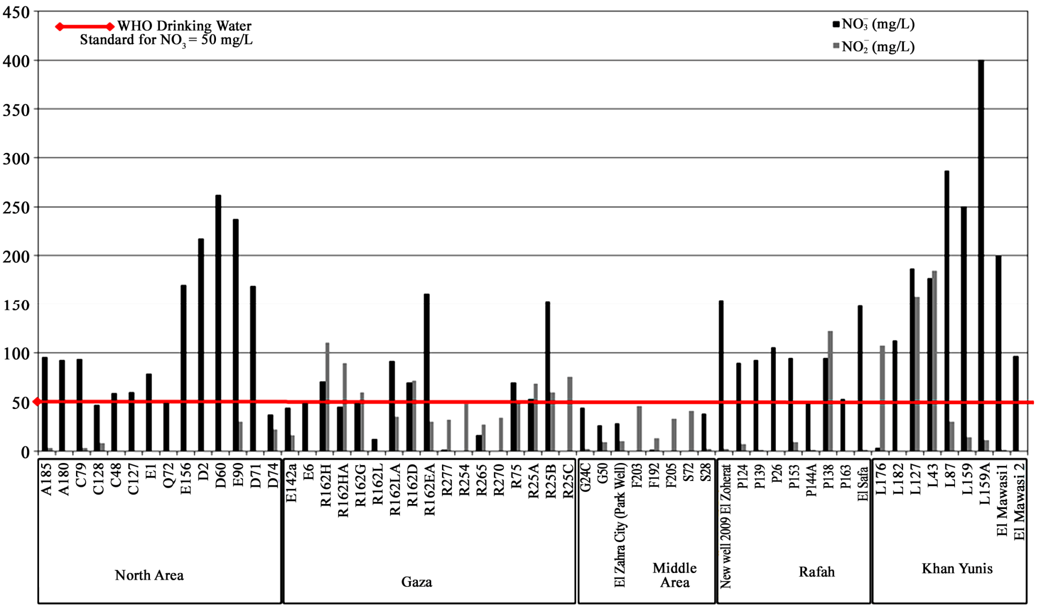

Figure 4. Variation of NO_3 and NO_2 concentrations in the groundwater wells of the Gaza Strip.

Gaza and the Middle area, respectively. Some of wells situated in Khan Yunis, Rafah and North area the concentrations of nitrate can exceed for 3 - 9 times the WHO standard. However the percentage of wells which exceed the WHO standards for nitrate decreased compared to 2002, **Table 4**. Nitrite average concentrations in the Gaza aquifer ranged from 4.8 until 56 mg/L. The results stress a concentration above the WHO standards in some wells of Gaza, Rafah and Khan Yunis. The lowest average values of chlorine were measured in North area (251 mg/L), while the highest average values were estimated in Gaza (1182 mg/L). The trend of this data is in agreement with the previous data. The maximum value of chlorine was measured in Gaza and it was 5405 mg/L; so, the minimum value of this one was estimated in Rafah and it was 69 mg/L. The 71% of the wells sampled showed chlorine levels above the WHO standard of 250 mg/L, **Table 4** and **Figure 5**. However the percentage of wells which exceed the WHO standards for chlorine increased compared to 2002, **Table 4**.

The average concentration of fluoride in the groundwater in the Gaza Strip is no higher than the WHO standard (1.5 mg/L). Only the 17% of the wells monitored showed fluoride concentration above the WHO standard of 1.5 mg/L. The percentage of wells which exceed the WHO standards for fluoride decreased compared to 2002, **Table 4** and **Figure 6** The most affected zones are Middle area (1.1 mg/L) and Rafah (1.1 mg/L). So, the maximum value of fluoride was measured in North area and it was 2.7 mg/L; the minimum value of this one was estimated in Gaza and it was 0.1 mg/L. The highest average values of SO_4 were in Rafah (307 mg/L), while the lowest average values were in North area (56 mg/L). So, the most of the wells in north area had SO_4 levels less than the WHO standard (250 mg/L). The 28% of the wells monitored showed sulfates concentration above the WHO standard. The percentage of wells which exceed the WHO standards for sulfates doubled compared to 2002, **Table 4**.

