ISSN: 2694-1708

Insights in
Chemistry and Biochemistry

DOI: 10.33552/ICBC.2026.03.000563

Iris Publishers

Research Article

Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt

Salah Abdelwahab El-Sayed[1], M STawfik[2]*

[1]Salah Abdel Wahab El-Sayed, Professor of hydrogeology, Department of Siting and Environment, Egyptian Atomic Energy Authority, Egypt, Cairo

[2]Mohamed Safwat Mohamed Tawfik, Associate professor of Radiochemistry, Department of Siting and Environment, Egyptian Atomic Energy Authority, Egypt, Cairo

Corresponding authors: M STawfik, Mohamed Safwat Mohamed Tawfik, Associate professor of Radiochemistry, Department of Siting and Environment, Egyptian Atomic Energy Authority, Egypt, Cairo

Received Date: January 27, 2026

Published Date: March 12, 2026

Abstract

Objectives

Using of the groundwater in industry is recommended as an important alternative solution to overcome the deficiency of fresh surface water resources in Egypt. This work aims to predict the scaling and corrosion impacts that may result from using the groundwater in industrial activities.

Material and Methods

Study method showed that 35 water samples were collected from the study area and analyzed for major ions using ion chromatographic and inductively coupled plasma- spectrometric techniques.

Results

The study results showed that 42.8% of sampling sites are being neither precipitating nor dissolving a scale layer of $CaCO3$, which make them suitable for being as source of industrial water. In case of using Stiff Davis index, results showed that 74.28% of the sampling sites were also suitable for industrial water in the studied area. On the other hand, using Rhyznar stability index, showed that 54.28% of these values were corrosively aggressive. While in case of using of Puckorious Stability 71.42 % of the sampling sites were showed little scaling and corrosion tendencies, while the rest of sampling sites with 28.57 % had tendency of little scale formation.

Conclusion

Study results recommend the using of suggested modified advanced water treatment method to mitigate the predicated corrosion problems resulting from using of groundwater at the studied areas.

Keywords: Groundwater; Scale Formation; Corrosion; Saturation Index; Water Treatment

Introduction

Egypt is an arid country in north-east Africa, but has a large hydro-geologic potential with many groundwater aquifers widely distributed throughout the country. Groundwater serving a wide variety of users such as the agricultural, domestic, commercial, recreational and industrial sectors [1]. It is regarded as a stable resource compared to surface water, particularly in areas like Egypt, where the fresh surface water is scarce or occasionally supplied [1]. The aquifers are large water reservoirs, which provide buffer storages during the dry years and their quality is usually better than that of the surface water. it was reported that the quality of groundwater plays an essential role for quantifying the water state with respect to the necessities of human industrial needs. Moreover, the groundwater quality is a vital determinate of the efficient operation of many industrial sectors [2].

Variable water resources in Egypt are limited mainly to the Nile River, rainfall and groundwater reservoirs. In Egypt, fresh groundwater contributes to less than 20% of the total potential of water resources, where the groundwater resources mangment provides solution against decline in water sources, especially in areas where aridty is increasing [3].

The quality of the groundwater can be seriously threatened directly or indirectly by the climatic changes, natural processes, human activities and atmospheric inputs [4]. The most common crucial problems associated with the quality of groundwater are scale formation and corrosion phenomena (It was defiend tha). Such problems decrease the effectiveness of industrial water systems and increase the maintenance (or replacing) costs of production equipment [5,6]. It was reported that the scale formation is a term used to describe any undesirable substances precipitated on the metal surfaces such as supply water systems (tubes, pipes, valves, etc.). It is, for instance, consists of deposited minerals, corrosion products, bacterial accumulation and deposited silt and sand grains coming from aquifers. The scale that is deposited inside the water systems of industrial facilities often causes serious technical problems such as blockages in water pipelines and declines in thermal transfer in heat exchangers (Fuller, 2014; Egbueri, 2020). It was reported that the critical parameters affecting the formation of scales are water pH, temperature, alkalinity, total hardness, calcium hardness, ionized silica and dissolved gases as well as dissolved minerals such as calcium carbonate. Technically, the scale has a low thermal conductivity of 0.2 to 1.3 Btu/hrft0F which prevents proper cooling of metal surface on which it forms. From the economic point of view, the scale formation can greatly affect heat transfer performance, for instance, 1mm,1.5mm and 7mm thick scales can increase cost by 7.5%, 15% and 70%, respectively [5,6].

