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GEOCHEMISTRY OF WATER RESOURCES AND POLLUTION PROBLEMS IN HELWAN AREA, EGYPT

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The objective of this paper is to evaluate the impact of the sources of water pollution on water supplies in Helwan area and its vicinities through the determination of different kinds of pollutants. The industrial complex at Helwan produces large amount of liquid wastes. About 115,000 m^3/ day of liquid wastes loaded by about 3.39 tons/day of suspended solids matter are discharged into El Khashab and El Hager canals, drains and the River Nile. In addition to the disposal of sanitary wastewater to agricultural canals and Nile river, fertilizers and pesticides seepage into irrigation canals and drains in the area under investigation disturb the environmental balance. These lead to the pollution of shallow and deep groundwater through vertical and lateral seepage from canals and drains. This paper was based on the evaluation of water chemistry and pollution. The latter is discussed on the basis of major ions, trace, minor and soluble heavy metals constituents as well as biological and bacteriological analyses. The results revealed that the surface water of the River Nile, canals and drains as well as the shallow and deep groundwater exploitated in the area are variably polluted from different sources.

Keywords: water pollution, Helwan area (Egypt), biochemical oxygen demands (BOD), chemical oxygen demands (COD).

The investigated area (Helwan-El Saaf) is located east of the River Nile and south Cairo between latitudes 31° 15' and 31° 23' N and longitudes 29° 44' and 29° 52' 30"E. Therefore, the area is located in the aird to semiaird belt of northeast Africa, where long-rainless summer, and warm winter mark the climate. The relative humidity is moderate and active winds of intermediate speeds are recorded. The highest recorded value of relative humidity was 71.8% in December. The mean annual precipitation ranges from 17.4 to 4.2 mm/y. Evaporation is generally high, it reaches up to 18.7mm/day in May and minimum value of 2.3 mm/day recorded in December. The average daily temperatures vary from about 37.1°C in August to about 5°C in January.

This area constitutes five population centers namely; El-Maadi, Helwan, Turah, El-Tibein and El-Saaf and is heavily populated (1,007180 person in 2004.), the target population according to the formula $P_t = P_0 e^{rt}$ is 1,217339 person in 2010, where P_t is the target population at time(t), P_0 is the recent population and r is the rate of growth.

The common cropping patterns include vegetables, fodders, fruit orchards and some field crops. Fertilization schemes involve N, P and K fertilizers together with organic manures with few addition of organic pesticides that contain appreciable concentration of some heavy metals.

Water resources within Helwan area include River Nile, irrigation canals, irrigation and industrial drains, shallow and deep groundwater. The water available for drinking, irrigation and other domestic uses are mainly from the River Nile and its canals in conjuction with some groundwater wells. Irrigation is mainly performed through surface water (flooding).

The surface and groundwater in Helwan area lie in the flood plain and tapped the Quaternary deposits (Holocene and Pleistocene). The Holocene deposits (Nile silt, clay and sand) have a thickness ranging from 10m North of Helwan to 14m southward, while the Pleistocene deposits are mainly composed of silt, sand and gravel ranging in thickness from 50m North of Helwan to 80m southward. Abdel Daiem (1971) considered the deep aquifer as a semi-confined one while the study of RIGW (1978) indicated that the shallow aquifer is considered as unconfined one. The main recharge sources of the Quaternary aquifers are the seepage from Nile water and downward infiltration from the excess irrigation water of cultivated lands as well as the seepage from canals and drains.

Helwan is considered as one of the main industrial area where pronounced activities such as iron, steel and cement industries,..etc are performed. With the progressive increase of industrial activities, in addition to the misuse of fertilizers in agriculture, the area under consideration suffered from surface and groundwater contamination with organic and inorganic chemical pollutants. The main sources of water pollution in the area are mainly originated from agriculture, domestic installations (sanitary wastewater and septic tanks) and industrial wastes (Sallouma *et al.*, 1998).

For a long time, pollution problems are ignored and their effect on the environment were not given due consideration. Consequently, pronounced efforts are needed to control such pollution. The current research is, therefore, carried out to threw light on some pollution problems in the study area.

MATERIALS AND METHODS

Sampling

The present research is based on the results of sixteen shallow groundwater samples (less than 30m depth) and three deep groundwater samples (more than 30m depth) collected from the study area (Fig. 1). Moreover, three water samples from the River Nile, eight samples from irrigation canals, five samples representing irrigation drains, and five samples from the wastewater disposal site of some factories were also collected. Four kinds of analyzed water samples were taken from each of the above water points for different measurements. The first kind is for the measurement of major cations, anions, minor elements and total organic carbon (TOC). The second kind includes acidified samples by nitric acid for the measurements of trace elements and soluble heavy metals. The third kind is collected in special container for the measurements of biochemical oxygen demands (BOD) and chemical oxygen demands (COD). Finally, the fourth kind samples are collected in a special antiseptic container for the measurements of microbiological and pathological analyses of water.

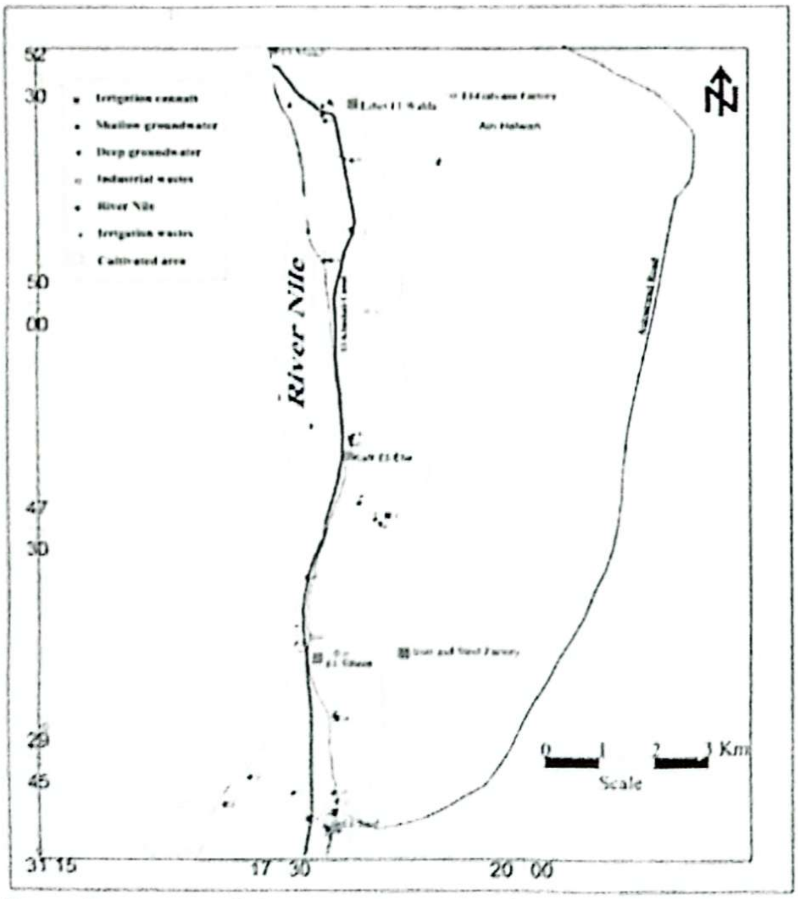

Fig. (1). Location map of the water samples in Helwan-ElSaaf area.

Field Measurements

In situ measurements of water samples location together with some physical and chemical characteristics of the collected water were determined in the field using GPS model (Magellan Nave 5000 pro.) for the determination of latitudes and longitudes and Electrical Conductivity meter (Jenway, model 470) for the determination of water salinity (EC in µS/cm) of the collected water samples. pH and dissolved oxygen were measured using pH meter (Jenway, model 3150) and DO meter (WTW, model oxi 315i), respectively .

Laboratory Analyses

The analyses include the determination of EC, total dissolved salts (TDS), pH, concentration of major ions Ca^{2+}, Mg^{2+}, Na^+, K^+, CO_3^{2-}, HCO_3^-, SO_4^{2-} and Cl^-. The minor, trace and soluble heavy metals and non metals are S^{2-}, NH_4^+, NO_2^-, NO_3^-, PO_4^{3-} , I^-, Br^-, soluble SiO_2, B^{3+}, Al^{3+}, Fe^{3+}, Mn^{2+}, Co^{2+}, Cu^{2+}, Ni^{2+}, Cr^{3+}, Cd^{2+}, Pb^{2+}, Sr^{2+}, V^{2+} and Zn^{2+}. This is beside TOC, BOD, COD and bacteriological measurements (Rainwater and Thatcher, 1960, Fishman and Friedman, 1985, Prescott *et al.*, 1993 and ASTM, 2002). Measurements were carried out by EC meter model Orion 150 A+, pH meter Jenway 3510, Flame photometer Jenway PFP 7, Ion selectivity meter Orion model 940 with 960 titration plus, UV/Visible spectrophotometer Thermo-Spectronic 300 and Plasma Optical Emission – mass spectrometer (POEMS III) (Thermo Jerral Ash). The obtained chemical data are expressed in milligram per liter (mg/l).

RESULTS AND DISCUSSION

Hydrogeochemical Characteristics

Chemical analysis of forty water samples collected from shallow and deep groundwater of the quaternary aquifer, River Nile, irrigation drains, and wastewater disposal sites of some factories (Tables 1and 2) revealed the following:

Hydrochemical Aspects

A- Water salinity

TDS of River Nile water samples range from 225 or 448 (El Kawmyia cement company) to 264 mg/l or 466 µS/cm (Kafr El Elw) while the water salinity of El Khashab and El Hagger canals ranges from 283 or 520 (Electrical Rural Association of Helwan) to 1123 mg/l or 2190µS/cm (Khashab canal beside well 31), reflecting a fresh water type. On the other hand, the water salinity of drains varies from 296 or 570 (beside El Khashab canal, water sample No. 11) to 1707 mg/l or 3200 µS/cm (Ezbet El Walda), i.e., fresh to brackish water types. This is due to leaching and dissolution of soluble salts from irrigated soils, ion exchange and concentration processes. With regard to industrial drains, the water salinity varies from 337 or 600 to

1138 mg/l or 2610 µS/cm (Iron and steel factory drain before mixing with Nile water and Galvanized and steel factory drain, respectively), therefore considered as a fresh water type.

