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Trace, Heavy Metals and Microbial Contamination of Groundwater and Its Evaluation in the Northwestern Portion of Sinai Peninsula, Egypt

R. El-Sheikh[1], A.S. Amin[2,*], M. Gomaa[3], H. Ezzeldin[3], E. Zaghlool[3]

[1] Chemistry department, Faculty of science, Zagazig University, Zagazig, Egypt.
[2] Chemistry department, Faculty of science, Benha University, Benha, Egypt.
[3] Desert research center, Hydrogeochemistry Department, Cairo, Egypt.

Abstract

This study aims to investigate the diversity, and distribution of some harmful pollutants in groundwater in the northwestern portion of Sinai, Egypt. It should be recognized that, studying trace elements, heavy metals and microbes along with major constituents in groundwater is necessary for its evaluation for drinking and irrigation purposes. Eighty six water samples representing both surface and groundwater were collected in November (2012), for analysis of trace and heavy metals (Al, B, Cd, Co, Cr, Cu, Fe, Mo, Mn, Ni, Pb, Sr, V and Zn) using plasma optical emission mass spectrometer (ICP-OE-MS). Twenty water samples were selected for Microbial analysis (total microbial count, Coliforms, Pseudomonas, Alcaligenes, Escherichia, Citrobacter, Salmonella, Shigella, Klebsiella, Proteus and Enterobacter). The analyses were performed according to APHA, 1998. Heavy metals pollution index (HPI) revealed that 8.0 % of the groundwater samples are contaminated and all surface water samples lying below the critical pollution index value. The results show that El-Salam canal is the main source of aluminum and zinc metals in the groundwater, while the agriculture activities and sewage disposal may be considered as the main source of the other pollutants. All of the surface water samples and about 77 % of the groundwater samples are contaminated according to their total microbial count with appearing of Shigella in El-Salam canal samples. It is worth mentioning that, groundwater samples have been evaluated according to

CCMEWQI based on 19 parameter for drinking and 17 parameter for irrigation purposes.

Keyword: Groundwater; Heavy metals contamination; Microbial contamination; Water analysis

1. Introduction

Pollution of groundwater is an impairment of water quality by chemicals, heat or bacteria to a degree, that does not necessarily create and actual public health hazards, but does adversely affect such water for domestic, farm, municipal or industrial use [1].

To maintain the sustainability of the renaissance agricultural development in the Northwestern portion of Sinai peninsula and increasing of population especially after El-Salam canal irrigation project which aims to carry the irrigation water to Sinai Peninsula by mixing River-Nile fresh water (Damietta branch) with the drainage water from Bahr-Hadous and El-Serw with a ratio of about 1:1 nearly [2], we must follow-up to the groundwater pollution indicators especially after increasing the sources of pollution (El-Salam canal water, agricultural fertilizers, fish farms remnants …….etc.).

In the absence of infrastructure (healthy drinking water and sewage) which makes people's in this area using shallow groundwater in the area so it must be study the sources of pollution especially trace, heavy metals and microbial pollutants which are detrimental to human health which that is the ultimate objective of this study.

Water samples were collected from (86) water point during of November (2012), (76) samples from groundwater wells and (10) samples from surface water point (Suez canal, Mediterranean sea, El-Bardawil lagoon, drainages and El-Salam canal tributaries).

2. Materials and Methods

2.1. Description of study area

a. location

The studied area lies in northwestern portion of Sinai peninsula between latitudes 30° 40′ to 31° 05′ N longitudes 32° 20′ to 33° 00′ E bordered from the north by the Mediterranean Sea, from the south by Ismailia, from the west by the Suez Canal and from the east by Bir-ElAbd with an approximate area of (2500 km^2) (Fig. 1).

The northern Sinai coast is located within the rainy belt of Egypt; while the aridity increases generally to the south [3]. The averages of the climate variables for the period (2010–2012) from Baloza meteoric station DRC shown temperature range from 15.4 °C in January to 28.96 °C in august with annual average 22.05 °C, humidity ranges from 69.6 % to 75.83 % with annual average 72.5 % and where is annual sum rainfall is 55.69 mm.

b. Geological and hydrogeological setting

Geologically, the study area is covered by Quaternary deposits of variable thickness [4]. It shows different geologic units of different ages (Holocene facies, Pleistocene deposits and Pliocene deposits**)** [5]. The Quaternary deposits (sand, gravel and calcareous sandstone) are considered the important water-bearing formations in the northwestern portion of Sinai [6].

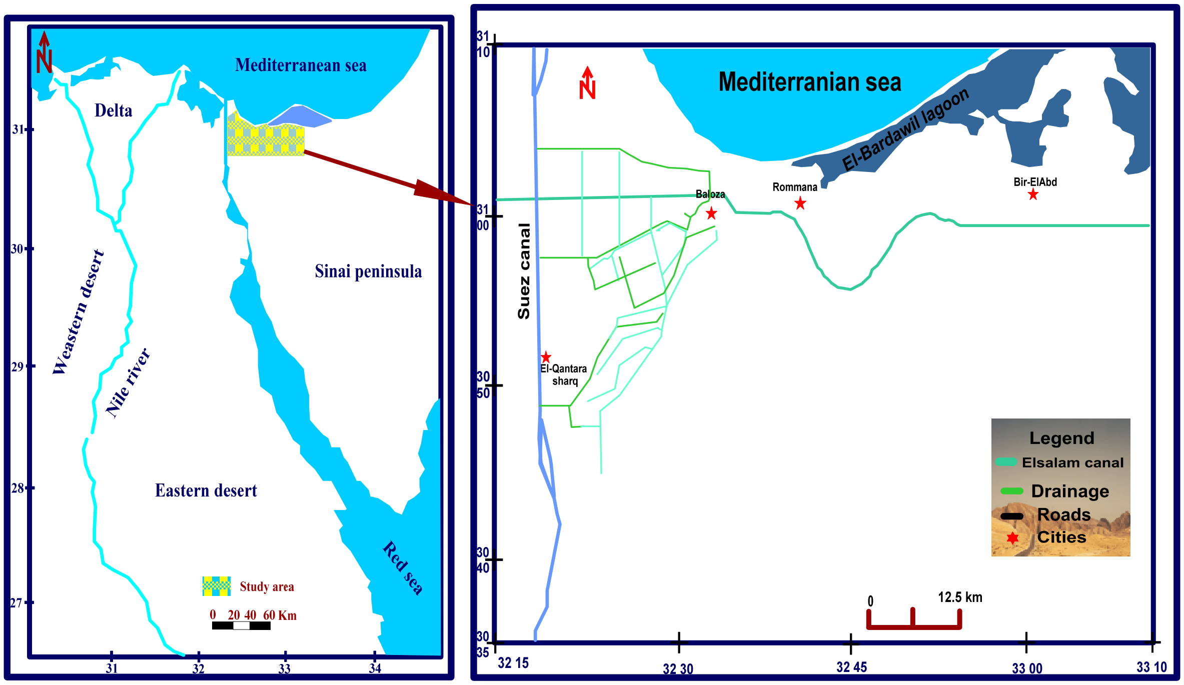

Fig (1): Location map of the study area

Two main Quaternary aquifers are recognized in the northwestern portion of Sinai; shallow aquifer (sand dune aquifer) with a thickness ranging from 1.4 m in the northwest, reaching about 60m in the extreme southeast and deep aquifer with a thickness ranging from 11.6 to about 165 m with an average depth of about 91 m. Both shallow and deep aquifers are separated with a thick clayey unit that grades from clay to silty clay to sand clay [7]. The depth to water ranges between 1.05 m at north of the study area and 31 m at south east principally controlled by the surface topography, lithology and recharge, groundwater is generally flowing from the southeast to the northwest [8].