The lowest average values of Na were found in the north (150 mg/L) and the highest average values of this one were in the region of Gaza (894 mg/L). The 67% of the wells monitored showed sodium levels above the WHO standard of 200 mg/L, **Table 4** and **Figure 5**. So, the maximum value of sodium was measured in Gaza and it was 3625 mg/L; the minimum value of this one was estimated in North area and it was 44 mg/L.

Most of wells analyzed for K showed the average value more than 5 mg/l. The highest average value of K was measured in Gaza (14 mg/L), followed by the average value of K in Rafah. The minimum value of K was estimated in Middle area and it was 0.4 mg/L.

The Rafah wells showed the lowest average values of calcium (126 mg/L), while the region of Gaza well had the highest average value of Ca (205 mg/L). The North area wells showed the lowest average values of Mg (109 mg/L), while the region of Gaza well had the highest average value of Mg (225 mg/L).

3.3. Trace Elements

Table 3 shows the results of trace elements and summarized the measured variables, minimum and maximum value, standard deviations, average and median found in the wells of the five regions of Gaza Strip. **Table 5**, instead, shows the percentage of wells which have trace elements above WHO standards, during 2010.

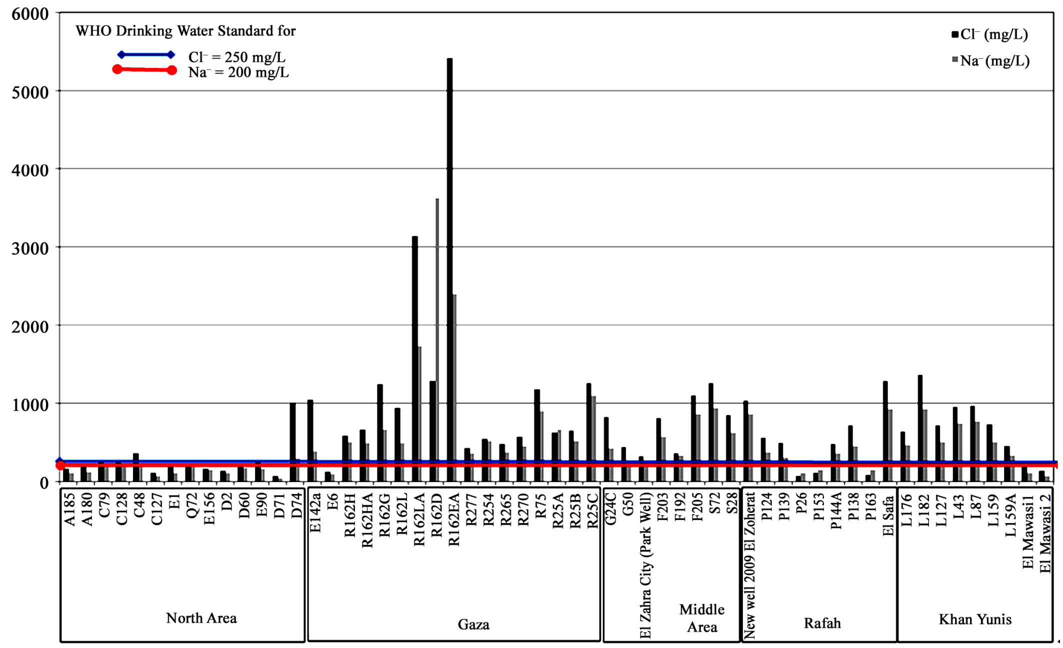

Figure 5. Variation of Cl^- and Na^- concentrations in the groundwater wells of the Gaza Strip.