Generally, the salinity of shallow groundwater (free water table, RIGW, 1978) changes from fresh (418 mg/l or 800 µS/cm, well 16), to brackish water types (3686 mg/l or 6000 µS/cm, well 9). This is due to recharge by fresh water from River Nile and seepage from canals and drains containing relatively high water salinity, as well as leaching and dissolution of terrestrial and marine salts of the aquifer matrices. With respect to TDS of deep groundwater, it lies between 593 or 1180 (well 23) and 617 mg/l or 1212 µS/cm (well 32) thus considered as fresh water type. This is attributed to direct recharge of such aquifer that is considered as semi-confined and confined types (Abdel Daiem, 1971) by fresh water from the River Nile. This means that, to a great extent, there is no downward infiltration from the excess irrigation water of cultivated lands and seepage from irrigation canals and drains as well as industrial wastes.

B- Water hardness

The mean value of total, temporary and permanent hardness (TH, CH and NCH) reached 180 (74% of TDS), 149 (61%) and 31 mg/l (13%) in River Nile water samples and 336 (53%), 194 (31%) and 142 mg/l (22%), respectively, in irrigation canal water (Table 3). Thus, the hardness of Nile and El Khashab canal water is, to a great extent, temporary one, reflecting a meteoric origin of such water (Table 2). On the other hand, the mean value of total, temporary and permanent hardness in drain water are 312 (49%), 165(26%) and 147 mg/l (23%) in the fresh water, respectively and 605(36%), 182(11%) and 423 mg/l (25%) in the brackish water, respectively (Table 3). Consequently, the temporary hardness exceeds the permanent one in fresh water and vice versa in case of brackish drains water, this may be due to local contamination by permanent salts in these drains. With regard to the total, temporary and permanent hardness of industrial drains it ranges from 148 to 474, 148 to 323 and 43 to 151 mg/l, respectively (Table 1). Therefore, the temporary hardness exceeds the permanent hardness in case of most industrial drains water and vice versa in case of Galvanized and steel factory drains water where the permanent hardness (825 mg/l) exceeds the temporary one (13 mg/l). In general, the permanent hardness of industrial drains water (215 mg/l, 31%) exceeds the temporary one (165 mg/l, 24%) as in table (3). This may be due to local contamination by permanent salts in such drains.

The mean values of total, temporary and permanent hardness of shallow groundwater reached 525 (73%), 292(41%) and 232 mg/l (32%) in the fresh water and 880 (39%), 244(11%) and 636 mg/l (28%) in the brackish water, respectively (Table 3). These data indicate an increase in total and permanent hardness with increasing water salinity and vice versa in case of temporary hardness. Also, the rate of increase in total hardness with increasing water salinity is about 1.7 folds, following the change of water type from fresh to brackish. This is mainly attributed to the effect of leaching and dissolution of salts, leading to an increase of hardness with particular importance to the effect of NaCl concentration (effect of ionic strength) on increasing solubility of Ca^{2+} and Mg^{2+} in water (Richards, 1954, Freeze and Cherry, 1979 and Hem, 1989). This does not exclude the contribution of CO_2 and longer residence time and influence of salty water and cation exchange process. Also, the mean value of the temporary hardness exceeds the permanent one in fresh water, reflecting the recharge by fresh water from the Nile and seepage from irrigation canals and drains while the permanent hardness exceeds the temporary one in the brackish water of shallow groundwater. This is due to leaching and dissolution of permanent salts from downward infiltration of the excess irrigation water of cultivated soils and seepage of irrigation canals and drains as well as industrial drains where the shallow groundwater is of unconfined type.

The total, temporary and permanent hardness in the deep groundwater are 391 (49%), 266 (33%) and 125 mg/l (16%), respectively (Table 3). This means that the temporary hardness exceeds the permanent one in deep groundwater, reflecting only the direct recharge by fresh water from the River Nile where such aquifer is considered as of semi-confined and confined types.

Geochemical Classification Based on Ion Relationships

The ions dominance in the Nile water (Table 1) follows the orders: $Ca^{2+} > Na^+ > Mg^{2+}$ or $Ca^{2+} > Mg^{2+} > Na^+$ as cations and $HCO_3^- > Cl^- > SO_4^{2-}$ as anions. Consequently, the main chemical water type is Ca-HCO_3.

Concerning the ion dominance in El Khashab and El Hagger canals water (fresh water), three different sequences from North to South in accordance with water flow of such canals are recognized:

i) $Na^+ > Ca^{2+} > Mg^{2+}$ or $Ca^{2+} > Mg^{2+} > Na^+$ or $Ca^{2+} > Na^+ > Mg^{2+}$ and $HCO_3^- > SO_4^{2-} > Cl^-$ or $HCO_3^- > Cl^- > SO_4^{2-}$, with Na-$HCO_3$ and Ca-HCO_3 chemical types in 50 % of the samples. These chemical types and sequences of ions are nearly the same as Nile water and anions dominance reveals a less advanced stage of hydrochemical evolution in such water.

ii) $Ca^{2+} > Mg^{2+} > Na^+$ and $SO_4^{2-} > Cl^- > HCO_3^-$ with Ca-SO_4 type in 13% of the samples. This indicates the solution of a local terrestrial source of sulfate such as gypsum, anhydrite, glauberite ($Na_2SO_4.10H_2O$) and epsomite ($MgSO_4.7H_2O$), reflecting the probability of existence of gypsum veins in the formation traversed by canals. This anions dominance reveals an intermediate (transitional) stage of hydrochemical evolution in such water.

iii) $Na^+ > Ca^{2+} > Mg^{2+}$ or $Na^+ > Mg^{2+} > Ca^{2+}$ and $Cl^- > HCO_3 > SO_4^2$ or $Cl^- > SO_4^{2-} > HCO_3$ with Na-Cl chemical type in 37 % of the samples. This anions dominance reveals a more advanced stage of hydrochemical evolution in such water.

TABLE (1). Chemical analysis of water samples in Helwan–El Saaf area.

Well	pH	EC	Concentration in mg/l											
NO.		(µS/cm)	TDS	TH	CH	NCH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}	Cl^{-}	Ass
							River Nile								
30	8.0	448	225.89	158	116	42	33.55	17.98	24	5	-	141.64	31.78	42.76	IV
40	7.5	466	264.84	171	152	19	35.53	19.78	36	4	-	184.92	36.68	40.39	II
44	8.3	448	238.7	212	179	33	47.37	22.78	12	4	15.4	187.11	10.26	33.26	IV
							Agricultural canals								
11	7.5	520	283.13	168	161	7	35.48	19.18	40	6	15.4	165.24	44	40.39	II
15	7.7	650	382.48	217	217	0	49.35	22.78	58	8	7.74	251.8	51.32	59.39	I
19	6.6	578	294.9	197	155	42	51.32	16.78	30	8	7.74	173.11	57.02	37.51	II
24	7.6	1370	780.3	266	253	13	55.27	31.17	200	12	38.7	282.21	50.2	251.84	I
34	7.2	1730	802.03	395	226	169	71.06	52.76	130	40	11.6	251.8	20.20	350.5	IV
36	7.6	540	319.7	232	213	19	55.27	22.78	32	3	19.3	220.87	36.52	40.39	II
39	7.6	2190	1123.4	691	200	491	146.07	79.14	130	5	15.4	212.46	420.74	220.67	V
41	8.5	1712	1046.0	523	129	394	134.23	45.57	180	10	7.74	141.64	150.81	446.87	VI
							Irrigation drains								
1	7.1	2780	1656.4	592	152	440	106.48	79.21	350	8	7.74	169.18	550	470.4	III
5	7.5	3200	1706.8	716	226	490	157.92	77.94	380	19	30.9	212.46	490.25	550.69	III
8	7.6	2870	1611.5	508	168	340	110.84	56	380	12	15.4	173.11	380.32	560.7	III
10	7.6	1690	973.5	444	175	269	110.54	40.77	190	13	11.6	188.85	40	473.2	VI
12	7.7	570	295.5	180	155	25	40.37	19.18	40	9	-	188.85	52.58	40.39	II
							Industrial drains								
2	6.0	2610	1137.8	838	13	825	296.1	23.94	80	10	-	15.73	40.35	679.5	VI
20	7.3	810	460.69	217	174	43	57.24	17.98	80	12	15.4	180.98	113.85	73.65	II
28	8.1	600	336.9	228	168	60	55.7	21.58	36	5	15.4	173.11	67.16	49.89	II
29	7.8	1400	719.23	474	323	151	90.8	59.96	75	10	-	393.45	144.25	142.5	IV
31	8.0	1318	786.13	148	148	0	23.68	21.58	150	98	-	224.26	250.7	130.0	I

Cont. table (1)																
Shallow groundwater (less than 30 m depth)																
4	7.7	4200	2498.6	666	227	439	157.92	65.95	650	28	7.74	220.33	576	902.8	III
6	7.1	3200	1775.6	710	200	510	165.81	71.95	370	17	27.1	188.85	470.94	558.4	III
7	6.9	3250	1782.6	685	232	453	165.81	65.95	370	17	38.7	204.59	300.33	722.49	V
9	7	6000	3686.3	1651	245	1406	364.8	179.9	720	15	38.7	220.33	757.4	1500.4	V
13	7.2	981	520.7	291	232	59	59.09	34.76	75	14	38.7	204.59	120.8	76.02	II
14	7.4	1050	532.47	291	270	21	59.22	34.76	90	17	46.4	310.82	75	54.64	I
16	7.3	800	417.5	247	240	7	59.22	23.98	70	7	46.4	251.8	8.95	76.02	I
17	7.2	1490	765.6	395	249	146	90.8	40.77	120	26	38.7	224.26	118.15	210.02	IV
18	7.4	2750	1586.5	691	316	375	98.7	107.9	310	4	27.1	330.48	461.1	412.41	II
21	7	2180	1176	691	161	530	157.92	71.95	160	12	19.3	157.38	200.5	475.6	VI
22	7.1	1650	910.79	581	448	133	149.76	50.36	110	8	15.4	514.94	200.93	118.79	II
33	7.2	2590	1346.3	1036	316	720	296.1	71.95	90	5	19.3	346.23	210.36	480.5	VI
35	7.2	1120	596.6	434	312	122	75.01	59.96	55	4	-	380.48	117.35	95.03	VI
38	7.2	2530	1178.7	789	543	246	177.66	83.94	120	5	15.4	630.61	280.79	180.5	II
42	7.5	1400	736.12	503	136	367	106.59	57.56	80	4	-	165.24	110.55	294.8	VI
43	7.1	1483	771.7	513	307	206	134.23	43.17	80	12	11.6	350.17	120.85	194.8	V
Deep groundwater (more than 30 m depth)																
23	7.4	1180	593.05	405	336	69	75.01	40.77	80	9	38.7	330.49	89.3	95.03	II
32	7.2	1212	617.55	472	284	188	90.08	59.96	55	5	-	346.23	113.15	120.53	IV
37	8.1	2900	1168.1	296	177	119	55.27	38.37	330	22	15.4	184.92	30.15	584.4	IV

TH= Total hardness. CH = Temporary hardness. NCH = Permanent hardness . Ass = Assemblage of hypothetical salts combination.