2.2. Sampling

a. Trace and heavy metals

Clean dray plastic bottles of 50 ml size were used to collect eighty six water samples (76 groundwater samples and 10 surface water samples) (Fig. 2), these samples were acidified with few drops of nitric acid for trace and heavy metal analysis. The analysis include determination of (Al, B, Cd, Co, Cr, Cu, Fe, Mo, Mn, Ni, Pb, Sr, V & Zn) using plasma optical emission mass spectrometer (ICP-OE-MS) (POEMSIII) thermo Jarrell elemental company USA, using 1000 ppm (Merck) Stock solution for standard preparation in the Hydrogeochemistry laboratory –Desert Research Center.

b. Microbial investigation

Twenty water samples were selected for microbial analysis (13 groundwater samples and 7 surface water samples), the analysis were performed in the Microbiology and soil fertility Department at the Desert Research Center. Examination was performed within 24 hours after the collection using standard Multiple Tube Fermentation Technique (MTFT), nine multiple tube dilution technique using double and single strength Bromo-Cresol Purple MacConkey medium for detection of E.coli (Thermotolerant coliform, TTC) with production of yellow colour colonies on membrane filter at 44.5 °C. To distinguish between different species of enteric bacteria, sub culturing colonies on Triple Sugar Iron (TSI) were done for contaminated water samples. The analyses were carried out according to A.P.H.A, [9].

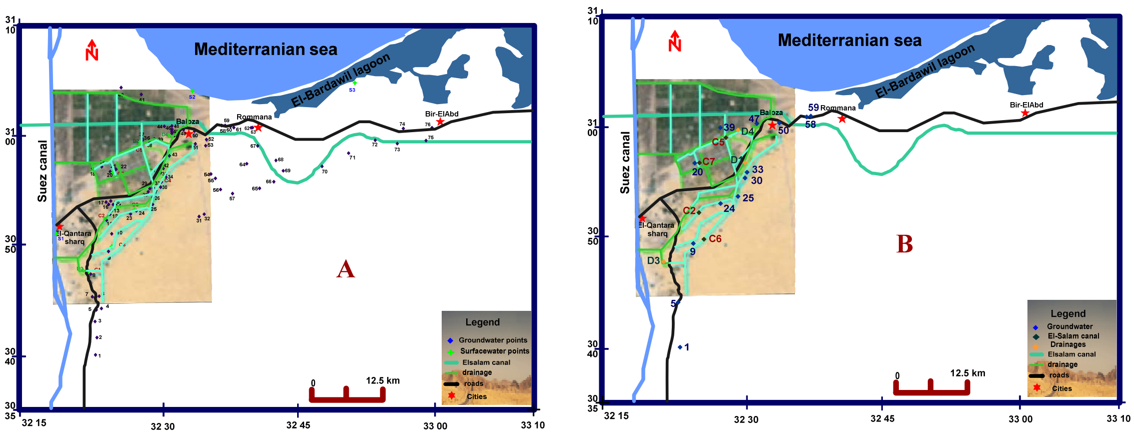

Fig (2): Sampling sites A- Trace and heavy metals B- Bacterial samples

3. Results and discussion

3.1. Trace and heavy metals

Studying the heavy elements concentrations in water is of great importance due to their direct effects on human and animals health in addition to plants growing. The source of these elements is due to rocks weathering beside human activities [10]. The distribution of some trace and heavy metals concentrations (Table 1) for the groundwater samples will be discussed according to different standards [11,12] (Table 2).

According to maximum contaminant levels (MCLs) (Table 2) it is clear that groundwater wells are polluted with respect to Aluminum (18.4% 6, 8, 13, 15, 16, 36, 42, 48, 51, 52, 54, 55, 62 & 66). High aluminum content in such localities suggests that El-Salam canal (Samples Nos. C_1, C_3, C_4 & C_5) and its tributaries are considered as the main source of aluminum, (Fig. 3). Groundwater samples are polluted with respect to Boron (60.5% 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14, 16, 19, 21, 22, 25, 27, 30, 31, 32, 35, 37, 40, 41, 44, 45, 49, 51, 52, 53, 54, 55, 60, 61, 62, 64, 67, 68, 69, 70, 71, 72, 73, 74, 75 & 76) indicating that the origin of Boron in the groundwater is due to the recharge from Seawater (Fig. 4). Groundwater samples are contaminated with respect to chromium (22.4% 3, 5, 8, 9, 31, 32, 42, 56, 57, 64, 65, 66, 67, 68, 70, 72 & 75). This may be due to the agricultural activities (fertilizers uses) or sewage and waste disposal. The high content of cadmium **(**4% 36, 52 & 71), iron **(**33% 3, 4, 6, 8, 13, 15, 19, 21, 33, 34, 36, 37, 38, 39, 40, 41, 42, 47, 48, 51, 52, 53, 55, 62 & 66) (Fig. 5), lead **(**79% 6, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71 & 72) (Fig. 6) and vanadium **(**14% 5, 6, 7, 8, 17, 37, 44, 51, 74, 75 & 76) in some localities may be attributed to the agricultural activities (fertilizers uses) [13]. It is to be mentioned that, high concentrations of zinc in such localities (4.0 % 36, 51 & 52), is mainly attributed to the direct effect of external stimulation such as fertilizer overdose due to shallow groundwater. This doesn't repeal the effect of El-Salam canal pollutants especially high concentration of Zn in such canal that attains 3.03 mg/l in some localities (Fig. 7). It should be noted that, most of the groundwater samples are safe with respect to cobalt, copper, manganese, molybdenum, nickel and strontium.

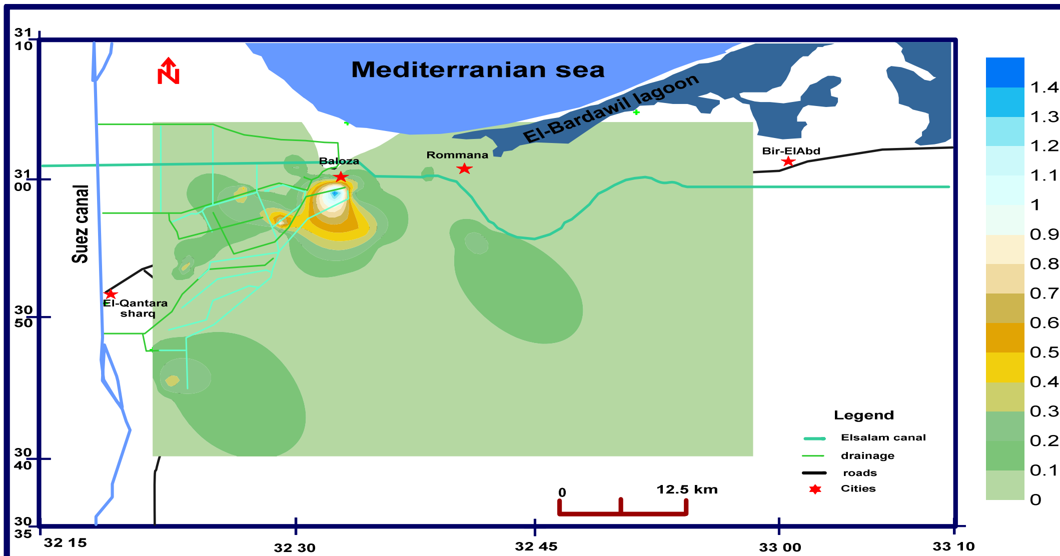

Fig (3): Aluminum concentration (mg/l) distribution of groundwater samples of the study area.

