Evaluation for the Groundwater Quality of the Domestic Water Wells in Gaza City

M. Abu Jabal and M. El-Baba

Water Research Center, Al Azhar University, Gaza

ABSTRACT

Domestic water supply in Gaza City is from more than 20 groundwater wells, controlled by Gaza municipality. The wells are of variable quality. Where total dissolve solids concentration varies from 365 to 2240 mg/L, chlorides from 56 to 945 mg/L, and nitrates from 10.08 to 200 mg/L.

The paper evaluates the chemical quality of the wells referring to WHO drinking water standard and piping corrosion characteristic indices. The result indicted that only six wells (27% of the wells) have water quality suitable for drinking. In the mean time according to driving force index, the water of all the wells are non-aggressive to pipes, and according to Langelier Index they considered as moderately aggressive to piping. While According to and Aggressive index water of one well has non aggressive tendency and others have moderately aggressive tendency.

Key words:

Gaza City, drinking water quality, corrosiveness indices

INTRODUCTION

Gaza City is the main and biggest city in the Gaza Strip covers an area of 63 km^2 with a total population of more than 340 thousands. It is one administration called Gaza Governorate. Since 1954 Water department in Gaza municipality is responsible for supply domestic water to the population. Groundwater is the only water source in the town. The City receives an annual average of 350 mm/yr (which is $21x10^6$ meter cube/yr), out of it 6.9×10^6 meter cube/yr recharge the groundwater, while the remainder is either lost to the Mediterranean through surface runoff or to the atmosphere via evaporation. Water supply in the city is from about 22 wells of varying quality owned by the municipality. Water consumption is about 22 mcm/yr through more than 33 thousands connections, and piping network of more than 75 km length.

Gaza Municipality through its Water Department responsible for domestic supply and through its Environmental Health Department responsible for the quality of the water supply from the time it is pumped from the well until it reaches the end user, the consumer. For the purpose, water samples are collected by the Environmental Department and analyzed at the laboratory of the Water Division /Ministry of Agriculture. Water is analyzed according to Standard Method for the Examination of Water and Wastewater.

Raw date for this paper collected from the Environmental Health Department and the Water Department at the Municipality.

1. GROUNDWATER QUALITY

The results of chemical quality for 22 ground water wells supplying Gaza City with domestic water supply are tabulated in Table (1). Table (2) shows the suitability of the quality for drinking according to WHO standard. The tables show that only six wells (27% of the wells) have water quality suitable for drinking.

From the table, the pH values of all the wells lies within the range of the WHO standards, (6.5-8.5). In the mean time only eight wells have electrical conductivity and total dissolved solids values below the permitted value of the WHO, (1.2 ms/cm and 500 mg/L respectively), while only two wells have values more than the maximum allowed value by the standard. The table also indicates that only eight well have chloride concentration values less than the permitted WHO value, (250 mg/L), and seven wells have sodium concentration values exceed the maximum limit of the WHO value, (200 mg/L).

Looking to the potassium concentration values, only twelve wells have concentration below 5 mg/L, (the maximum permitted value of the WHO), where none of them have value less than the permitted value (0.5 mg/L). The table also shows the nitrates concentration, where ten wells have values more than the WHO maximum allowed concentration (90 mg/L), and only four wells have values less than the minimum allowed WHO value (45 mg/L).

In examining the hardness of the water, it has been indicated that the water of all the wells considered to be as hard water, where thirteen considered as very hard water (have total hardness values of more than 300 mg/L as $CaCO_3$). According the permitted WHO value (hardness concentration between 200 and 500 mg/L as $CaCO_3$), only four wells more than the range, and the other wells are within the range.