TABLE (2). Heavy metals, minor, trace constituents and biological analyses of water samples (mg/l) in Helwan-El Saaf area.

Well No.	Al^{3+}	B^{3+}	Fe^{3+}	Mn^{2+}	Sr^{2+}	V^{2+}	Zn^{2+}	SiO_2	Br^-	I^-	BOD	COD	TOC	PO_4^{3-}	NO_3^-	NH_4^+	NO_2^-	S^{2-}
River Nile																		
30	0.1001	<0.006	0.681	0.1222	0.3116	0.0504	0.0794	0.518	1.2	0.0097			4.5	2.014	15.656	N.D	N.D	6.208
40	<0.07	<0.006	0.0011	0.0235	0.2979	0.0041	0.0007	8.699	0.96	0.0039	2.4	80	ND	0.592	2.656	5.68	N.D	-4.16
44	<0.07	<0.006	0.0077	0.0217	0.2796	0.0498	0.0571	9.371	0.83	0.0057			18	0.201	3.399	4.723	0.022	6.976
Agricultural canals																		
11	0.5581	0.0179	1.319	0.1415	0.511	0.0274	0.0772	1.037	1.4	0.0199			13	0.488	16.664	0.569	0.146	8.128
15	0.3862	0.0163	0.9399	0.4258	0.6762	0.0458	0.1437	1.886	1.0	0.008	0.6	40	18	0.181	23.328	0.268	0.177	8.512
19	5.042	0.0349	1.417	0.3223	0.5191	0.0221	0.422	1.412	0.86	0.012	2.4	10	ND	0.217	2.595	5.513	0.066	6.592
24	<0.07	0.0268	0.6096	0.3103	0.7288	0.079	0.0571	5.077	3.6	0.011			3	2.854	66.114	12.636	0.131	6.592
34	<0.07	0.1385	0.8394	0.5672	1.372	0.1042	0.0827	8.132	3.6	0.011			27	9.357	19.78	58.972	0.387	14.656
36	0.3927	<0.006	0.8977	0.1922	0.3725	0.0353	0.0306	12.586	0.97	0.004			10	0.578	1.178	1.638	0.189	6.208
39	0.0767	<0.006	0.0097	0.3244	1.501	0.1925	0.0008	22.439	3.7	0.019			ND	7.174	51.502	36.707	7.325	-23.744
41	<0.07	0.0941	0.1012	0.2108	2.378	0.0964	0.0684	5.562	4.8	0.01				0.929	4.579	9.383	0.267	5.44
Irrigation drains																		
1	0.4869	0.245	0.9742	0.1366	6.774	0.0896	0.3176	3.923	7.6	0.0349			9	1.079	7.2	1.222	0.257	8.512
5	0.529	0.4413	1.339	0.1174	11.81	0.0877	0.2904	20.00	6.9	0.0159			27.5	0.275	47.132	2.484	0.536	6.208
8	0.5695	0.3094	1.867	0.1924	7.601	0.0917	0.7359	8.994	8.8	0.0246			6	0.639	37.002	16.414	0.839	5.44
10	0.9618	0.1705	1.349	0.3233	3.932	0.0665	0.152	4.051	4.8	0.0175			15	0.697	44.432	0.316	0.636	5.44
12	0.5726	0.0183	1.012	0.1126	0.7536	0.0264	0.2996	1.089	1.0	0.009	6.00	80	ND	1.085	50.777	0.709	0.178	7.36
Industrial drains																		
2	0.4015	0.1721	57.36	1.133	1.993	0.212	203.6	4.319	7.8	0.0122			8	0.143	8.245	10.596	0.082	5.44

Cont. table(2)																		
20	0.8813	0.1113	1.803	1.772	1.446	0.0198	0.1233	16.634	1.0	0.0205			ND	0.176	11.745	N.D	0.356	5.056
28	1.426	0.0375	0.65	0.2035	0.4327	0.025	0.1782	2.069	1.2	0.0049			9	0.259	35.053	0.883	0.464	3.904
29	0.5901	0.0545	1.048	1.497	1.041	0.1039	0.1616	9.082	3.7	0.069	2.4	10	16.5	3.639	54.386	11.814	3.718	-2.24
31	<0.07	0.0278	0.077	0.5022	0.0715	0.0261	0.0328	4.586	2.2	0.016			100	1.088	17.775	7.866	0.732	6.592
Shallow groundwater (less than 30 m depth)																		
4	0.4676	0.5775	1.239	0.2091	4.3	0.1159	0.1634	2.439	12	0.0228			30	6.664	25.761	1.384	1.036	12.352
6	0.4923	0.4082	0.8324	0.0919	11.16	0.0854	0.1554	26.298	6.4	0.0199			10	0.111	53.887	0.417	0.367	13.12
7	<0.07	0.4817	8.112	0.0541	10.7	0.1018	0.1028	22.86	5.6	0.0113			9	0.219	51.908	0.123	0.117	8.512
9	0.289	0.3652	0.7522	0.1601	20.7	0.4176	0.2126	17.681	19	0.0528			13	0.128	22.909	51.556	N.D	8.896
13	0.2475	0.0485	0.4618	0.0525	17.23	0.1401	0.1425	25.563	1.0	0.015			16.5	0.092	53.055	6.703	0.027	8.512
14	0.1705	0.0602	1.214	0.1468	20.42	0.1684	2.535	34.068	1.0	0.014	3.6	160	24	0.123	45.018	N.D	0.086	7.36
16	<0.07	0.0452	0.8677	0.0666	3.469	0.0885	0.1964	32.764	1.2	0.008			2	0.047	31.787	N.D	0.112	9.28
17	0.681	0.1278	3.313	0.2165	2.254	0.0761	0.1277	23.924	2.2	0.012			ND	0.081	48.422	1.217	1.84	5.44
18	0.3363	0.9513	5.307	0.0535	2.199	0.2328	11.2	19.823	3.8	0.05			ND	0.066	51.031	N.D	2.14	5.44
21	1.589	0.0038	5.478	2.929	1.198	0.1028	0.1898	25.007	5.1	0.08			25	0.105	3.755	9.372	0.108	6.208
22	<0.07	0.0658	0.8605	0.1148	0.9427	0.1305	1.197	30.275	2.1	0.018	4.801	20	ND	0.172	28.801	6.208	2.668	-2.24
33	<0.07	0.055	1.423	0.028	7.489	0.1934	7.003	37.598	8.1	0.05			26	0.135	33.029	20.453	N.D	7.36
35	<0.07	0.0418	0.3215	0.0162	4.688	0.1372	0.6022	22.919	2.0	0.021	0.6	20	2	0.229	35.238	5.634	N.D	7.36
38	<0.07	0.0992	0.0119	1.375	1.447	0.2135	0.0036	20.528	4.6	0.04			11	0.91	41.309	41.982	7.977	-10.304
42	<0.07	0.0792	0.0018	0.9053	0.5254	0.1702	1.103	26.055	3.3	0.02			ND	0.363	19.642	12.346	0.281	5.056
43	<0.07	0.0471	0.0032	0.5894	0.973	0.1408	0.7989	25.314	3.3	0.0198			8	0.327	1.725	9.894	N.D	6.208
Deep groundwater (more than 30 m depth)																		
23	<0.07	0.0193	0.6843	0.6342	1.695	0.1317	0.0742	30.425	1.8	0.02			ND	0.132	31.521	4.543	0.464	5.056
32	<0.07	0.0585	0.3062	0.1348	3.368	0.1436	0.1084	32.141	1.9	0.038	2.4	30	3	0.263	28.17	9.105	0.016	0.064
37	<0.07	0.1171	1.069	0.106	0.6185	0.2001	1.217	15.282	9.2	0.036			212	0.56	2.803	38.561	0.589	11.968

TABLE (3). **Average and relative values of total, temporary and permanent hardness compared to the water salinity of groundwater in surface, shallow and deep groundwater of the alluvium aquifer (Helwan area and its vicinities).**

TDS mg/l	TH mg/l	CH mg/l	NCH mg/l	(TH/TDS) %	(CH/TDS) %	(NCH/TDS) %
Nile water						
Fresh water (TDS <1500 mg/l)						
243	180	149	31	74	61	13
Agricultural canals water						
Fresh water (TDS <1500 mg/l)						
629	336	194	141	53	31	22
Irrigation drains water						
Fresh water (TDS <1500 mg/l)						
635	312	165	147	49	26	23
Brackish water (TDS 1500 -5000 mg/l)						
1658	605	182	423	36	11	25
Industrial drains water						
Fresh water (TDS <1500 mg/l)						
688	381	165	216	55	24	31
Shallow groundwater						
Fresh water (TDS <1500 mg/l)						
718	525	292	232	73	41	32
Brackish water (TDS 1500 -5000 mg/l)						
2266	880	244	636	39	11	28
Deep groundwater						
Fresh water (TDS <1500 mg/l)						
793	391	266	125	49	33	16

TDS = Total Dissolves Salts

Carbonate hardness or temporary hardness (CH% of TDS) = [$Mg(HCO_3)_2$ + $Ca(HCO_3)_2$] salts as percent.

Non-carbonate hardness or permanent hardness (NCH% of TDS) = [$MgSO_4$ + $CaSO_4$ + $MgCl_2$ + $CaCl_2$] salts as percent.