Table (1): Trace and heavy metals concentrations in mg/l

No	Al	B	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sr	V	Zn
Groundwater samples														
1	<0.0	0.79	<0.001	<0.001	<0.02	<0.01	0.17	0.004	0.02	<0.0009	<0.001	1.84	<0.01	<0.0
2	<0.0	0.67	<0.001	<0.001	0.05	<0.01	0.07	<0.002	0.01	<0.0009	<0.001	5.39	<0.01	<0.0
3	<0.0	0.69	<0.001	<0.001	0.06	<0.01	1.11	0.018	0.02	<0.0009	<0.001	3.49	<0.01	1.03
4	0.10	0.52	<0.001	<0.001	<0.02	<0.01	0.55	0.015	0.02	<0.0009	0.005	2.56	<0.01	0.00
5	<0.0	2.11	<0.001	0.003	0.15	<0.01	<.03	<0.002	0.01	<0.0009	<0.001	8.24	0.059	0.01
6	0.38	3.15	<0.001	<0.001	<0.02	<0.01	0.49	0.019	0.01	<0.0009	0.014	3.31	0.123	0.00
7	<.06	2.70	<0.001	<0.001	0.03	<0.01	<0.0	<0.002	0.02	<.0009	<0.001	2.67	0.105	<0.0
8	0.12	1.30	<0.001	<0.001	0.29	<0.01	0.39	0.017	0.01	0.0011	0.014	13.3	0.104	0.01
9	<0.0	1.44	<0.001	<0.001	0.05	<0.01	<0.0	<0.002	<0.003	<0.0009	0.011	2.65	<0.01	0.26
10	<0.0	<0.03	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	<0.003	<0.0009	<0.001	<0.0	<0.01	<0.0
11	<0.0	0.07	0.003	<0.001	<0.02	<0.01	<0.0	<0.002	0.01	<0.0009	0.017	1.49	0.021	0.01
12	<0.0	<0.03	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	0.01	<0.0009	0.016	1.33	<0.01	<0.0
13	0.15	3.70	<0.001	<0.001	<0.02	<0.01	1.53	<0.002	0.02	<0.0009	0.016	1.28	0.043	0.08
14	<0.0	1.17	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	<0.003	<0.0009	0.016	1.65	<0.01	0.01
15	0.38	<0.03	<0.001	<0.001	<0.02	<0.01	1.15	0.015	<0.003	<0.0009	0.018	0.97	0.029	0.43
16	0.43	1.01	<0.001	<0.001	<0.02	<0.01	0.12	<0.002	0.01	<0.0009	0.024	1.77	0.026	0.17
17	<0.0	0.13	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	0.02	<0.0009	0.041	1.27	0.061	0.19
18	<0.0	0.35	<0.001	<0.001	<0.02	<0.01	<0.0	0.012	0.01	<0.0009	0.020	0.78	0.020	0.01
19	0.08	0.58	<0.001	<0.001	<0.02	<0.01	0.44	0.115	0.01	0.0026	0.046	2.13	<0.01	0.76
20	<0.0	0.13	<0.001	<0.001	<0.02	<0.01	0.12	0.068	0.01	<0.0009	0.016	0.54	0.038	0.01
21	<0.0	4.83	<0.001	<0.001	<0.02	<0.01	1.48	0.035	0.05	0.0059	0.012	3.30	<0.01	0.02
22	<0.0	1.90	<0.001	<0.001	<0.02	<0.01	<0.0	0.018	0.02	0.0015	0.011	0.78	0.038	0.01
23	<0.0	<0.03	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	<0.003	<0.0009	<0.001	0.05	<0.01	<0.0
24	<0.0	0.12	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	0.00	<0.0009	0.017	14.4	0.021	0.01
25	<0.0	1.29	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	<0.003	<0.0009	0.015	1.13	<0.01	1.12
26	<0.0	0.11	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	<0.003	<0.0009	0.017	2.02	0.037	0.00
27	<0.0	1.17	<0.001	<0.001	<0.02	<0.01	0.05	<0.002	0.01	<0.0009	0.024	1.68	0.024	0.09
28	<0.0	0.48	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	<0.003	<0.0009	0.019	1.86	0.023	0.005
29	<0.0	0.05	<0.001	<0.001	<0.02	<0.01	0.05	<0.002	<0.003	<0.0009	0.016	2.04	<0.01	0.007
30	<0.0	2.21	<0.001	0.003	<0.02	<0.01	0.06	<0.002	0.01	<0.0009	0.017	1.32	0.032	0.020
31	<0.0	0.51	<0.001	<0.001	0.10	<0.01	<0.0	<0.002	<0.003	<0.0009	0.015	4.84	<0.01	0.278

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Table (1): Trace and heavy metals concentrations in mg/l