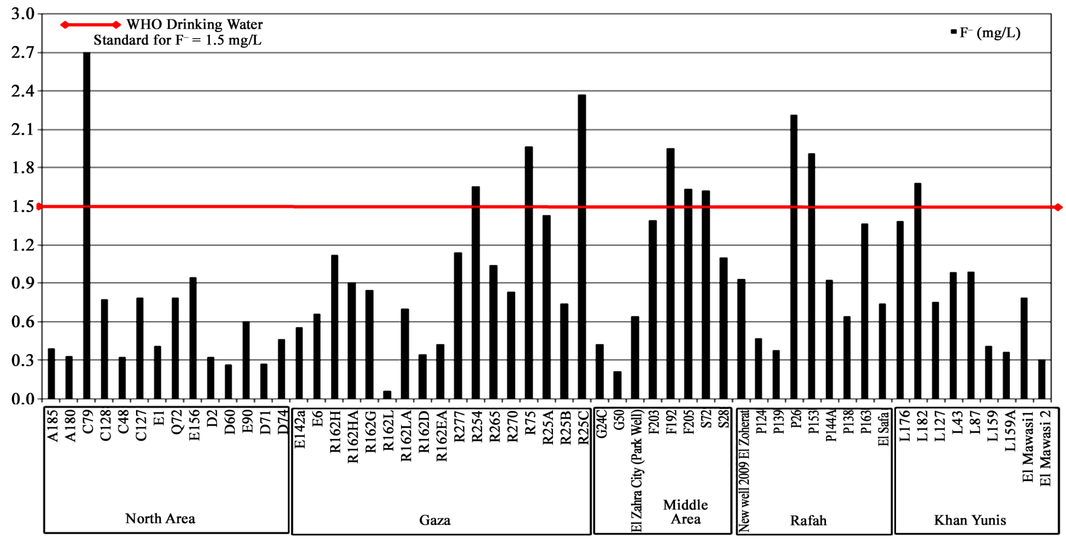

Figure 6. Variation of F-concentrations in the groundwater wells of the Gaza Strip.

Table 5. Percentage of wells which have trace elements above WHO standards, during 2010.

Parameter (µg/l)	WHO	Above WHO (%)[b]
Al	200	100
B	500	41.4
Cr	50	1.7
Fe	300	8.6
Hg	1	12.1
Pb	10	1.7

[b]WHO 2010 [6].

The most striking case concerns the concentration of aluminum in 2010 compared with that measured by Shomar in 2002. Our results show that 100% of the wells sampled have a higher concentration of aluminum to the WHO standard of 200 µg/L, **Table 5**. The lowest average values of Al were measured in Middle area and in Khan Yunis (both with 351 µg/L), while the highest average values were estimated in North area (439 µg/L) this one was estimated in the same area and it was 2.7 µg/L, **Table 3**. The maximum value of Al was measured in North area and it was 921 µg /L; the minimum value of this one was estimated in Gaza and it was 285 µg/L. It is clear that from 2002 to 2010 aluminum in groundwater of the

Strip has increased compared to 2002. Also the concentration of Hg measured by Shomar in 2002 shows very low values. In 2010, the 12.1% of the wells monitored showed mercury levels above the WHO standard of 1 µg/L, **Table 5**. Hg concentrations averaged 0.3 to 1.2 µg/L. The maximum value of Hg was measured in North area and it was 4.2 µg/L; the minimum value of this one was estimated in Gaza and it was 1.4 µg/L.

In Middle area, Khan Yunis and Rafah, Hg was not found in any of the sampled wells.

Generally, the Fe concentration were lower than the WHO standard (300 µg/L) and only the 8.6% of the wells monitored showed Fe levels above the WHO standard, **Table 5**. Fe concentrations averaged 107 to 191 µg/L. The maximum value of Fe was measured in Gaza and it was 499 µg/L; the minimum value of this one was estimated in Middle area and it was 87 µg/L, **Table 3**. So, the 1.7% of the wells monitored showed both Cr and Pb levels above the WHO standard of 50 and 10 µg/L, respectively, **Table 5**. The average concentration of Cr in the southern area of Gaza Strip (Khan Yunis and Rafah) was higher than those of the northern area and these data are in agreement with the previous data presented. However, the average concentration of chromium in 2010 decreased slightly compared to 2002. The maximum value of Cr was measured in Khan Yunis (50 µg/L); the minimum value of Pb concentrations averaged 0.8 to 2.5 µg/L then most of the wells had Pb less than WHO standard (10 µg/L). The maximum value of Pb was measured in North area and it was 13 µg/L; the minimum value of this one was estimated in Khan Yunis (0.2 µg/L), **Table 3**.