Referring to calcium and magnesium concentration from the table, we notice that all the values within the maximum WHO permitted values for drinking purpose, (less than 200 mg/L as Ca^{2+} and less than 150 mg/L as Mg^{2+}). While seven wells have concentrations less than the minimum WHO permitted

values, (80 mg/L as Ca^{2+} and 50 mg/L as Mg^{2+}). By noticing sulfates and alkalinity values, the table indicates that all the wells values within the permitted values of the WHO standard, that is less than 250 mg/L as SO_4^{2-} minimum value and less than 450 mg/L as $CaCO_3$ maximum value for alkalinity. Where it has been found that only four wells have alkalinity less than the minimum permitted value of the standard, which is 200 mg/L as $CaCO_3$.

2. GROUNDWATER QUALITY AND CORROSIVENESS

Domestic water supply is considered stable when it is just saturated with calcium carbonate. In this condition the water will neither dissolve nor deposit calcium carbonate. Thus, in this water the calcium carbonate is in equilibrium with the hydrogen-ion concentration. If the pH of water is raised from the equilibrium point (pH_s), the water becomes scale forming and will deposit calcium carbonate. If the pH is lowered from the equilibrium pH point the water turns corrosive. This paper will discuss the various indices used to determine the corrosiveness of the groundwater wells supply Gaza City for domestic use.

The following table summarizes the corrosively characteristics associated with the Langelier, Aggressive and Driving Force Indices used in this study. In the mean time, Tables (4) and (5) show the values of corrosivity indices and the suitability of the water quality of Gaza city wells to corrosion of the piping system.

Table (1): Chemical quality for the domestic water wells in Gaza City

Well Location	Well Number	PH	EC Ms/cm	TDS mg/L	Cl^{+2} Mg/L	Na^{+} mg/L	K^{+} mg/L	NO_3^{-} Mg/L	Hard. mg/L	Ca^{+2} mg/L	Mg^{+2} mg/L	SO_4^{-2} mg/L	Alk. mg/L
Al-Shajia	R-75	7.1	3.380	2103	707	270	10.3	135	404	69	56	188	414
Al-Shajia	R-64	7.3	3.625	2240	798	288	11	60	207	40	26	162	444
Al-Shajia	R-SHJ	7.2	2.415	500	441	64	2.4	120	376	76	45	92	345
Al-Safa.	R-25-A	7.2	2.988	1852	437	238	9.1	120	338	66	42	130	368
Al-Safa	R-25-D	7.7	3.137	1945	546	250	9.5	70	288	53	38	135	412
Al-Safa	R-25-B	7	-	-	532	277	9.1	200	661	105	97	140	425
Shaekh Ejlain	R-254	7.3	1.818	1130	315	145	5.5	68	282	57	34	110	239
Shaekh Ejlain	R-SHE	7.5	0.552	365	56	47	1.8	27	188	39	22	2.5	138
Shaekh Ejlain	R-112	-	3.341	2228	946	-	-	22.4	-	-	-	-	-
Al Ashgal	R-ASH	7.48	0.766	511	70	69	2.5	10.08	266	63	26	37	228
Shaekh Redwan	R-162-I	7.2	1.662	1024	287	132	5	129	466	93	57	60	241
Shaekh Redwan	R-162-Ha	7.1	3.158	1900	546	244	9.3	200	526	98	69	163	280
Shaekh Redwan	R-162-Hb	7.4	2.702	1640	458	211	8	170	545	73	88	150	322
Shaekh Redwan	E-154	6.8	1.080	666	178	86	3.3	65	310	63	37	26	195
Shaekh Redwan	E-157	7.5	1.202	770	136	99	3.8	96	376	75	46	46	230
Shaekh Redwan	D-68	7.6	0.915	458	112	59	2.2	55	267	48	36	32	214
Shaekh Redwan	R-SHR1	7.5	0.820	410	78	53	2	92	295	64	33	32	196
Shaekh Redwan	R-SHR2	7.4	0.810	405	70	52	2	78	301	68	32	12.5	227
Shaekh Redwan	R-162-G	7.6	2.409	1495	441	192	7.3	122	507	100	63	132	276
Shaekh Redwan	R-SHR3	7.3	0.802	396	70	51	1.9	79	407	89	45	20	196
Al-Naser	R-NAS	7.2	1.416	882	273	113	4.3	116	442	90	53	10	172
Al Naser	R-162E	7.8	1.811	1207	298	155	4	28.18	489	131	39	80	232