No	Al	B	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sr	V	Zn
32	<0.0	0.70	<0.001	<0.001	0.10	<0.01	<0.0	<0.002	<0.003	<0.0009	0.015	5.19	<0.01	0.014
33	<0.0	0.25	<0.001	<0.001	<0.02	<0.01	0.43	<0.002	0.01	<0.0009	0.019	1.53	0.024	0.261
34	<0.0	0.39	<0.001	<0.001	<0.02	<0.01	0.39	<0.002	0.00	<0.0009	0.020	1.85	0.024	0.059
35	<0.0	1.54	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	0.01	<0.0009	0.018	2.13	0.023	0.004
36	0.44	0.24	0.0059	<0.001	<0.02	0.02	7.72	0.039	<0.003	0.0024	0.423	2.21	0.038	44.480
37	<0.0	0.93	<0.001	<0.001	<0.02	<0.01	0.32	0.086	0.01	<0.0009	0.004	9.16	0.376	<0.001
38	<0.0	<0.03	<0.001	<0.001	<0.02	<0.01	0.74	0.192	<0.003	<0.0009	<0.001	<0.0	<0.01	<0.001
39	<0.0	0.29	<0.001	<0.001	<0.02	<0.01	0.31	0.027	0.00	<0.0009	<0.001	0.88	0.046	1.116
40	<0.0	0.62	<0.001	<0.001	<0.02	<0.01	0.40	0.421	<0.003	<0.0009	0.010	10.0	<0.01	<0.001
41	<0.0	3.28	<0.001	0.0022	<0.02	<0.01	0.67	0.252	0.01	0.001	0.019	6.00	<0.01	<0.001
42	0.91	0.16	<0.001	<0.001	0.06	<0.01	2.19	0.017	0.01	<0.0009	0.027	9.63	0.021	0.273
43	<0.0	0.06	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	0.00	<0.0009	0.015	1.77	<0.01	<0.001
44	<0.0	1.16	<0.001	<0.001	<0.02	<0.01	0.29	0.055	0.01	<0.0009	0.036	4.93	0.052	1.740
45	<0.0	1.44	<0.001	<0.001	<0.02	<0.01	0.09	0.134	0.01	<0.0009	0.030	1.29	<0.01	0.009
46	<0.0	0.09	<0.001	<0.001	<0.02	<0.01	0.19	0.012	0.01	0.0016	0.023	0.79	<0.01	0.161
47	<0.0	<0.03	<0.001	<0.001	<0.02	<0.01	0.37	0.075	0.01	0.002	0.027	0.96	<0.01	0.076
48	0.27	<0.03	<0.001	<0.001	<0.02	<0.01	0.46	0.038	0.00	<0.0009	0.022	1.13	<0.01	0.053
49	<0.0	0.86	<0.001	<0.001	<0.02	<0.01	<0.0	0.348	<0.003	<0.0009	0.015	2.15	<0.01	<0.001
50	<0.0	0.14	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	<0.003	<0.0009	0.018	0.44	0.023	0.249
51	1.56	1.27	<0.001	0.0022	<0.02	0.12	8.14	0.133	<0.003	0.0521	0.207	1.94	0.054	33.730
52	0.37	0.90	0.0048	<0.001	0.04	<0.01	5.59	0.097	<0.003	0.0134	0.461	8.50	<0.01	46.950
53	<0.0	1.91	<0.001	<0.001	<0.02	<0.01	0.34	0.099	<0.003	<0.0009	0.031	0.93	<0.01	<0.001
54	0.49	0.71	<0.001	<0.001	0.04	<0.01	<0.0	<0.002	<0.003	<0.0009	0.015	10.9	<0.01	0.002
55	0.31	2.71	<0.001	0.004	<0.02	<0.01	1.01	0.021	<0.003	<0.0009	0.006	13.8	<0.01	0.009
56	<0.0	0.49	<0.001	<0.001	0.14	<0.01	<0.0	<0.002	<0.003	<0.0009	0.014	5.69	0.021	0.018
57	<0.0	0.36	<0.001	<0.001	0.10	<0.01	<0.0	<0.002	<0.003	<0.0009	0.017	7.55	<0.01	0.002
58	<0.0	<0.03	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	<0.003	<0.0009	0.017	0.42	0.029	<0.001
59	<0.0	<0.03	<0.001	<0.001	<0.02	<0.01	<0.0	<0.002	<0.003	<0.0009	0.020	0.75	0.024	0.033
60	<0.0	0.64	<0.001	0.002	<0.02	<0.01	<0.0	<0.002	<0.003	<0.0009	0.025	4.76	<0.01	<0.001
61	<0.0	1.00	<0.001	<0.001	<0.02	<0.01	<0.0	0.023	0.00	<0.0009	0.023	4.55	0.031	0.290
62	0.14	9.16	<0.001	<0.001	0.04	<0.01	4.03	0.042	0.01	0.001	0.028	0.73	<0.01	2.822
63	<0.0	0.13	<0.001	<0.001	0.21	<0.01	<0.0	<0.002	0.01	<0.0009	0.025	1.99	0.025	0.014
64	<0.0	1.08	<0.001	<0.001	0.09	<0.01	<0.0	<0.002	<0.003	<0.0009	0.017	6.77	0.021	<0.001
65	<0.0	0.09	<0.001	<0.001	0.07	<0.01	<0.0	<0.002	<0.003	<0.0009	0.019	4.52	<0.01	<0.001
66	0.29	0.50	<0.001	<0.001	0.07	0.06	1.78	0.079	<0.003	<0.0009	0.015	4.06	<0.01	1.322
67	<0.0	1.15	<0.001	<0.001	0.10	<0.01	<0.0	<0.002	<0.003	<0.0009	0.023	6.34	0.028	<0.001
68	<0.0	0.92	<0.001	<0.001	0.07	<0.01	<0.0	<0.002	<0.003	<0.0009	0.021	8.58	<0.01	<0.001
69	<0.0	1.14	<0.001	<0.001	0.04	<0.01	<0.0	<0.002	<0.003	<0.0009	0.024	7.10	0.045	0.002
70	<0.0	1.09	<0.001	<0.001	0.06	<0.01	0.06	<0.002	<0.003	<0.0009	0.021	5.98	0.021	0.002
71	<0.0	<0.03	0.00934	<0.001	<0.02	0.32	<0.0	<0.002	<0.003	<0.0009	0.020	11.3	<0.01	<0.001
72	<0.0	0.80	<0.001	<0.001	0.08	<0.01	0.05	<0.002	<0.003	<0.0009	0.019	11.2	<0.01	0.041
73	<0.0	1.25	<0.001	<0.001	0.05	<0.01	<0.0	<0.002	<0.003	<0.0009	<0.001	19.9	0.036	<0.001
74	<0.0	2.00	<0.001	<0.001	<0.02	<0.01	<0.0	0.001	0.00	<0.0009	<0.001	1.85	0.180	0.033
75	<0.0	3.22	<0.001	<0.001	0.06	<0.01	<0.0	0.007	<0.003	<0.0009	<0.001	14.6	0.081	<0.001
76	<0.0	2.46	<0.001	<0.001	0.04	<0.01	0.18	0.006	<0.003	<0.0009	0.003	6.46	0.094	1.195
Surface water samples														
C_1	0.35	0.19	<0.001	<0.001	<0.02	<0.01	0.54	0.11	0.00	0.0045	0.005	1.63	0.044	0.197
C_2	<0.0	<0.03	<0.001	<0.001	<0.02	<0.01	<0.03	<0.002	<0.003	<0.0009	<0.001	<0.0005	<0.01	<0.001
C_3	0.60	<0.03	<0.001	<0.001	<0.02	<0.01	0.71	0.063	<0.003	0.0023	0.012	1.54	<0.01	0.047
C_4	1.53	<0.03	<0.001	0.003	<0.02	<0.01	2.67	0.362	<0.003	0.0066	0.032	1.14	<0.01	3.032
C_5	0.63	0.07	<0.001	<0.001	<0.02	<0.01	1.15	0.123	<0.003	0.0024	0.011	0.76	<0.01	0.033
S_1	0.37	3.96	<0.001	<0.001	<0.02	<0.01	0.32	0.019	0.01	<0.0009	<0.001	7.45	<0.01	0.021

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Table (1): Trace and heavy metals concentrations in mg/l

No	Al	B	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sr	V	Zn
S_2	0.34	7.22	<0.001	<0.001	<0.02	<0.01	0.34	0.030	0.01	<0.0009	<0.001	12.90	<0.01	0.028
S_3	0.09	9.85	<0.001	<0.001	<0.02	<0.01	<0.03	0.018	0.01	<0.0009	<0.001	16.21	<0.01	<0.001
D_1	<0.0	1.16	<0.001	<0.001	<0.02	<0.01	<0.03	0.004	0.00	<0.0009	0.017	3.40	0.002	<0.001
D_2	0.71	1.71	<0.001	<0.001	<0.02	<0.01	0.74	0.192	<0.003	<0.0009	<0.001	<0.0005	<0.01	<0.001

C_1,C_2,C_3,C_4 and C_5 samples of El-Salam canal and its tributaries $D_1$and D_2 drainages S_1,S_2 and S_3 sea water samples