All wells had Ba less the WHO standard (700 µg/L) except in the North area where its average concentration corresponds to 870 µg/L.

The results about the other trace elements are not discussed in this session because they do not exceed the WHO standard and are not dangerous to human health.

4. Discussion

The Gaza Strip is one of the most densely populated in the world: 4505 inhabitants per km^2, with a growth rate of around 3% [9]. Over 90% of the population benefits of drinking water supplied from municipal water mains while the remaining 10% of the population lives in rural area and uses private wells. The exploitation of groundwater is expected to grow and it is therefore necessary to develop an appropriate management plan, primarily to prevent further deterioration of an already impaired water resource, but also in an attempt to improve the current state.

More than 50% of wells sampled showed Na levels higher than WHO standard (200 mg/L). Groundwater of most areas is hard and this could indicate the origin and geochemical characteristics of the groundwater system in Gaza. The aquifer is composed mainly of sand, sandstone and conglomerate strata of Pleistocene age [1]. Also the proximity of wells to the coastline makes the Gaza aquifer is impacted by contaminants from seawater intrusion. Sodium has the same trend of chlorine. The wells near the coastline in Gaza region (R162LA, R162D, R162EA) are affected by seawater, than they have high values of E.C. (respectively 9910, 20500, 13450 µS), TDS, **Figure 2**, Na and Cl, **Figure 3**, and Bromine (respectively 8.6, 20, 11 mg/L). One of the problems affecting the population of the Gaza Strip is dental fluorosis [10]. The sources of fluorides in the groundwater of Gaza Strip are believed to be natural bedrock that supplies the fluoride ions to the water. Maybe, there are other factors to be involved in the development of dental fluorosis. These factors revolve around the intake of fluoride from dietary sources such as the consumption of fish and tea [10]. This study shows that the 17% of wells are contaminated by high concentrations of fluoride, favoring the occurrence of health problems associated with fluoride.

According to this study the 60% of the wells analyzed exceeded the WHO standards as regard nitrate.

Nitrate in contaminated water is known to cause methemoglobinemia in infants [11]. The association of diarrhea and acidosis with methemoglobinemia is more common than previously thought and can produce dangerously high methemoglobin levels [12-15]. Shomar [16] proposed that the excess NO_3 in the groundwater of the Gaza Strip occurred as a results of NO_3 leaching from irrigation, wastewater septic tanks, sewage sludge, animal manure and synthetic fertilizers. Moreover the high values of nitrites in Gaza area, Khan Yunis and Rafah suggest that the source of nitrogenous compounds contamination is near the wells, so the nitrite didn't yet undergo the oxidation process.

The findings of this study show that the 100% of wells exceeded the WHO standards regarding aluminum concentrations. The results of the only published study about trace elements in the Gaza Strip [1] reported that all the wells monitored during 2002 had an aluminum concentration below the WHO standards. As well as Hg and Ba where found to be less than the WHO standard during the monitoring reported by Shomar in 2002. This study detects that 41.4% and 8.6% of the 58 wells sampled in 2010 has a concentrations of respectively B and Hg higher than the WHO standards. Besides many of the agricultural wells have openings large surface area (greater than 1 m), where petroleum products, fertilizers, or any other substance can easily contaminate the aquifer, through carelessness or accident. In general, the greatest threat to the aquifer from these wells appear to be petroleum products or pesticides, since both of these products tend to be stored in well construction or during the application of pesticides, farmers spray, eat and smoke, disregarding the general spraying instructions [1]. This study has revealed that the state of contamination of the Gaza Strip, despite the recommendations of Shomar, has not improved. Between trace elements there is also a high concentration of boron related to states of pollution due to civil and industrial discharges. Chlorine, fluoride, nitrite and nitrate are still above the limits set by WHO at times showing a decline compared to the analyses conducted in 2002 by Shomar. It is well known that the presence of metal particles is able to enter, in soluble form in the natural environment, as soil and water.