Table (2): Suitability of water wells in Gaza City for drinking according to WHO standard

Well Location	Well Number	PH	EC	TDS	Cl^{+2}	Na^{+}	K^{+}	NO_3^{-}	TH	Ca^{+2}	Mg^{+2}	SO_4^{-2}	Alk
Al-Shajia	R-75	SS	N	N	N	N	N	N	S	SS	S	SS	S
Al-Shajia	R-64	SS	N	N	N	N	N	S	S	SS	SS	SS	S
Al-Shajia	R-SHJ	SS	S	SS	N	SS	SS	N	S	SS	SS	SS	S
Al-Safa.	R-25-A	SS	S	N	N	N	N	N	S	SS	SS	SS	S
Al-Safa	R-25-D	SS	S	N	N	N	N	S	S	SS	SS	SS	S
Al-Safa	R-25-B	SS	-	-	N	N	N	N	N	S	S	SS	S
Shaekh Ejlain	R-254	SS	S	S	N	SS	N	S	S	SS	SS	SS	S
Shaekh Ejlain	R-SHE	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Shaekh Ejlain	R-112	SS	S	N	N	-	-	SS	-	-	-	-	-
Al Ashgal	R-ASH	SS	SS	SS	SS	SS	SS	SS	S	SS	SS	SS	S
Shaekh Redwan	R-162-I	SS	S	S	N	SS	SS	N	S	S	S	SS	S
Shaekh Redwan	R-162-Ha	SS	S	N	N	N	N	N	N	S	S	SS	S
Shaekh Redwan	R-162-Hb	SS	S	N	N	N	N	N	N	SS	S	SS	S
Shaekh Redwan	E-154	SS	SS	S	SS	SS	SS	S	S	SS	SS	SS	S
Shaekh Redwan	E-157	SS	SS	S	SS	SS	SS	N	S	SS	SS	SS	S
Shaekh Redwan	D-68	SS	SS	SS	SS	SS	SS	S	S	SS	SS	SS	S
Shaekh Redwan	R-SHR1	SS	SS	SS	SS	SS	SS	N	S	SS	SS	SS	SS
Shaekh Redwan	R-SHR2	SS	SS	SS	SS	SS	SS	S	S	SS	SS	SS	S
Shaekh Redwan	R-162-G	SS	S	S	N	S	N	N	N	S	S	SS	S
Shaekh Redwan	R-SHR3	SS	SS	SS	SS	SS	SS	S	S	S	SS	SS	SS
Al-Naser	R-NAS	SS	S	S	N	SS	SS	N	S	S	S	SS	S
Al Naser	R-162E	SS	S	S	N	SS	SS	SS	S	S	SS	SS	S

SS = Suitable. S = Suitable, according to maximum allowable value N = Unsuitable

Table (3): Corrosively characteristics as addressed by indices

Corrosive Characteristic	Driving Force Index	Langelier Index	Aggressive Index
Highly Aggressive	< 0.01	< -2	< 10
Moderately Aggressive	0.01 to <1	-2 to < zero	10 to < 12
Nonaggressive	>1	> zero	> 12

2.1. Driving Force Index (D.F.I):

Driving Force Index (D.F.I) defined by Equation (1), calculated for the Ground Water wells, are shown in Table (4).

$$D.F.I = [Ca^{2+}][CO_3^{2-}] / (k'_{sp} \times 10^{10}) \quad \ldots\ldots(1)$$

where:

$[Ca^{2+}]$ = calcium hardness in mg/L as $CaCO_3$
$[CO_3^{2-}]$ = carbonate alkalinity in mg/L as $CaCO_3$, and
k'_{sp} = solubility product for calcium carbonate, it is constant for any given water and varies with temperature and a measure of mineralization (TDS, called ionic strength).