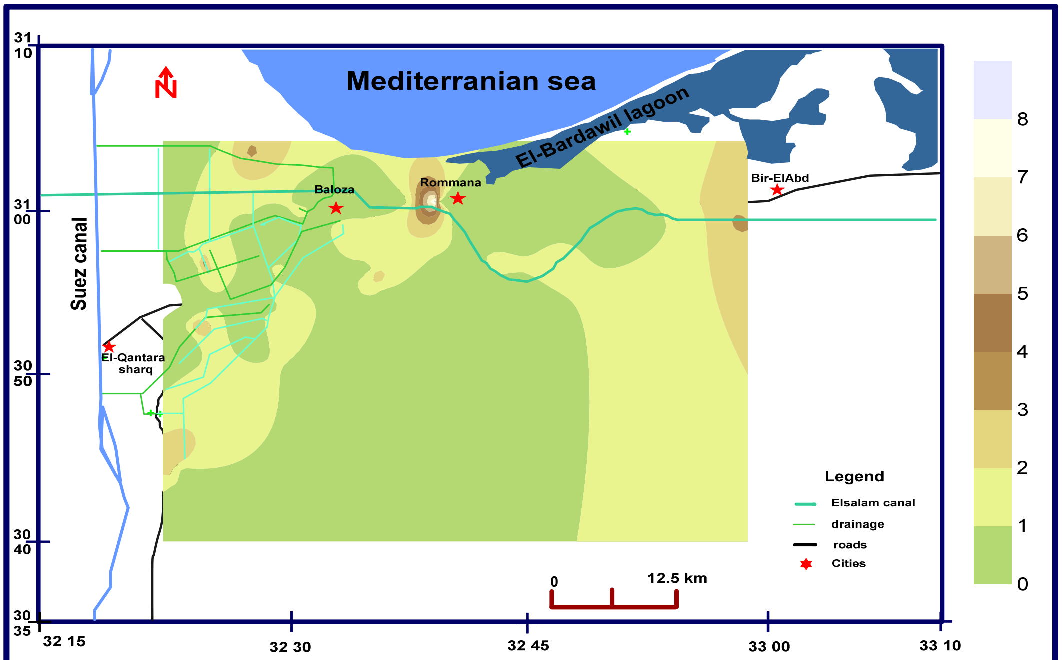

Fig (4): Boron concentration (mg/l) distribution of groundwater samples of the study area.

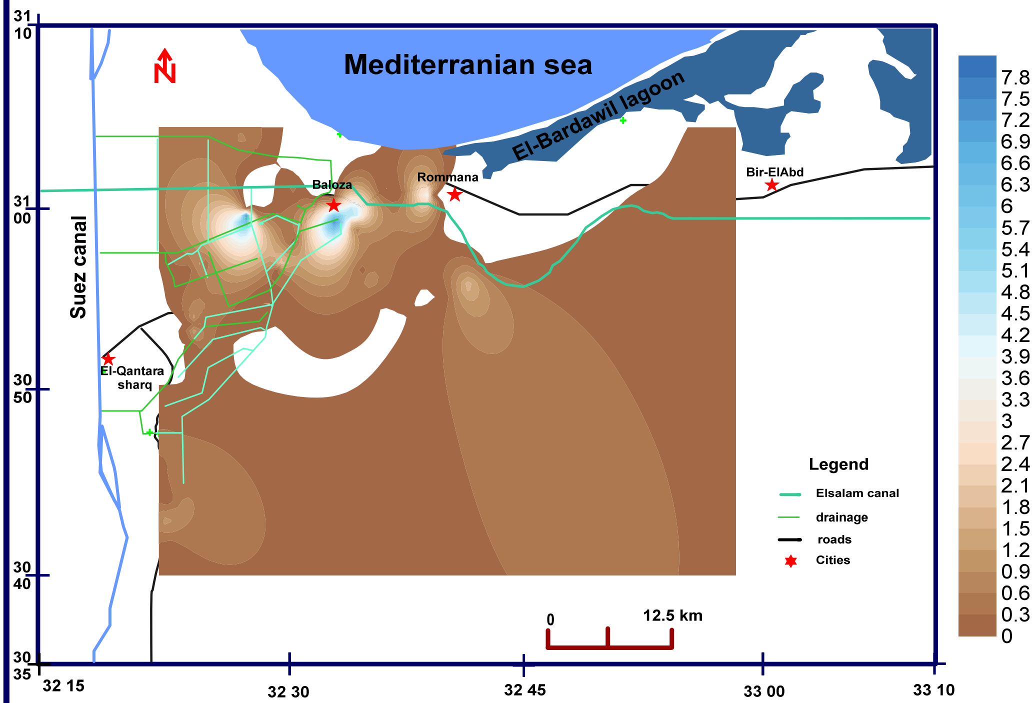

Fig (5): Iron concentration (mg/l) distribution of groundwater samples of the study area .

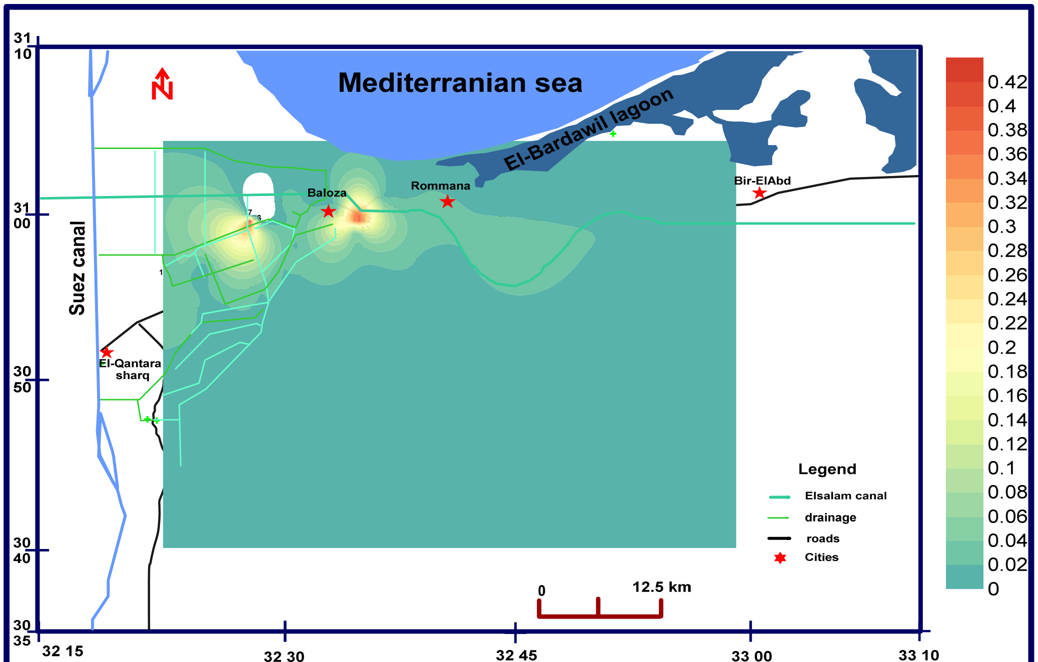

Fig (6): Lead concentration (mg/l) distribution of groundwater samples of the study area.