The geochemical evolution of canals water changed from less advanced stage HCO_3^- > Cl^- >SO_4^{2-} at North to more advanced stage Cl^- > SO_4^{2-} > HCO_3^- at the South. This prominent change follows the expected changes according to the general gradient evolution. This is due to leaching and dissolution of terrestrial and marine salts during water movement for a long distance from North at El Maadi to South at El Saaf. Thus, this leads to water salinity increases from 283 to 1123mg/l and prominent change of ions species from less to more hydrochemical evolution.

In irrigation drain water (fresh and brackish water) as in table (1), the order of anions is HCO_3^- > Cl^- >SO_4^{2-} or Cl^- > HCO_3^- >SO_4^{2-} or Cl^- >SO_4^{2-} > HCO_3^- and the order of cations is Ca^{2+} > Na^+ >Mg^{2+} or Na^+ > Ca^{2+} >Mg^{2+} or Na^+ > Mg^{2+} >Ca^{2+}, i.e., the chemical water types are Ca-HCO_3 and Na-Cl. The former type indicates seepage from canal to drain water, i.e., the canal water No.11 lies nearby drain water No.12, (see Fig.1). The latter type reflects leaching and dissolution of terrestrial and marine salts from downward infiltration of the excess irrigation water of cultivated soils to drain water.

On the other hand, the sequence of ions of industrial drains water (fresh water) as in table (1), follows the order:
$Ca^{2+} > Mg^{2+} > Na^{+}$ or $Mg^{2+} > Ca^{2+} > Na^{+}$ or $Na^{+} > Ca^{2+} > Mg^{2+}$ or $Na^{+} > Mg^{2+} > Ca^{2+}$ or $Ca^{2+} > Na^{+} > Mg^{2+}$ and $HCO_3^{-} > Cl^{-} > SO_4^{2-}$ or $HCO_3^{-} > SO_4^{2-} > Cl^{-}$ with Ca-HCO_3, Mg- HCO_3 and Na- HCO_3 chemical types in 60 % of the samples or $SO_4^{2-} > Cl^{-} > HCO_3^{-}$ with Na-SO_4 chemical type in 20 % of the samples or $Cl^{-} > SO_4^{2-} > HCO_3$ with Ca-Cl chemical type in 20% of the samples. These chemical types Ca-HCO_3, Mg- HCO_3 and Na- HCO_3 are the same as Nile water while other chemical types reflect local contamination.

In deep groundwater samples (fresh water) as in table (1), one main category for ion is $Mg^{2+} > Ca^{2+} > Na^{+}$ or $Ca^{2+} > Na^{+} > Mg^{2+}$ and $HCO_3^{-} > Cl^{-} > SO_4^{2}$, with Ca-$HCO_3$ and Mg-HCO_3 chemical types which are the same as Nile water, indicating the only recharge from Nile water to such aquifer. Consequently, there is no detected pollution from canals, drains and shallow groundwater because such aquifer has semi-confined and confined types where the top layer is impervious bed (clay).

With regard to the ion dominance of shallow groundwater (Table 1), two main sequences are recognized:

i) $Na^{+} > Ca^{2+} > Mg^{2+}$ or $Ca^{2+} > Na^{+} > Mg^{2+}$ or $Ca^{2+} > Mg^{2+} > Na^{+}$ or $Mg^{2+} > Ca^{2+} > Na^{+}$ / $HCO_3^{-} > Cl^{-} > SO_4^{2-}$ or $HCO_3^{-} > SO_4^{2-} > Cl^{-}$, with Ca-$HCO_3$, Mg-$HCO_3$ and Na-HCO_3 chemical types in 38 % of the samples (fresh water). These chemical types and sequences of ions are nearly the same as Nile water and deep groundwater. Consequently, the anions dominance reveal a less advanced stage of Hydrochemical evolution in such water. This confirms the recharge of such aquifer from Nile water.

ii) $Na^{+} > Ca^{2+} > Mg^{2+}$ or $Na^{+} > Mg^{2+} > Ca^{2+}$ or $Ca^{2+} > Mg^{2+} > Na^{+}$ or $Ca^{2+} > Na^{+} > Mg^{2+}$ / $Cl^{-} > HCO_3 > SO_4^{2-}$ or $Cl^{-} > SO_4^{2-} > HCO_3$ with Na-Cl and Ca- Cl chemical types in 62% of the samples (fresh and brackish water). These types reflects the cation exchange between Ca^{2+} and Na^{+}. Consequently, the anions dominance reveal a more advanced stage of hydrochemical evolution in such water. These chemical types and sequences of ions suggest the contamination of the shallow groundwater by excess irrigation water and seepage from canals and drains as well as leaching and dissolution of soluble salts within aquifer matrices where such aquifer is unconfined.

Hypothetical Salt Combinations

Six main groups of salt combinations are distinguished in surface, shallow and deep groundwater samples as follows (Table 1)

Assemblage I: NaCl, Na_2SO_4, Na (HCO_3), Mg $(HCO_3)_2$, Ca $(HCO_3)_2$.

Assemblage II: NaCl, Na_2SO_4, $MgSO_4$, $Mg(HCO_3)_2$, Ca $(HCO_3)_2$.

Assemblage III: $NaCl$, Na_2SO_4, $MgSO_4$, $CaSO_4$, $Ca(HCO_3)_2$

Assemblage IV: $NaCl$, $MgCl_2$, $MgSO_4$, $Mg(HCO_3)_2$, $Ca(HCO_3)_2$.

Assemblage V: $NaCl$, $MgCl_2$, $MgSO_4$, $CaSO_4$, $Ca(HCO_3)_2$.

Assemblage VI: $NaCl$, $MgCl_2$, $CaCl_2$, $CaSO_4$, $Ca(HCO_3)_2$.

Regarding hypothetical salt combinations in Nile water (Table 1), two main assemblages (II and IV) are detected. The presence of Na_2SO_4 and $MgCl_2$ salts in those assemblages are true indication of dissolution of terrestrial and marine salts from continental and marine deposits, respectively, in addition to contribution of the cation exchange process. The presence of $Mg(HCO_3)_2$ and $Ca(HCO_3)_2$ salts indicates possible contamination of a meteoric water. Therefore, such water acquires its chemical composition from leaching and dissolution of terrestrial and marine salts with some contribution of cation exchange process.

The combination between major anions and cations reveals the formation of four main groups of hypothetical salts combinations (I, II, IV and V) in the canal water from North to South (Table 1).

These types of hypothetical salt combinations (I, II, IV and V) are nearly close to that of the Nile water. Assemblage I represents an earlier stage of chemical development than that of assemblages II, IV and V. Also, assemblage I (three bicarbonate salts) reflects a pure meteoric origin of such water, while assemblages II and IV (two bicarbonate salts) and V (two chloride salts) characterize irrigation canal water which is affected by leaching and dissolution of continental and marine deposits. Assemblage V represents a more advanced stage of chemical development than that of assemblages IV. The presence of Na_2SO_4 salt in both assemblages (I and II) combination is a true indication of dissolution of terrestrial salts from continental deposits while the presence of $MgCl_2$ salt in both assemblages (IV and V) combination is a true indication of dissolution of marine salts from marine deposits. Also, the presence of Na_2SO_4, $MgCl_2$ and $Mg(HCO_3)_2$ salts in these samples, reflects the contribution of the cation exchange process.

Aggradation in chemical development is noticed in groundwater dominated by salt assemblage I at the North (earlier stage of chemical development), where three bicarbonate salts occur, to that dominated by assemblages IV and V at the South (more advanced stage of chemical development), where two chloride salts are found. Thus, assemblage II (intermediate stage of chemical development, two sulfate salts) is considered as a transitional stage between assemblages I (continental facies water) and IV (marine facies water).

In agricultural drain water (Table 1), three groups of hypothetical salts combinations (II, III and VI) are recorded. The hypothetical salts combinations II is nearly close to the Nile and canal water while assemblage

III and VI reflect the impact of leaching and dissolution of the continental and marine salts by irrigation water of lagoonal soils with some contribution of cation exchange process. The assemblage II confirms the seepage from irrigation canals to drain water (samples 10 and 12).

In industrial drain water (Table 1), four main assemblage combinations (I, II, IV and VI) are reported. These types of hypothetical salt combinations of industrial drain water resemble the Nile and canals water. However, assemblage VI confirms the water contamination in this locality (sample No.29). Consequently, such water acquires its water quality from leaching and dissolution of terrestrial and marine salts with some contribution of cation exchange process.

In shallow groundwater (Table 1), six groups of hypothetical salt assemblages (I, II, III, IV, V and VI) are distinguished. These types of hypothetical salt combinations of shallow groundwater are represented in the Nile water (assemblages II and IV), canals water (assemblages I, II, IV and V), agricultural drain water (assemblages II, III and VI) and industrial drains water (assemblages I, II, IV and VI). This is due to leaching and dissolution of terrestrial (I, II and III) and marine salts (IV, V and VI) from aquifer matrices, downward infiltration of the excess irrigation water of cultivated soils and seepage of irrigation canals and drains, where the shallow groundwater is unconfined aquifer type. This is reflected on the increase of water salinity (3686 mg /l, brackish water type).

Aggradation in chemical development is noticed from groundwater dominated by salt assemblage I (earlier stage of chemical development), where three bicarbonate salts occur, to that dominated by assemblage VI (more advanced stage of chemical development), where three chloride salts are found. Thus, assemblage III (intermediate stage of chemical development, three sulfate salts) is considered as a transitional stage between continental facies and marine water facies. However, the prominent change does not follow the concept of changes according to the general gradient evolution, this means that chemical changes is not in accordance with general water flow from West to East within such aquifer. This can be explained on basis of different recharge sources from Nile, canals and drains with non-conspicuous trend of water flow.

In the deep groundwater (Table 1), two groups of hypothetical salt assemblages (II and IV) are detected. Those hypothetical salt combinations are similar to that of Nile water, confirming the direct recharge only from Nile water. This is supported by low water salinity (range from 593 to 1168 mg/l with a mean value 793 mg/l, fresh water type) of the concerned aquifer which has a semi-confined and confined types. Also, such hypothetical salts reflect the impact of continental (assemblage II) and marine sediments (assemblage IV) on water quality.

Minor (non-metalic) Content in Surface and Groundwater

Table (4) includes the ranges and mean values of Br^- and I^- concentrations in the surface and groundwater of Helwan area which reveal that Br^- and I^- concentrations are generally less than that of sea water (Mediterrianen sea, Br^- =167 mg/l and I^- = 0.6 mg/l) in the same time, they are more than those of Nile water (Br^-=1mg/l and I^- = 0.006 mg/l). These concentrations differ according to TDS where the concentrations of Br^- and I^- ions increase as the total water salinity increases (Table 2).