Table (4) indicates that for all the wells, the Driving Force Index is greater than one. Looking to Table (3) above and to Table (5), the water considered as noncorrosive water. Where it is supersaturated with respect to calcium carbonate, and will tends to form scale inside water pipes.

2.2. Langelier Index (L.I):

Langelier Index reflects the equilibrium water pH with respect to calcium and alkalinity. Langelier Index defined by Equation (2), calculated for the Ground Water wells, is shown in Table (4).

$$\text{Langelier Index (L.I)} = pH - pH_s \quad \ldots\ldots (2)$$

where,

pH = actual pH of the water, and
pH_s = pH at which water having the same alkalinity and calcium content is just saturated with calcium carbonate

In Equation (2) pH_s is defined as the pH value where water of a given calcium content and alkalinity is just saturated with calcium carbonate (at the equilibrium point). It has been indicated that water of low calcium content and alkalinity there is no pH value that satisfies this definition and that for most waters there will be two values for pH_s. These difficulties can be avoided by defining pH_s as that pH where a water of given calcium and bicarbonate concentrations are just saturated with calcium carbonate.

T.E. Larson's method for calculating pH_s is a satisfactory approximation when the value of pH_s is calculated using Equation (3).

$pH_s = A + B - \log (Ca^{2+}) - \log (Alky)$ ……………………………………………(3)

where:

The values for A and B are constants, functions of temperature and total dissolved solids.
(Ca^{2+}) = the calcium hardness as $CaCO_3$, and
(Alky) = the alkalinity as $CaCO_3$

The positive Langelier Index (pH greater than pH_s) indicates that the water is supersaturated with calcium carbonate ($CaCO_3$) and will tend to form scale in the pipes. Because of the various water quality indicators involved, the L.I. should only be used to determine the corrosive tendencies of water within a pH range of 6.5 to 9.5 provided that a sufficient amount of calcium ions and alkalinity over 40 mg/L are present in the water.

Referring to Table (5), after comparing the values of Langelier index from Table (4) with Table (3), it has been indicated that all the water of wells have moderately aggressive tendency (has L.I. values between –2 and less than zero).

2.3. Aggressive Index (A.I.):

Aggressive index defined by Equation (4), calculated for the Ground Water wells, are shown in Table (4).

$A.I. = pH + \log (Ca^{2+}) + \log (Alky)$ ……………………………………………(4)

where:

(Ca^{2+}) = the calcium hardness as $CaCO_3$, and
(Alky) = the alkalinity as $CaCO_3$

Water is supposed to be supersaturated if its aggressive index value exceeds 12. After comparing the values of Aggressive index calculated for the wells and tabulated in Table (4). It has been indicated that the water quality for one well have

nonaggressive tendency, while all the other wells have moderately aggressive tendency, (Table 5).

Table (4): Corrosivity indexes for domestic water wells in Gaza City

Well Location	Well Number	Driving force Index	Langelier Index	Aggressive Index
Al-Shajia	R-75	17.06	-0.44	11.64
Al-Shajia	R-64	8.13	-0.55	11.55
Al-Shajia	R-SHJ	27.78	-0.24	11.62
Safa	R-25-A	12.95	-0.46	11.59
Safa	R-25-D	11.50	-0.01	12.05
Shaekh Ejlain	R-254	9.73	-0.54	11.43
Shaekh Ejlain	R-SHE	6.49	-0.59	11.24
Al Ashgal	R-ASH	14.88	-0.23	11.64
Shaekh-Redwan	R-162-I	14.86	-0.45	11.50
Shaekh-Redwan	R-162-Ha	14.37	-0.51	11.54
Shaekh-Redwan	R-162-Hb	18.67	-0.12	11.91
Shaekh-Redwan	E-154	11.19	-1.02	10.88
Shaekh-Redwan	E-157	14.80	-0.19	11.73
Shaekh-Redwan	D-68	13.42	-0.16	11.69
Shaekh-Redwan	R-SHR1	13.84	-0.25	11.59
Shaekh-Redwan	R-SHR2	17.54	-0.24	11.59
Shaekh-Redwan	R-162-G	16.83	1.04	12.04
Shaekh-Redwan	R-SHR3	5.36	-0.87	10.97
Al-Naser	R-NAS	12.53	-0.55	11.39
Al Naser	R-162E	21.07	0.15	12.28