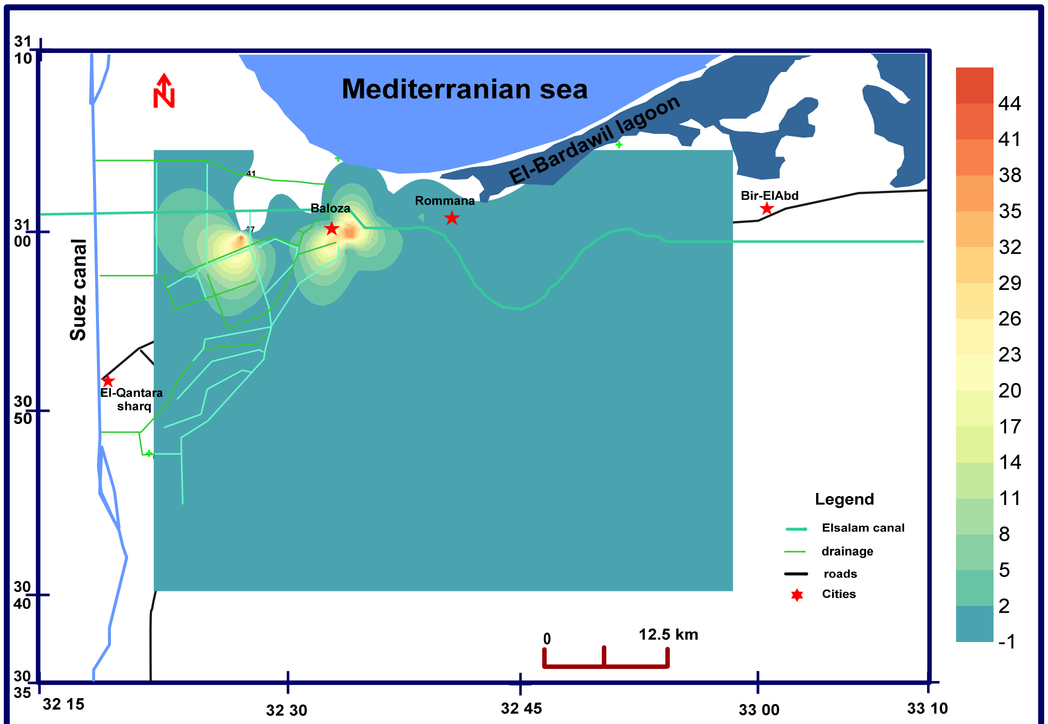

Fig (7): Zinc concentration (mg/l) distribution of groundwater samples in the study area.

3.2. Heavy metal pollution index

Heavy metal pollution index (HPI) is a method of rating that shows the composite influence of individual heavy metal on the overall quality of water. The rating is a value between zero and one, reflecting the relative importance of individual quality considerations and defined as inversely proportional to the recommended standard (Si) for each parameter. Water quality and its suitability for drinking purpose can be examined by determining its quality index. Generally, the critical pollution index value is 100 [14-16].

$$HPI = \sum_{i=1}^{n} Qi \times Wi / \sum_{i=1}^{n} wi$$

Where, Qi is the sub index of i parameter. Wi is the unit weightage for i parameter and n is the number of parameters considered.

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$$Wi = {}^{K}/_{Si} \quad K = 1/\sum_{i=1}^{n} 1/Si$$

Where, Wi is the unit weightage and Si the recommended standard for i parameter (i = 1-13), k is the constant of proportionality.

$$Qi = 100 \times {}^{Vi}/_{Si}$$

Where, Qi is the sub index of i parameter, Vi is the monitored value of the i parameter in mg/l and Si the standard or permissible limit for the i parameter.

To calculate the HPI of the water, the mean concentration value of the selected metals (Al, B, Cd, Cr, Cu, Fe, Mo, Mn, Ni, Pb, Sr, V & Zn) has been taken into account. Calculations of the unit weightage (Wi) and standard permissible value (Si) are obtained in the present study according to WHO, [11,12] (Table 2).

HPI values ranging from 24.8 to 949.1 for groundwater samples and from 24.8 to 94,8 for surface water. About 8% of the groundwater samples exceed the critical pollution index value, while all of the surface water samples showed values less than the critical pollution index.

On the other hand, El-Salam canal sample (No. C_4) approaches the critical pollution index with a value of 94.8 (Table 3).

Table (2): Unit weightage (Wi) and standard permissible value (Si) in mg/l

Item	WHO 2006 (MCLs)	Egy 2007 MCLs	Wi WHO	Wi Egy
Al	0.1	0.2	0.02	0.01
B	0.5	0.5	0.00	0.003
Cd	0.003	0.003	0.60	0.60
Cr	0.05	0.05	0.04	0.04
Cu	2	2	0.0009	0.0009
Fe	0.3	0.3	0.01	0.01
Mo	0.07	0.07	0.03	0.03
Mn	0.4	0.4	0.00	0.00

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Ni	**0.02**	**0.02**	**0.09**	**0.09**
Pb	**0.01**	**0.01**	**0.18**	**0.18**
Sr*	**25**	**25**	**0.00**	**0.00**
V**	**0.05**	**0.05**	**0.04**	**0.04**
Zn	**3**	**3**	**0.0006**	**0.0006**

K WHO= 0.001798 K Egy= 0.001814

WHO Guidelines were mentioned in "Water Quality For Ecosystem and Human Health", 2006 & "Global Drinking Water Quality Index Development and Sensitivity Analysis Report", 2007 Prepared and Published by the United Nations Environment Program Global Environmental Monitoring System/ Water Program

Egypt Guidelines according to the Minister of Health decree Number (108) for 1995 and (458) for 2007

Table (3): Heavy metal pollution index (HPI) values in mg/l

No	HPI	map no	HPI	No	HPI	No	HPI	No	HPI	map no	HPI
				Groundwater						Surface water	
1	26.1	17	101.8	33	59.9	49	50.6	65	60.6	C_1	37.9
2	27.5	18	60.7	34	60.4	50	55.5	66	58.2	C_2	24.8
3	31.0	19	108.7	35	56.9	51	446.0	67	71.4	C_3	48.4
4	34.7	20	54.3	36	901.5	52	949.1	68	65.5	C_4	94.8
5	39.4	21	54.6	37	58.5	53	80.3	69	71.4	C_5	48.8
6	60.8	22	47.3	38	26.4	54	53.0	70	65.3	S_1	29.8
7	34.8	23	24.8	39	28.2	55	39.4	71	225.8	S_2	32.0
8	76.9	24	53.6	40	43.0	56	57.6	72	62.4	S_3	32.3
9	45.9	25	51.3	41	62.0	57	59.4	73	29.6	D_1	54.1
10	24.8	26	55.6	42	84.2	58	54.8	74	38.5	D_2	30.6
11	55.2	27	68.1	43	50.4	59	59.4	75	35.3		
12	52.4	28	58.0	44	92.4	60	67.5	76	37.1		
13	60.5	29	52.4	45	77.7	61	67.0				
14	52.6	30	56.5	46	65.0	62	90.2				
15	60.2	31	56.5	47	73.1	63	82.5				
16	70.5	32	56.7	48	63.6	64	59.4				

3.3. Microbial detection

Generally shallow and / or deep aquifers are rarely or never found completely sterile. Under certain conditions, coliform organisms may also persist on nutrients derived from nonmetallic construction materials [17]. Use of normal intestinal organisms as indicators for fecal pollution rather than the pathogens themselves is a universally accepted principle for monitoring and assessing the microbiological safety of water supplies [18], which presence of small numbers of coliform organisms (1-10 organisms per 100 ml) particularly in untreated groundwater may be of limited sanitary significant provided fecal coliform organisms are absent. But when the number of coliform bacteria exceeds the usual levels, it becomes very serious and needs immediate attention to protect inhabitants life from outbreaks of pathogenic disease [19].

The results of the total microbial count, Coliforms, Pseudomonas, Alcaligenes, Escherichia, Citrobacter, salmonella, Shigella, Klebsiella, Proteus and Enterobacter are tabulated (Table 4). Surface water samples and about 77% of the groundwater samples (Nos. 21, 24, 26, 30, 33, 39, 50, 58, 59, & 74) are contaminated according to the total microbial count, while coliforms were detected only in two groundwater sites (Nos. 21 & 30) and three surface water sites (Nos. C_6, C_7 & D_3). They ranged between 3 and 15 count (cfu/100ml) with the appearance of some types of organisms as Pseudomonas, Escherichia, Shigella and Entrobacter [12], (Table 5).