The mean values of Br^- and I^- concentrations in the deep groundwater samples (1.9 and 0.026 mg/l, respectively) are slightly high with respect to Nile water (Br^- =1 and I^- = 0.006 mg/l) and rain water (Br^- =0.08 and I^- = 0.002 mg/l) while they are less than that of sea water. This indicates the recharge of deep groundwater on account of seepage from River Nile. This may confirm that such an aquifer has continental facies with traces of marine deposits. This would be the resultant of a long recharge history of Nile water. On the other hand, the mean values of Br^- and I^- concentrations of the shallow groundwater (5.3 and 0.03 mg/l, respectively), are more than those in canals (2.5 and 0.01mg/l, respectively), irrigation drains (5.8 and 0.02 mg/l, respectively), industrial drains (3.2 and 0.03 mg/l, respectively) and deep groundwater (1.9 and 0.026 mg/l, respectively). This confirms the recharge from the Nile and water seepage from canals and drains to the shallow aquifer. Generally, the low concentrations of Br^- and I^- indicate that surface and groundwater is originally formed under continental condition rather than marine one, this would be the resultant of a meteoric origin.

The concentrations of soluble silica in the Nile water, canals and drains are nearly identical and have low values, while being obviously higher in shallow and deep groundwater (Tables 2 and 4). The low values of silica is due to the surface water equilibrium with quartz and amorphous inorganic silicates while the high values in shallow and deep groundwater are in equilibrium with clay minerals, some amorphous silica and siliceous rock-forming minerals. The mineralogical composition of the materials in contact with the water is the most important factor controlling the amount of silica in the water.

Water Pollution

Pollution of water is discussed on the basis of determining inorganic and organic pollutants as well as biological and bacteriological analyses with regard to the recommended level of contamination (WHO, 1971 a and b, 1972 and 1996).

Inorganic Pollutants

The pollution of water samples in the area of study is discussed through the measurements of trace elements, heavy metals and minor ions, including; B^{3+}, Al^{3+}, Cd^{2+}, Co^{2+}, Cr^{3+}, Cu^{2+}, Fe^{3+}, Mn^{2+}, Mo^{2+}, Ni^{2+}, Pb^{2+},

Sr^{2+}, V^{2+} and Zn^{2+} and soluble silica (SiO_2), I^-,Br^-, PO_4^{3-}, S^{2-}, NH_4^+, NO_2^- and NO_3^- as in Table (2).

TABLE (4). Range and average concentration of minor element (mg/l) in surface, shallow and deep groundwater of the alluvium aquifer (Helwan area and its vicinities).

Br^-		I^-		Soluble SiO_2	
Range	Mean	Range	Mean	Range	Mean
Nile water					
0.83-1.20	1.00	0.0039-0.0097	0.006	0.50-9.40	6.20
Irrigation canals water					
0.86-4.80	2.50	0.001-0.02	0.01	1.00-22.40	7.3
Irrigation drains water					
1.10-8.80	5.82	0.009-0.04	0.02	1.10-20.00	7.60
Industrial drains water					
1.00-7.80	3.18	0.005-0.069	0.025	2.10-16.6	7.30
Shallow groundwater					
3.30-19.00	5.50	0.02-0.05	0.03	2.40-37.60	24.60
Deep groundwater					
1.80-2.00	1.90	0.02-0.04	0.026	15.30-30.4	25.90

i) Soluble heavy metals contents

Based on the results of analysis of trace elements, heavy metals and minor ions and acceptable contaminant levels, it is clear that:

1-The ions concentration of Cd^{2+}, Co^{2+}, Cr^{3+}, Cu^{2+}, Mo^{2+}, Pb^{2+} and Ni^{2+} in all water samples are below the acceptable levels of contamination, (0.005, <0.05, 0.05, <0.05, <0.01, 0.05 and 0.1mg/l, respectively) as in Table (2).

2-For River Nile water, all samples are within the acceptable and permissible limits of contamination, (Table 2), although, about 4000 m^3/h of liquid wastes were discharged into the stream, (Abdel-Aal *et al.,* 1988). With the observation that; sample No. (30) contains a slightly high concentration of Fe^{3+} and Mn^{2+} ions (0.681 and 0.1222 mg/l, respectively) but they are still below the acceptable levels of contamination (1 and 0.5 mg/l, respectively). This is due to its location at the outlet of the waste of Iron and Steel Factory (sample No. 29).

3-For industrial drains water, high concentrations of some heavy metals (Al^{3+}, Fe^{3+}, Mn^{2+} and Zn^{2+}) are recorded in most samples, i.e., above the acceptable levels of pollution (0.2, 1, 0.5 and 5 mg/l, respectively) as in Table (2). The higher concentrations of Al^{3+}, Fe^{3+}, Mn^{2+} and Zn^2 (1.426, 57.36, 1.772 and 203.6 mg/l) are strictly confined to water samples Nos. 28, 2, 20 and 2, respectively. Very high concentrations of Zn^{2+} and Fe^{3+} are found in sample No. (2), which is the outlet of Galvanic factory.

4-For irrigation canals water, most samples (63%) have high concentrations of soluble heavy metals more than the recommended levels of pollution (Table 2). For instance, water samples Nos. 11, 15, 19 and 36 have high Al^{3+} concentrations (0.56, 0.39, 5 and 0.39 mg/l, respectively) more than the acceptable level of pollution (0.2 mg/l). Also, water samples Nos. 11

and 19 have high Fe^{3+} concentrations (1.32 and 1.42 mg/l, respectively) more than the acceptable level of pollution (1 mg/l). The higher Al^{3+} and Fe^{3+} concentrations (5 and 1.42 mg/l, respectively) are recorded in water sample No. 19, located beside Iron and Steel Factory. In addition, higher Mn^{2+} concentration (0.57 mg/l) is detected in irrigation canal (water sample No.34) that contains sanitary wastewater. The results of soluble heavy metals analysis (Al^{3+}, Fe^{-3+}, Mn^{2+}, Zn^{2+}, Sr^{2+} and V^{2+}) indicate their higher concentrations in El Khashab and El Hagger canals water (mean values 0.83, 0.77, 0.31, 0.11, 1.01 and 0.08), about 2 and 10 times more than in the Nile stream (mean values 0.08, 0.20, 0.06, 0.05, 0.30 and 0.04, respectively) as in table (5). This can be attributed to the deposition of most of the waste suspended materials in those canals, which increase the particle water interaction and subsequent release of such soluble metals. Consequently, the distribution of soluble heavy metals ions in the irrigation water was mainly affected by their occurrence in the liquid wastes discharged into them. The industrial complex at Helwan produces large amount of liquid wastes, about, 115,000 m^3/ day of liquid wastes loaded by about 3.39 tons/day of suspended solids which currently are discharged into El Khashab and El Hagger canals, drains and the River Nile and certainly pollute such water (Abdel-Aal *et al.*, 1988).

5- Most drains water samples have high concentrations of Al^{3+} and Fe^{3+} (range 0.49-1.00, 1-1.9 mg/l, respectively) that exceed the acceptable level of pollution (Al^{3+} =0.2 and Fe^{3+} =1 mg/l) as in table (2). The results of soluble heavy metals (Al^{3+}, Fe^{3+}, Mn^{2+}, Zn^{2+}, Sr^{2+} and V^{2+}) indicate their higher concentrations in such water (mean values of 0.62, 1.30, 0.18, 0.36, 6.17 and 0.07, respectively), about 3 and 21 folds more than in the Nile stream (mean values of 0.08, 0.20, 0.06, 0.05, 0.30 and 0.04, respectively) as in table (5). This is due to the discharge of large amounts of irrigation drainage water containing impurities of soluble heavy metals from fertilizers and pesticides application together with industrial wastes discharged into such drains.

6-For shallow groundwater samples, 56% of water samples contain low concentrations of soluble heavy metals (Al^{3+} and Fe^{3+}) which are less than the permissible limits of pollution and vice versa in the rest of samples (44%) which have higher concentrations of Al^{3+} and Fe^{3+} ions more than the acceptable levels of pollution (Table 2). On the other hand, the majority of samples (87%) have low soluble Mn^{2+} and Zn^{2+} concentrations, i.e., below the acceptable limits of pollution (0.5 and 5 mg/l, respectively), but few samples (13%) have higher soluble Mn^{2+} and Zn^{2+} concentrations above the acceptable limits of pollution. The higher ions concentrations of Al^{3+}, Fe^{3+}, Mn^{2+} and Zn^{2+} (1.59, 8.11, 2.93 and 11.2 mg/l, respectively) are strictly confined to water samples No. 21, 7, 21 and 18, respectively, (Table 2). These shallow groundwater are located in vicinity of the canals and drains rich in soluble heavy metals due to disposal industrial wastes and sanitary wastewater. Generally, the results of soluble heavy metals analysis (Al^{3+}, Fe^{2+}, Mn^{2+}, Zn^{2+}, Sr^{+2} and V^{2+}) indicate their presence in higher concentrations in such water (mean values of 0.30, 1.89, 0.44, 1.61, 6.86 and 0.16 mg/l, respectively) about 4 and 35 times more than in the Nile stream (mean values of 0.08, 0.20, 0.06, 0.05, 0.30 and 0.04, respectively) as in table (5). Also, the soluble heavy metals (Fe^{2+}, Mn^{2+}, Zn^{2+}, Sr^{+2} and V^{2+}) of such shallow aquifer (mean values of 1.89, 0.44, 1.61, 6.86 and 0.16 mg/l, respectively) are much higher than those in irrigation canals (mean values of 0.77, 0.31, 0.11, 1.01 and 0.08, respectively) and drains water (mean values of 1.3, 0.18, 0.36, 6.17 and 0.07, respectively) as in table (5). This confirms seepage from canals and drains which contain relatively high soluble heavy metals as well as downward infiltration of excess amount of irrigation water (fertilizers and pesticides application) to such aquifer, where the shallow groundwater is unconfined aquifer type (free water table) according to RIGW (1978). This does not exclude the contribution of groundwater and minerals of aquifer matrices interaction, which leads to some release of more soluble heavy metals. Therefore, most shallow groundwater are seriously polluted by soluble heavy metals especially near the industrial and agricultural liquid wastes.