The toxicity of mercury (Hg) has been linked to serious reactions that occur in the central nervous system and during fetal development [17]. Aluminum (Al) accumulates in the brain, kidneys, lungs, thyroid, liver, bones and intestines is recognized as a potentially harmful metal fetotoxic. Aluminum (Al) has been the most intensively studied neurotoxic substance [18]. Lead can cause kidney damage and nervous system impairment. The population of the Gaza Strip who lives in precarious conditions, in direct contact with soil/water/air, is exposed at risk of coming into contact with poisonous substances through the skin, respiratory and through food (agricultural products). Drinking water is one of the major sources of human exposure to lead [19,20]. Lead particularly targets the nervous system, blood and kidney [19] distal motor neuropathy and possibly seizures and coma [21]. Infants and small children are more sensitive to the effects of lead, which moreover is transported through the placenta to the fetus [22].

Lead accumulation in fetuses and small children might cause developmental disruption in terms of neurological impairment characterized by a decrease of cognitive faculties, which can be reversible or not, evaluated by psychomotor tests such as the verbal IQ (Intellectual Quotient) test [23]. The period when IQ is most affected is from birth to/about 4 years of age [24] Health effects of metal contamination, even at low levels, are only beginning to understand and study their effects. For that it is needed to pay attention to the data presented in this study demonstrate that the risk from exposure to toxins and pollutants that can cause cancer and reproductive problems, but specially can have serious consequences on children.

5. Conclusions

This study has revealed that the state of contamination of the Gaza Strip, despite the recommendations of Shomar [1], has not improved. No groundwater in Gaza Strip meets all WHO drinking water standards. The contaminants which affected the Gaza Strip are of various kind and they originate from different sources.

The percentage of wells which present concentrations of chlorine and sodium above the WHO standards has increased from 2002 to 2010, **Table 4**, in Gaza Strip. The aquifer is contaminated and not recharging adequately. The coastal aquifer is the main source of drinking water and seawater intrusion in the coastal aquifer is still a problem for the population health.

Pesticides and fertilizers are one of the main sources of contaminations. Pesticides compositions and their excessive use contaminated the groundwater with nitrate, nitrite, chlorine and trace elements. Despite high level of Al in all wells analysed could be due to the large use of pesticides, several studies should be conducted to find other possible sources (of Al and the other trace metals) and minimize the health risk assessment.

Some actions should carry out on several fronts:

- Groundwater constant monitoring which integrated the analysis of biological, organics and inorganic contaminants;
- Wastewater and solid waste management;
- Setting up a management system for use of pesticides and fertilizers through safe storage and safe application training;
- Proper maintenance and cleaning of the areas surrounding the wells;
- Management of groundwater withdrawal in the areas vulnerable seawater intrusion.

Searching for an alternative resource of water is one of the primarily action which should be carry out.

Meanwhile private tube water filter or drinkable water point of distribution could be a short term solution.

To reduce the over exploitation of groundwater the rain water should be collected and used for agricultural purpose

It is necessary to keep in mind that the armed attacks cause environmental contamination [25].

We keep still little into consideration the fact that the attacks with no-conventional weapons have an impact on the environmental and consequently on the population with devastating consequences on the health and reproduction, even and especially in the long term.

Some of the initiatives are extremely important to safeguard the population:

a) Develop the knowledge to counteract the long-term effects of such attacks by deploying structures for risk of attacks on people's health and reproduction. Therefore operate for an inquiry on the risk of exposure to genotoxic materials of war.

b) Assumption of responsibility for the scientific community to continue to investigate the nature of the weapons used to understand how to treat the victims and the effects of environmental contamination.

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