Table 4. Results of bacterial analyses of surface and groundwater samples

No	TCC	TMC	Pseudo-monas	Alcali-genes	Escher-ichia	Citro-bacter	Salmo-nella	Shig-ella	Klebs-iella	Prot-eus	Entero-bacter
Groundwater samples											
1	0	20	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
5	0	30	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
9	0	40	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
21	9	165	-ve	-ve	+ve	-ve	-ve	-ve	-ve	-ve	-ve

24	0	194	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
26	0	185	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
30	15	135	-ve	-ve	+ve	-ve	-ve	-ve	-ve	-ve	-ve
33	0	1400	+ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
39	0	80	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
50	0	70	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve

Table 5. Microbial drinking-water quality standards.

Parameter	Egyptian guidelines
TMC	TMC (per1cm^3): ≤ 50 cell at 37 °C for 24 hours - ≤ 50 cell at 22 °C for 48 hours

58	0	100	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
59	0	125	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
74	0	58	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
Surface water samples											
C_2	0	244	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
C_5	0	170	-ve	-ve	+ve	-ve	-ve	-ve	-ve	-ve	-ve
C_6	3	700	-ve	-ve	-ve	-ve	-ve	+ve	-ve	-ve	-ve
C_7	15	300	-ve	-ve	-ve	-ve	-ve	+ve	-ve	-ve	-ve
D_2	0	60	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve
D_3	11	300	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	+ve
D_4	0	500	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve	-ve

TMC: Total microbial count CFU /ml TCC: Coliforms count: cfu/ 100 ml

Generally, the obtained results indicated that El-Salam canal considered as the main source of microbial pollutants due to the presence of coliform bacteria and Shigella which are a principal indicators of water pollution by human sewage [20,21].

TCC	TCC (per 100 cm^3): 95% of samples taken in 1 year should be free. No sample should contain more than two cells/100 cm^3 in two consecutive samples of the same source.

Egyptian guidelines: Decree of Minister of Health and Population No.(458)/2007
TMC: Total microbial count CFU/ ml
TCC : Total Coliforms count CFU / 100 ml

Table 6. CCME WQI Categorization Schema**.**

Rank	WQI Value	Description
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels; these index values can only be obtained if all measurements are within objectives virtually all of the time.
Good	80-94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

3.5. Evaluation of groundwater quality

There are many methods to evaluate water quality for different uses. When there are many variables, it is difficult to process the evaluation because of the complexity associated with analyzing a large number of measured variables. In this paper the evaluation of ground water was done depending on water quality index (WQI). Water quality index is a mathematical way of summarizing multiple properties into a single value. The evaluation of groundwater for drinking and agriculture purposes is achieved according to Canadian water quality guidelines for the protection of aquatic life index [22]. CCME WQI value has been determined, water quality is ranked by relating it to one of the following categories (Table 6).

3.6. Groundwater suitability for human drinking purposes

WQI based upon the CCME WQI was calculated for human drinking purposes suitability according to [11,12] guidelines for drinking purposes. CCMEWQI results according to 19 parameters (TDS (total dissolved solids), PH, Na, K, Ca, Mg, Cl, SO_4, NO_3, Al, B, Cd, Cr, Cu, Fe, Mn, Ni, Pb & Zn) showed that 95% of groundwater samples are unsuitable for drinking purposes. Only 4 groundwater wells (Nos. 50, 58, 59 , 74) are suitable (Table. 7) and (Fig. 8). According to microbial investigations, all of groundwater and surface water samples are contaminated according to their total microbial count (Table. 5).

3.7. Evaluation of groundwater for irrigation purposes

WQI based upon the CCME WQI was calculated for irrigation purposes suitability according to [23-25] (Table. 8). CCMEWQI results according to 17 parameters (TDS, Al, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Cd, Mo, SAR (sodium adsorption ratio), SSP (soluble sodium percentage), RSC (Residual Sodium Carbonate), PI (permeability index) and MR (Magnesium ratio)), showed that 4%

of groundwater samples (Nos. 16, 35 & 37) and location C_5 of El-Salam water canal are excellent, 66% of groundwater samples and (Nos. 1, 4, 5, 6, 7, 11, 12, 14, 15, 17, 18, 19, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 38, 39, 43, 45, 46, 47, 48, 50, 54, 56, 57, 58, 59, 60, 61, 63, 64, 65, 66, 68, 69, 70, 72, 73, 75 & 76), and locations C_1, C_2, C_3, C_4 of El-Salam water canal and drainage water (D_1) are good, 29% of groundwater samples (Nos. 2, 3, 8, 9, 10, 13, 20, 21, 22, 36, 40, 41, 42, 44, 49, 51, 53, 55 62, 67, 71& 74) and drainage water (D_2) are fair while about one of groundwater sample only (No. 52) is marginal for irrigation purposes (Fig. 9).

4. Conclusions

An integrated approach of pollution evaluation indices, Heavy metal pollution index (HPI), water quality index (WQI) and the Canadian water quality guidelines for the protection of aquatic life index (CCME WQI) were employed to evaluate the intensity and sources of pollution in the groundwater and surface water systems in the northwestern portion of Sinai. Analysis results showed that Aluminum, Boron, Cadmium, Chromium, Iron, Lead, Vanadium and Zinc increment in groundwater with different percentages (18.4%, 60.5%, 4%, 22.4%, 33%, 79%, 14% and 4%, respectively) makes the sources of groundwater

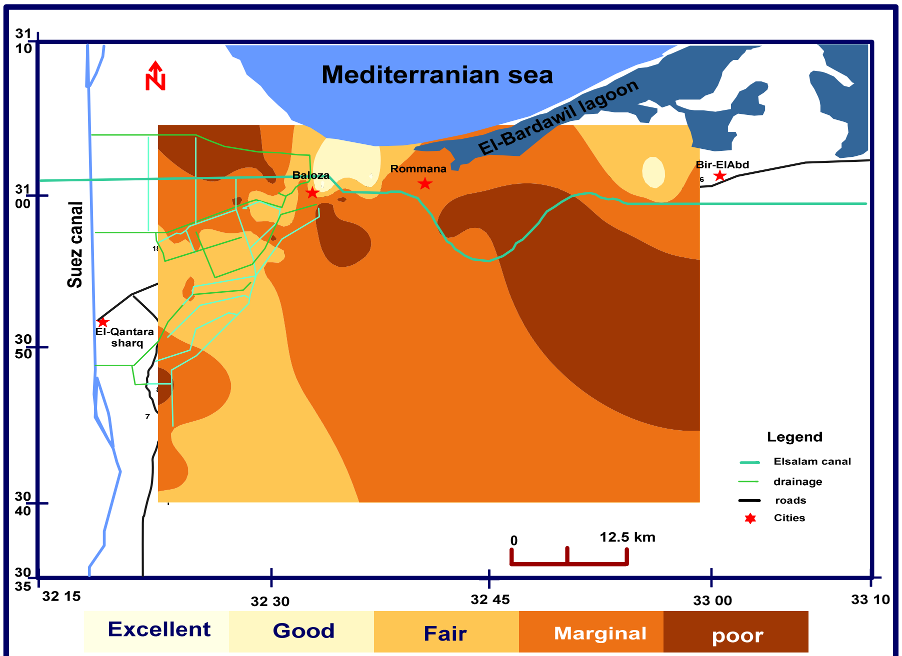

Fig (8):Drinking water suitability distribution of the groundwater samples according to CCME WQI.