7-In general, the deep groundwater samples have low concentrations of soluble heavy metals, i.e., below the acceptable level of contamination. However, some water (samples Nos. 37 and 23) have slightly high concentrations of heavy metals especially Fe^{3+} and Mn^{2+} (1.07 and 0.63 mg/l, respectively) over the acceptable levels of pollution (1 and 0.5 mg/l). This is attributed to the nature of deep groundwater which is considered as semi-confined aquifer type (Abdel Daiem, 1971). Generally, the concentrations of soluble heavy metals (Al^{3+}, Fe^{3+}, Mn, Zn^{2+}, Sr^{2+} and V^{2+}) in deep groundwater samples (mean values of 0.07, 0.69, 0.29, 0.47, 1.89 and 0.16 mg/l, respectively) are 3 to 10 times higher than in the Nile stream (mean values of 0.08, 0.20, 0.06, 0.05, 0.30 and 0.04, respectively) as in table (5). This is mainly due to interaction between groundwater and minerals of aquifer matrices, which leads, to a great extent, to the release of most soluble heavy metals.

The concentrations of soluble heavy metals (Al^{3+}, Fe^{3+}, Mn^{2+}, Zn^{2+} and Sr^{2+}) in shallow groundwater samples (mean values of 0.30, 1.89, 0.44, 1.61 and 6.86 mg/l, respectively) are 2 to 4 times higher than that in the deep groundwater samples (mean values of 0.07, 0.69, 0.29, 0.47 and 1.89 mg/l, respectively) as in table (5). Therefore, most shallow groundwater samples (uncofined type) are seriously polluted by the soluble heavy metals while the deep groundwater (semi-confined and confined types) was slightly polluted by the soluble heavy metals.

TABLE (5). Range and average values of soluble heavy metals (mg/l) in surface, shallow and deep groundwater of the alluvium aquifer (Helwan area and its vicinities).

Al^{3+}		Fe^{3+}		Mn^{2+}		Zn^{2+}		Sr^{2+}		V^{2+}	
Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Nile water											
0.07 - 0.10	0.08	0.001-0.68	0.20	0.022-0.122	0.056	0.0007-0.079	0.046	0.28-0.312	0.30	0.004-10.05	0.035
Irrigation canals water											
0.07-5.04	0.83	0.10-1.42	0.77	0.14-0.57	0.31	0.008-0.422	0.11	0.37-2.28	1.01	0.022-0.193	0.08
Agricultural drains water											
0.49-0.96	0.62	0.97-1.87	1.30	0.11-0.32	0.18	0.15-0.74	0.36	0.75-11.81	6.17	0.026-.092	0.072
Industrial drains water											
0.07-1.43	0.67	0.077-57.36	12.19	0.20-1.77	1.02	0.033-203.60	40.8	0.072-1.99	1.00	0.10-0.21	0.08
Shallow groundwater											
0.07-1.59	0.30	0.002-8.11	1.89	0.02-2.93	0.44	0.004-11.2	1.61	0.53-20.70	6.86	0.085-0.42	0.16
Deep groundwater											
0.07	0.07	0.32-1.07	0.69	0.11-0.63	0.29	0.07-1.22	0.47	0.62-3.37	1.89	0.13-0.20	0.16

ii) Boron content

A low concentration of boron in the water samples of the study area ranges from less than 0.006 to 0.48 mg/l, i.e., below the acceptable limits for pollution (0.5 mg/l) as in table (2). The relatively high concentrations of B^{3+} (0.6 and 1 mg/l) are found only in shallow groundwater samples Nos. 4 and 18, respectively. The former is due to pollution from domestic sewage water rich in boron content while the latter is due to pollution from the excessive irrigation water.

iii) Phosphate content

In the River Nile samples, phosphate ions concentration ranges from 0.2 (sample No.44) to 2.01 mg/l (sample No. 30) as in table (2). The high PO_4^{3-} concentration (2.01 mg/l) refers to the disposal of industrial waste effluents from Stainless Steel Factory drain water (sample No. 29, 3.6 mg/l) to Nile water which is adjacent to such drain. The maximum permissible concentration of phosphate ions in surface water is 1 mg/l (Dojlido and Best, 1992).

On the other hand, small amounts are found in shallow and deep groundwater except for the shallow groundwater sample No. 4 where the concentration of phosphate ions is exceptionally high (6.7mg/l) as in table (2). This is due to the sanitary wastewater mixed with such water (depth to water from ground surface is few centimeters).

For the irrigation canals, the concentration of PO_4^{3-} ranges between 0.18 and 9.4 mg/l (Table 2). The high concentrations of PO_4^{3-} (7.2 and 9.4 mg/l) are recorded in the water samples Nos. 39 and 34, respectively. This is attributed to the disposal of sanitary wastewater to irrigation canals in these localities.

Concerning the irrigation and industrial wastes, they have low concentration of PO_4^{3-} (0.14 – 1.1 mg/l) except for Stainless Steel Factory drain water sample No. 29 (3.6 mg/l) where industrial sanitary wastewater effluents represent important sources of phosphorus in natural water.

iv) Nitrogen compounds

The nitrogen compounds play an important role in many processes that takes place in natural water. Nitrogen is also one of the basic components of proteins, so it can enter surface water in sewage and industrial wastewater from the breakdown of proteins and other nitrogenous compounds. Nitrogen fertilizers are used extensively in agriculture, and the excess over crop requirements is mostly leached into drainage water.

1. Nitrate content

In the Nile water samples, low nitrate concentrations (2.7-3.4 mg/l) is recorded except for sample No. 30 which has relatively high concentration (15.7 mg/l) but still below the level of pollution (45 mg/l) as in table (2). This is due to its location in contact to the end of the pathway of waste of Iron and Steel Factory (sample No.29) which has high NO_3^- concentration (54.4 mg/l), leading to an increase of nitrate concentration in Nile water at such location.

Concerning irrigation water, the NO_3^- concentration ranges widely between 1.2 and 23.3 mg/l. The relatively high concentration of NO_3^- compared to that of Nile water is referred to the excess amount of nitrogen fertilizer used in this cultivated area but NO_3^- concentration is still below the acceptable level of pollution. Moreover, the high nitrate contents (51.5 and 66.1 mg/l) are recorded in two samples (Nos. 24 and 39) that are considered to be polluted. This is rendered to disposal of domestic sanitary wastewater, rich in nitrate content to canals water in such localities.

In agricultural drains water, high NO_3^- concentrations (37- 50.8 mg/l) are detected except for sample No. 1(7.2 mg/l), reflecting the excess amount of nitrogen fertilizer used. Actually, wastewater high in nitrate is adequate for crops. On the other hand, in most industrial drains water samples (except for sample 29, 54.4 mg/l), NO_3^- ranged from 8.2 to 35.1mg/l, i.e., below the acceptable level of pollution (> 45mg/l).

Nitrate ions concentration in deep groundwater is below the acceptable level of pollution where it ranges from 2.8 to 31.5 mg/l, confirming the aquifer type (semi-confined aquifer). On the other hand, concentrations of NO_3^- (1.7- 41.3 mg/l with a mean value of 24.4) are found in most samples of shallow groundwater (62%) but still below the acceptable level of pollution. About 38% of samples are polluted. Generally, the high concentrations of nitrate ions are due to the excess nitrogen fertilization, seepage of irrigation canals and drains as well as the disposal of sanitary wastewater rich in nitrate content in canals and drains water in some localities. For instance, shallow groundwater samples Nos. 6 and 7 are located nearby Ezbet El Walda drain (water samples Nos. 5 and 8, respectively). This leads to increase the NO_3^- concentration of such shallow groundwater samples (53.9 and 51.9 mg/l) as a result of seepage from drain to shallow aquifer (Fig. 1). Also, shallow groundwater samples Nos. 13 and 14 are located nearby domestic installations (sanitary wastewater and septic tanks, rich in nitrate content), leading to the increase of nitrate ions concentration of such shallow groundwater samples (53 and 45 mg/l) as a result of downward infiltration of sanitary wastewater to shallow groundwater. With regard to the shallow groundwater sample No. 38 which contains relatively high nitrate concentration (41.3 mg/l) as a result of seepage of canal water polluted by sanitary wastewater at this locality (canal water sample No. 39, 51.5 mg /l) as in fig. (1).

2. Nitrite content

Concentration of NO_2^- in the water samples within the study area ranges from a trace amount up to 3.7 mg/l, i.e., below the acceptable level of pollution (4.5 mg/l) as in table (2). An exceptional case is found in shallow groundwater sample No. (38), which has high NO_3^- concentration (7.9 mg/l), indicating that a high contamination by nitrite ions as a result of seepage from canal water polluted by sanitary wastewater at this locality (canal water sample No. 39, 7.3 mg /l) as in fig. (1).

3. Ammonia content

A range between non-detected and 0.42 mg/l of NH_4^+ concentration is detected in some shallow groundwater samples (31%), confirming non-polluted water, i.e., below of acceptable level of contamination (0.5 mg/l). High ammonium concentrations (1.2- 51.6 mg/l) are found in most shallow groundwater samples (69%), indicating pollution through disposal of sanitary wastewater or organic waste and fertilizers as ammonium sulfate $(NH_4)_2SO_4$, ammonium nitrate NH_4NO_3, ammonium phosphate $(NH_4)_3PO_4$ and urea $CO(NH_2)_2$. In details, high ammonium concentration (51.6 mg/l) of shallow groundwater No. 9 that is located close to drainage irrigation (sample No. 10) rich in ammonium fertilizer. Also, shallow groundwater sample No.33 having relatively high ammonium concentration (20.5 mg/l) lies nearby irrigation canal (sample No.34) rich in ammonium ions concentration (59 mg/l) as a result of sanitary wastewater disposal in such canal. With regard to the shallow groundwater sample No. 38 having high ammonium concentration (42 mg/l), this is due to seepage from irrigation canal (sample No.39) rich in ammonium fertilizer and sanitary wastewater (36.7 mg/l).

Relatively high concentrations of NH_4^+ (4.7 –5.7mg/l) are found in River Nile samples (Nos. 40 and 44 at Kafr El Elw, respectively), i.e., above the acceptable level of contamination (0.5 mg/l). This may be related to disposal of sanitary wastewater in the Nile at this locality. On the other hand, sample No. 30 has non-detectable concentration of NH_4^+.