Table (5): Suitability of water wells in Gaza City for corrosivity.

Well Location	Well Number	Driving force Index	Langelier Index	Aggressive Index
Al-Shajia	R-75	N	M	M
Al-Shajia	R-64	N	M	M
Al-Shajia	R-SHJ	N	M	M
Safa	R-25-A	N	M	M
Safa	R-25-D	N	M	N
Shaekh Ejlain	R-254	N	M	M
Shaekh Ejlain	R-SHE	N	M	M
Al Ashgal	R-ASH	N	M	M
Shaekh-Redwan	R-162-I	N	M	M
Shaekh-Redwan	R-162-Ha	N	M	M
Shaekh-Redwan	R-162-Hb	N	M	M
Shaekh-Redwan	E-154	N	M	M
Shaekh-Redwan	E-157	N	M	M
Shaekh-Redwan	D-68	N	M	M
Shaekh-Redwan	R-SHR1	N	M	M
Shaekh-Redwan	R-SHR2	N	M	M
Shaekh-Redwan	R-162-G	N	M	M
Shaekh-Redwan	R-SHR3	N	M	M
Al-Naser	R-NAS	N	M	M
Al Naser	R-162E	N	M	M

H = Highly Aggressive. M = Moderately Aggressive
N = Nonaggressive

3. CONCLUSIONS

1. Gaza City has only one domestic water supply source that is the groundwater.
2. Gaza municipality is the owner of the well (about 22) and responsible for water supply through its Water Department and for the water quality through its Environmental Health Department.
3. The department analyzes the water quality at the water laboratory of the Water Division /Ministry of Agriculture.
4. After evaluating the quality the water quality with the drinking water standard of the WHO. Only six wells (27% of the wells) have water quality suitable for drinking. While the other wells have cations and anions concentrations of varying values.

5. Also, after calculating the corrosively indices for all the wells, it has been discovered that:

i) All the wells have non-aggressive tendency according to driving force index, (positive D.F.I values).

ii) All the wells have moderately aggressive tendency according to Langelier index, (values more tan –2 and less than zero).

iii) According to Aggressive index, only one well has non aggressive tendency, (value more than 12) while other wells have moderately aggressive tendency, (values between 10 and 12).

Acknowledgment:

The authors are very thankful for the Environmental Health Department and the Water Department at the Municipality of Gaza for their support by providing the date for this paper.

References

1) APHA (1995): Standard Method for the Examination of Water and Wastewater, 19th ed. American Public Health Association, Washington, D.C.

2) American Water Works Association, Water Quality and Treatment, McGraw Hill, New York, 1990.

3) CDM, Strategic Actions for Development of environmental Health Sector in the Gaza Strip. Report by Camp Dresser & McKee International Inc., for the United Nations Relief and Works Agency (UNRWA) Gaza, 1993.

4) Larson, T.E. and Buswell, A.M., Calcium Carbonate Saturation Index and Alkalinity Interpretations, Journal of American Water works Association, Vol. 34, page 1667, 1942.

5) U.S. Environmental Protection Agency, Federal Register. Interim Primary Drinking Water Regulations, Vol. 45, No. 168, August 27, 1980.

6) WHO, Guidelines for Drinking Water quality, Vol. 2 & 1, Recommendations, World Health Organization, Geneva.