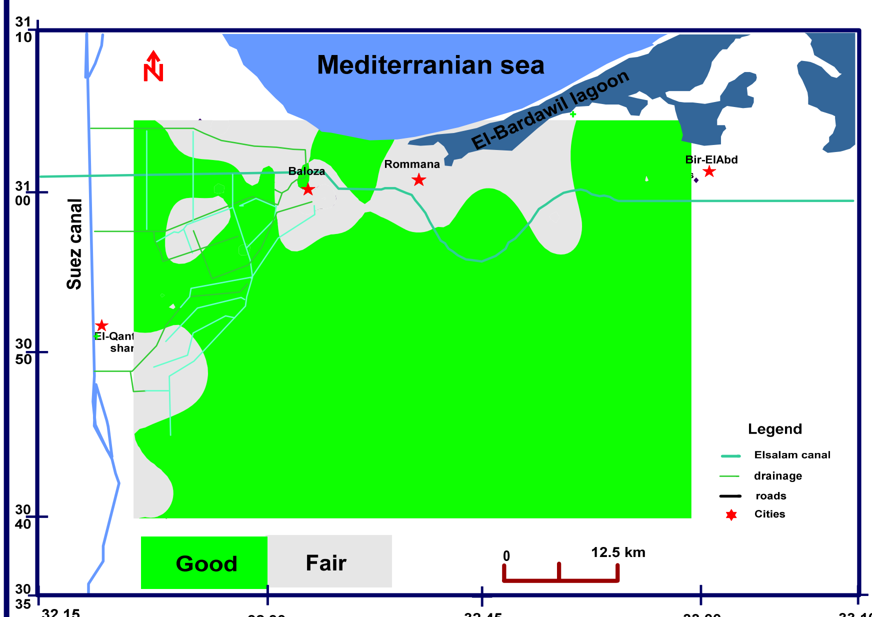

Fig (9):Groundwater suitability for irrigation uses according to CCME WQI

Table 7. Groundwater suitability for drinking and irrigation purposes according to CME.

No	Drinking DWQI(Egy)	Drinking DWQI(WHO)	Irrigation water	No	Drinking DWQI(Egy)	Drinking DWQI(WHO)	Irrigation water	No	Drinking DWQI(Egy)	Drinking DWQI(WHO)	Irrigation water
1	73.4	73.	80.3	30	61.	61.5	80.4	59	95.1	95.1	85.5
2	59.5	58.	75.8	31	54.	50.9	80.7	60	65.7	62.2	85.6
3	57.1	53.	75.5	32	54.	50.5	85.5	61	55.1	51.5	85.6
4	70.0	66.	84.6	33	73.	73.4	85.4	62	61.1	61.1	69.8
5	48.6	45.	80.1	34	77.	77.3	85.6	63	60.5	60.8	80.0
6	48.3	51.	80.5	35	67.	63.2	95.2	64	45.1	44.6	85.4
7	62.3	62.	80.4	36	32.	31.9	66.2	65	54.9	51.1	85.5
8	42.6	42.	74.2	37	49.	48.6	95.0	66	49.7	46.1	85.5
9	53.2	49.	75.8	38	77.	73.5	85.6	67	47.9	44.5	70.7
10	65.5	65.	75.4	39	74.	74.2	85.6	68	42.9	39.1	80.4
11	76.2	76.	85.3	40	36.	35.5	78.7	69	45.6	41.9	80.2
12	76.8	76.	85.5	41	34.	30.9	67.7	70	44.9	44.4	90.1
13	55.3	58.	75.2	42	35.	34.8	79.5	71	31.9	31.8	67.6
14	71.8	71.	85.5	43	77.	77.4	85.5	72	47.9	47.4	89.9
15	64.5	64.	85.6	44	43.	43.0	75.3	73	50.5	46.9	89.9
16	53.3	49.	95.2	45	59.	52.3	80.5	74	80.0	80.3	79.6
17	69.2	69.	80.3	46	72.	72.4	85.5	75	48.5	45.2	80.1
18	65.6	65.	85.2	47	74.	74.4	85.44	76	63.9	60.8	85.5
19	56.9	49.	85.6	48	69.	69.7	85.5		Surface water		
20	78.0	78.	79.8	49	55.	54.5	70.0	C1	74.6	74.6	90.3
21	40.7	40.	76.7	50	95.	95.4	85.5	C2	81.5	81.5	85.6
22	67.3	67.	74.9	51	33.	30.3	65.3	C3	72.7	72.7	90.3
23	78.1	78.	85.4	52	21.	21.4	55.4	C4	60.6	56.2	80.2
24	78.1	78.	85.3	53	58.	58.7	71.0	C5	83.1	79.7	95.1
25	68.9	68.	85.4	54	42.	38.4	84.9	S1	30.4	30.3	62.9
26	71.9	71.	85.4	55	44.	38.4	79.9	S2	30.4	30.3	63.2
27	68.1	68.	90.2	56	57.	54.2	80.6	S3	34.5	34.5	61.3
28	73.7	73.	85.5	57	53.	53.2	90.2	D1	63.5	59.9	85.4
29	72.4	72.	85.5	58	91.	91.6	85.5	D2	34.5	30.9	79.2

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Table 8. Water quality limits for irrigation water (FAO, 1985).

item	limits	item	limits	item	limits
TDS	3200*	Mn	0.2	Cd	0.1
Al	5	Ni	0.2	Mo	0.01
Co	0.05	Pb	5	RSC	1.25***
Cr	0.1	Zn	2	PI	75***
Cu	0.2	SAR	18**	(MR)	50***
Fe	5	SSP	60		

* [24] ** (College of Agricultural Sciences, 2002 and U.S. salinity laboratory Staff, 1954 *** [25]

pollutants. This study revealed that the diversity of the pollution sources is mainly due to El-Salam canal water, agriculture activities (fertilizers) and disposal sewage.

Microbial analysis results indicated that all of surface water samples and 77 % of groundwater samples are contaminated according to their total microbial count. Coliforms were detected only in two groundwater sites and three surface water sites and El-Salam canal is considered as the main source of microbial pollutants. The detection of coliform bacteria and Shigella in El-Salam canal samples suggests the presence of Human feces proving the mixing of El-Salam canal water with sewage.

About 95% of the groundwater samples are unsuitable for drinking purposes according to CCME WQI, while the microbial investigation showed that all of the groundwater samples are unsuitable for drinking purposes. According to the Canadian water quality guidelines for the protection of aquatic life index (CCME WQI), 4% of samples are excellent, 66% are good, 29% are fair while about one sample is marginal for irrigation purposes.

5. Recommendations

-The Government should adopt some treatment technologies to minimize the heavy metals in drainages before mixing with River Nile water in El-Salam canal.

- It is recommended to control and restrict the agricultural activities in the study area to prevent the leachate from reaching the groundwater.

-Routine checks of the quality of the groundwater supply in the study area are advocated for so as to ascertain its pollution status.

- Both the three tiers of government, non-governmental agencies and international organizations should join hands together to ensure that adequate and safe drinking water are provided for as many people as possible.

- Enforcement of laws to protect and manage pollutants that may affect ground water quality should be put in place.

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