In irrigation canals, NH_4^+ concentration ranges between 0.6 (sample No.19) to 59 mg/l (sample No.34). In the latter, this is related to disposal of sanitary wastewater while in the former, it is due to seepage from irrigation water containing ammonium fertilizer. With respect to irrigation canal sample No. 15, it has low ammonium concentration (0.3 mg/l).

Finally, the range of ammonia concentrations is between 1.2 to 16.4 mg/l in agricultural drain water. The high ammonium ions concentration in the agricultural drainage reflects pollution by fertilizers and pesticides. Similar results are obtained for most industrial drain water samples, where high NH_4^+ concentration (0.9-11.8 mg/l), indicating water pollution as a result of nitric acids and dyes used in Stainless Steel Factory and Helwan factory for Textile and Spining drains, respectively.

In deep groundwater, relatively high NH_4^+ concentrations (4.5-9.1 mg/l) indicate contamination. Moreover, very high NH_4^+ concentration (38.6 mg/l) is recorded in sample No.37, indicating pollution from sanitary wastewater beside such deep well. In addition, the depth to water is about 0.5 m from land surface and the aquifer is considered semi-confined at this locality.

Noteworthy to mention that NO_3^- is considered the final stage of NH_4^+ oxidation to NO_2^-, then to NO_3^- in the presence of bacteria and oxygen. Consequently, the authors believe that the presence of high ammonium concentration (more than nitrate) in shallow and deep groundwater samples confirms that the concerned water was subjected to reducing conditions more than oxidizing ones. On the contrary, when NO_3^- concentration exceed NH_4^+ in such water, this confirms the prevalence of oxidizing conditions.

v) Sulfide content

Sulfide is a pollutant (> 1 mg/l) in most water samples of the area under investigation where it forms 3.9 up to 14.7 mg/l. The S^{2-} presence is attributed to the depletion of oxygen and reduction of sulfate ions, caused by biochemical degradation of high content of organic matter.

Oxygen demand and evaluation of organic pollution load

Various methods have been used to estimate the requirement of given water for oxygen or to evaluate the organic pollution load in a quantitative way. These include measurement of BOD, COD and TOC.

Biochemical Oxygen Demand (BOD)

The representative surface, shallow and deep groundwater samples have BOD values from 0.6 to 4.8 mg/l, indicating non-contamination level since the BOD value of non-polluted fresh water is 6 mg/l. These results are confirmed by the occurrence of pathogenic microorganism belonging to family interobacteriaceae in such water (Table 6).

Chemical Oxygen Demand (COD)

The results of COD determinations obviously do not correspond to values obtained by BOD determination where COD values are higher than BOD values, but they may be helpful in comparing conditions in a stream at one time with those at another time (Table 2).

Results revealed that the representative surface, shallow and deep groundwater samples have high values of COD (20-160 mg/l) more than the acceptable level of pollution for fresh water (10 mg/l), except for some irrigation and industrial water (Nos. 19 and 29, respectively) which have values of COD concentration lower than 10 mg/l, indicating non-polluted water, i.e., these water have low material loads.

Total Organic Carbon (TOC)

In the Nile water samples, the TOC values range from non detectable to 4.5 mg/l, indicating non-polluted water while the higher value (18 mg/l) is only found in sample No. 44 at Kafr El Elw, this may be related to disposal of sanitary wastewater in River Nile at this locality.

In irrigation canals, the TOC concentration is generally high (10 to 27 mg/l), indicating that water is polluted as a result of excessive amount of irrigation water containing fertilizers and pesticides beside the disposal of sanitary wastewater rich in organic carbon. In contrast, the water samples Nos. 19, 24 and 39 have low values of TOC (non detectable to 3 mg/l), i.e., below the acceptable level of pollution (10 mg/l). On the other hand, the agricultural drains are characterized by lower values of TOC (nil to 9 mg/l) whereas some water samples (Nos. 5 and 10) have TOC concentration (15-27.5 mg/l) more than the acceptable level of pollution. This is attributed to excess amount of irrigation water containing organic fertilizers and pesticides. With regard to the industrial drainage water, the TOC concentrations range from nil to 9 mg/l, whilst some water samples have high values (16.5-100 mg/l) more than the acceptable level of pollution. The high TOC values indicate that industrial water (samples Nos. 29 and 31) are rich in organic dyes (Helwan factory for Textile and Spining drain) and coal (Iron and Steel Factory drain).

In the shallow groundwater, the TOC values vary from non detectable to 30 mg/l. Thus, 50% of the shallow groundwater samples are polluted while the rest of samples are non-polluted where the TOC of clean water is usually in the range of a few mg /l, whilst polluted water have values in the tens of mg/l. The high value of TOC is related to disposal of sanitary wastewater in agricultural canals and drains that infiltrate to such aquifer as well as downward infiltration of excess amount of irrigation water containing fertilizers and pesticides. Thus, these are rich in total organic carbon. On the other hand, the deep groundwater samples have low values of TOC (nil to 3 mg/l) indicating non-polluted water. The exceptionally high

TOC content (212 mg/l) is recorded in water sample No.37, indicating severe pollution from sanitary wastewater for such deep well.

Pollution by Bacteria

Some water samples representing all water types from the area under investigation were analyzed for microorganisms belonging to family interobacteriaceae as an indicator of potential bacteria contamination (Table 6). The obtained results show that:

1- Sample representing Nile water (No.40) is not infected by bacteria.

2- Some samples representing agricultural canal water are infected by *E.coli*, *Citobacter*, *Klebsiella*, *Salmonella* and *Shigella* (sample No.24) and *E.coli*, *Citobacter*, *Klebsiella*, and *Salmonella* (sample No.34). This is due to disposal of sanitary wastewater in such canal water.

3- Sample representing industrial drain water (No.28) is infected by *Shigella*.

4- Shallow groundwater samples (Nos. 13, 21 and 35) are not infected by bacteria. On the other hand, *Proteus* infects the shallow groundwater sample (No.42).

5- Deep groundwater (No. 32, drinking station) is not infected by bacteria. However, *E. coli* and *Klebsiella* infect deep groundwater sample (No.23).

Diseases caused by members of interobacteriaceae:

1- *E. coli* is a frequent cause of urinary tract infection, appendicitis, peritonitis and cholecystitis.

2- *Klebsiella* is a frequent cause of: Fried Lander's pneumonia by *K. pneumoniae* and Rhinoscleroma by *K. rhinosclromatis*. Urinary tract infection and some other suppurative infections by *K. aerogenes*

3- The *Citrobacter* relationship to disease is doubtful.

4- *Salmonella* cause enteric fever and food poisoning.

5- *Shigella* cause Bacillary dysentery and Shigella toxin.

6- *Proteus* cause wound infection, otitis media and urinary tract infection.

TABLE (6). Pathogenic microorganisms of water samples in cpu/ml (Cell per unit /ml).

Well no.	E. coli	Citrobacter	Klebsiella	Salmonella	Shigella	Proteus
13	--	--	--	--	--	--
21	--	--	--	--	--	--
23	3	--	2	--	--	--
24	240	370	360	190	80	--
28	--	--	--	--	1	--
32	--	--	--	--	--	--
34	140	210	320	260	--	--
35	--	--	--	--	--	--
40	--	--	--	--	--	--
42	--	--	--	--	--	1
Permissible Limits	<9	<9	<1	<1	<1	<1

In light of the foregoing results, one can conclude that the surface water of Nile, canals and drains as well as the shallow and deep groundwater exploited in the area are variably polluted from different sources.

CONCLUSION

Water salinity shows a fresh water type in River Nile, irrigation canals, industrial drains and deep groundwater (semiconfined and confined types) while water salinity varies from fresh to brackish water types in agricultural drains and shallow groundwater(unconfined type).

The hardness in Nile and El Khashab and El Hagger canals water is, to a great extent, temporary one, reflecting a meteoric origin of such water. The temporary hardness exceeds the permanent one in fresh water and vice versa in case of brackish water of agricultural drains, where the permanent hardness exceeds the temporary one, this may be due to local contamination by permanent salts in such drains.

Also, the mean value of the temporary hardness exceeds the permanent one in fresh water of shallow groundwater, reflecting the recharge by fresh water from the Nile and seepage from irrigation canals and drains while the permanent hardness exceeds the temporary one in the brackish type of shallow groundwater. This is due to leaching and dissolution of permanent salts from downward infiltration of the excess agricultural water and seepage of irrigation canals and drains as well as industrial drains. On the other hand, the mean value of the temporary hardness exceeds the permanent one in deep groundwater, reflecting only the direct recharge by fresh water from the River Nile.

Concerning the ion dominance in the River Nile, the main chemical water type is Ca-HCO_3 while the main chemical water types of irrigation canals from North to South, in accordance with water flow are Na-HCO_3 and Ca-HCO_3, Ca-SO_4 and Na-Cl types. This is due to leaching and dissolution of terrestrial and marine salts during water movement for a long distance from North (El Maadi) to South (El Saaf). In agricultural drains, the chemical water types are Ca-HCO_3 and Na-Cl. The former type indicates seepage from canal water. The latter type reflects leaching and dissolution of terrestrial and marine salts from downward infiltration of the excess irrigation water of cultivated soils. The main chemical water types in industrial drains are Ca-HCO_3, Mg- HCO_3 and Na- HCO_3 , Na-SO_4 and Ca-Cl types. These types Ca-HCO_3, Mg-HCO_3 and Na- HCO_3 are the same as Nile water while other types reflect local contamination.

In deep groundwater samples, Ca-HCO_3 and Mg-HCO_3 chemical types which are the same as the Nile water, indicate the only recharge from Nile water to such aquifer. Consequently, there is no pollution from canals, drains and shallow groundwater.

The main chemical water types in some shallow groundwater samples are $Ca\text{-}HCO_3$, $Mg\text{-}HCO_3$ and $Na\text{-}HCO_3$. These types are nearly the same as the Nile and deep groundwater, confirming that the recharge of such aquifer is mainly from Nile water. On the other hand, the main chemical water types in most shallow groundwater samples are Na-Cl and Ca-Cl. These types suggest the contamination of the shallow groundwater with excess irrigation water and water seepage from canals and drains as well as leaching and dissolution of soluble salts within aquifer matrices.

In the shallow groundwater, six groups of hypothetical salt assemblages (I, II, III, IV, V and VI) are distinguished. These types of hypothetical salt combinations of shallow groundwater are represented in the Nile (assemblages II and IV), canals (assemblages I, II, IV and V), agricultural drains (assemblages II, III and VI) and industrial drains (assemblages I, II, IV and VI) water. These six groups of salts combination of shallow groundwater confirm seepage of canals and drains water, as well as downward infiltration of the excess irrigation water. This does not exclude the contribution of leaching and dissolution of terrestrial (I, II and III) and marine salts (IV, V and VI) within aquifer matrices. In the deep groundwater, two groups of hypothetical salt assemblages are detected (II and IV). Those hypothetical salt combinations are similar to that of Nile water, confirming the direct recharge only from Nile water. Also, such hypothetical salts reflect the impact of continental (assemblage II) and marine sediments (assemblage IV) on water quality.

The mean values of Br^- and I^- concentrations of the shallow groundwater are more than those of canals, irrigation drains, industrial drains and deep groundwater. This confirms recharge from Nile and seepage from canals and drains water to the concerned aquifer. On the other hand, the mean values of Br^- and I^- concentrations in the deep groundwater samples are slightly high relative to Nile water, indicating the recharge of such aquifer from River Nile.

For River Nile water, all samples are in the acceptable and permissible limits of contamination with regard to the soluble heavy metals (Al^{3+}, Fe^{3+}, Mn^{2+}, Co^{2+}, Cu^{2+}, Ni^{2+}, Cr^{3+}, Cd^{2+}, Pb^{2+}, Sr^{2+}, V^{2+} and Zn^{2+}). However, most shallow groundwater, canals and drains water are seriously polluted by some soluble heavy metals (Al^{3+}, Fe^{3+}, Mn^{2+} and Zn^{2+}) while most deep groundwater are slightly polluted by such soluble heavy metals.

Most water samples in the area under study have low B^{3+} concentration below the acceptable level of pollution while some water samples of River Nile, canals, drains and shallow aquifer have high PO_4^{3-} concentration above the acceptable level of pollution.

Nile water and deep groundwater have low NO_3^- concentration below the acceptable level of pollution while most water samples of shallow aquifer, canals and drains have high NO_3^- concentration above such level.

Surface, shallow and deep groundwater samples have low values of NO_2^-, indicating non-contamination water. An exceptional case is found in very few shallow groundwater which have high nitrite concentration above the acceptable level of pollution.

Most surface, shallow and deep groundwater have high NH_4^+ and S^{2-} concentrations relative to the acceptable level of pollution.

Most surface, shallow and deep groundwater samples have low values of BOD, indicating non-contamination water while such samples have high values of COD and TOC more than the acceptable levels of pollution.

Some samples representing agricultural canals, drains, shallow and deep groundwater are infected by bacteria which are considered as indicators of potential bacterial contamination while some samples representing Nile water is not infected by bacteria.

RECOMMENDATIONS

According to the obtained results, the following recommendations should be followed:

1- Wells should be dug down from 60 to 100 m. depth and should be remoted from the pollution sources.
2- Shallow wells should not be used for drinking since they contain non-permissible limits of different pollutant materials according to the international standards.
3- Chemical fertilizers and pesticides treatments should be used at mininum limits as they pollute drainage water that feed shallow groundwater.
4- Sewage sludge and human-used water should not be drained in the Nile or its tributaries or canals and drains that feed shallow groundwater.
5- The area should be sewered and sanitary wastewater treated in a central plant. Treated water will be reused for irrigation depending on its quality. Industrial wastewater should be treated at the industry's site where industrial wastewater may be recycled in the plant.
6- The use of hydrogels for treatment of soluble heavy metals in industrial drains before disposal of industrial wastes into the Nile, irrigation canal and drains water is recommended.
7- Chemical, biological and bacteriological analyses must be carried out periodically for the surface, shallow and deep groundwater.

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جيوكيميائية مصادر المياه ومشاكل التلوث بمنطقة حلوان – مصر

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يتعلق هذا البحث بدراسة الخواص الكيميائية لمصادر المياه الموجودة بمنطقة حلوان– الصف وأنواع التلوث الموجودة بها، وقد أظهرت النتائج ما يلي:

١ – أن ملوحة المياه من النوع العذب وذلك في نهر النيل وقنوات الري (الترع) والمصارف الصناعية والمياه الجوفية العميقة (النوع المغلق وشبه المغلق) بينما تتراوح ملوحة المياه ما بين العذب إلي الأسنة (متوسطة الملوحة) وذلك في المصارف الزراعية والمياه الجوفية السطحية (النوع الحر).

٢– يعتبر عسر المياه الموجود في نهر النيل وترعتي الخشاب والحاجر بدرجة كبيرة عسراً مؤقتا، وأما في حالة مياه المصارف الزراعية والمياه الجوفية السطحية نجد أن العسر المؤقت أكبر من العسر الدائم في المياه العذبة والعكس صحيح في المياه الاسنة . من جهة أخري وجد أن العسر المؤقت أكبر من العسر الدائم في حالة المياه الجوفية العميقة.

٣– أظهر توزيع الأيونات السائدة في نهر النيل أن النوع السائد في المياه هو كربونات الكالسيوم بينما هو في الترع من الشمال إلي الجنوب(وذلك مع حركة سريان المياه) هي بالترتيب بيكربونات الصوديوم وبيكربونات الكالسيوم وكبريتات الكالسيوم وكلوريد الصوديوم. كما أظهرت النتائج أن النوع السائد في المصارف الزراعية هو بيكربونات الكالسيوم وكلوريد الصوديوم. وكذلك تبين أن الأنواع السائدة في المصارف الصناعية هي بيكربونات الكالسيوم وبيكربونات الماغنسيوم وبيكربونات الصوديوم وكبريتات الصوديوم وكلوريد الكالسيوم. أظهرت النتائج أيضا أن الأنواع السائدة في المياه الجوفية العميقة هي بيكربونات الكالسيوم وبيكربونات الماغنسيوم كما في مياه النيل. أما بالنسبة للمياه الجوفية السطحية فإن بعضها تكون الأنواع السائدة فيها هي بيكربونات الكالسيوم وبيكربونات الماغنسيوم وبيكربونات الصوديوم كما في مياه النيل. وعلي الجانب الأخر، تكون الأنواع السائدة في معظم المياه الجوفية السطحية كلوريد الصوديوم وكلوريد الكالسيوم.

٤– أوضحت الدراسة وجود ست أنواع من مجموعات الأملاح الافتراضية في المياه الجوفية السطحية وهي حصيلة الأملاح الافتراضية الموجودة في كل من نهر النيل (المجموعات الثانية والرابعة) والترع (المجموعات الأولي والثانية والرابعة والخامسة) والمصارف الزراعية (المجموعات الثانية والثالثة والسادسة) والمصارف الصناعية (المجموعات الأولي والثانية والرابعة والسادسة).

٥– أظهرت الدراسة أن متوسط تركيزات أيونات البروم واليود في المياه الجوفية السطحية أعلي منها في الترع والمصارف الزراعية والصناعية والمياه الجوفية العميقة. ومن جهة أخرى توضح أيضا القيم المتوسطة لتركيزات أيونات البروم واليود في المياه الجوفية العميقة أعلى طفيفا منها في مياه النيل.

وقد أوضحت دراسة الملوثات المختلفة الموجودة بمنطقة الدراسة ما يلي:–

١– خلو نهر النيل من التركيزات العالية من العناصر الثقيلة الذائبة بينما معظم المياه الجوفية السطحية والترع والمصارف ملوثة بكميات كبيرة من العناصر الثقيلة الذائبة وخصوصا الألومنيوم والحديد والمنجنيز والزنك وأن غالبية المياه الجوفية العميقة ملوثة ولكن بدرجة أقل من هذه العناصر.

٢- معظم عينات المياه السطحية والجوفية العميقة غير ملوثة بأيون البورون (ماعدا بعض المياه الجوفية السطحية) بينما بعض المياه الجوفية السطحية والنيل والترع والمصارف ملوثة بتركيزات عالية من أيونات الفوسفات (أعلى من المسموح به).

٣- معظم عينات المياه الجوفية السطحية والترع والمصارف (ما عدا مياه النيل والجوفية العميقة) ملوثة بتركيزات عالية من أيونات النترات (أعلى من المسموح به).

٤-عدم تلوث المياه السطحية والجوفية السطحية والعميقة بأيون النيتريت باستثناء قليل جدا من المياه الجوفية السطحية.

٥-وجود تركيزات عالية من أيونات الكبرتيد والامونيا بتركيزات أعلى من المسموح به في معظم المياه السطحية والجوفية بنوعيها.

٦-تتميز معظم المياه السطحية والجوفية السطحية والعميقة بقيم عالية من المواد العضوية الذائبة والأكسجين الكيميائي المستهلك مما يدل علي التلوث البيولوجي.

٧- بعض العينات الممثلة لكل مصادر المياه الموجودة بالمنطقة ملوثة بالبكتريا.

وفي ضوء النتائج السابقة يتبين أن كل مصادر المياه الموجودة بمنطقة الدراسة ملوثة بمصادر مختلفة من التلوث تعتمد على نوعية المادة الملوثة والتي تختلف من مكان لأخر ولذلك نوصي بالأتي:

١-عند حفر أبار جديدة يجب أن يكون العمق الكلي للبئر من ٦٠-١٠٠م والبعد عن مصادر التلوث.

٢-عدم استخدام مياه الأبار الجوفية السطحية (عمق أقل من ٣٠م) للشرب أو للاستخدامات المختلفة وذلك لتلوثها.

٣-ترشيد استخدام الأسمدة والمبيدات الزراعية إلى الحد الأدنى حتى لا تلوث مياه الترع والمصارف الزراعية والتي تتسرب إلى الخزان الجوفي.

٤-عدم إلقاء المخلفات البشرية من الصرف الصحي والمخلفات الصناعية في نهر النيل والترع والمصارف الزراعية حتى لا تتسبب في تلوث المياه الجوفية.

٥-ضرورة معالجة مياه الصرف الصناعي قبل إلقائها وذلك باستخدام الطرق المختلفة للمعالجة.

٦- ضرورة إجراء تحليلات دورية (كيميائية، وبيولوجية، وبكتريولوجية) لمصادر المياه.