It was defiend that the corrosion is the partial dissolution of the materials comprising the treatment and supply systems, pumps, pipes, valves and tanks. It is a vital problem where it robustly affects the natural and industrial environments. Not only the corrosion leads to water leaks that in turn increase the maintenance (or replacing) costs, but it also contaminates water flow inside pipelines. In general, the corrosion rate depends on both the type of the metals and the physicochemical parameter of water. The most common factors affecting the corrosion rates of water industrial systems include abnormal water total dissolved solids, pH, chloride, high temperature and water flow rate, dissolved metals, dissolved gases, and bacterial load as well as iron and steel specifications of pipelines (Fuller, 2014; Egbueri, 2020). At the beginning of the new millennium, industrial water demand has been increasing in Egypt with the pace of industrial growth. most industrial areas exist in the greatly fruitful Nile Valley flood plain. The study area, Mostorod industrial area, located at the Northeast Cairo, Egypt, is one of these important industrial areas. Mostorod area contains a number of industries such as oil product processing projects, and it will receive more activities in the future. This work discusses the scale formation and corrosion problems that may result from using the groundwater in industrial activities in Mostorod area. In this regard, numerical water quality indices including Langelier Saturation Index (LSI), Ryznar stability index (RSI), Puckorius scaling index (PSI), Stiff-Davis index were used to reveal the groundwater quality. Accordingly, decision support suggestions will discussed to augment the likelihood of a successful usage of groundwater for the current and projected industrial projects [5,6].

Materials and Methods

Study Area and Existing Industries

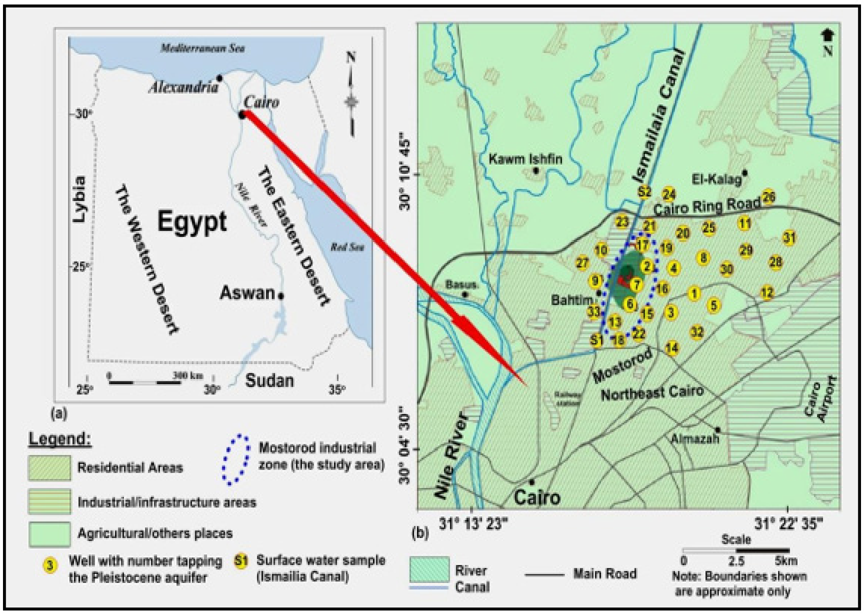

Figure 1: (a) Map of Egypt (source: Brown and Kumar, 2011). (b) Map of the study area (source: WorleyParsons, 2008a) and water sampling points.

Citation: Salah Abdelwahab El-Sayed, M STawfik*. Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt. Insi in Chem & Biochem. 3(3): 2026. ICBC. MS.ID.000563.
DOI: 10.33552/ICBC.2026.03.000563.

The investigated area is located in the arid zone of Egypt and its climate is almost dry throughout most of the year, with very hot summer months and a mild winter ones. The climate is characterized by high evaporation rate (121.3 mm/year) that exceeds 9 times greater than the precipitation (14.7 mm/year. The area lies on the eastern bank of the Nile River, within the latitudes 30° 06’ 15” and 30° 10’ 45” north and longitudes 31° 15’ 49” and 31° 22’ 45” east (Figure 1). It overlooks directly Ismailia Canal that is a branch of the Nile River in the southeastern part of the Eastern Nile Delta. The land surface is nearly flat and rises 16m above mean sea level (amsl) in the west to 14m (amsl) in the east.

The common land use patterns in Mostorod area are the residential, agriculture and industry lands. The study area occupies part of the eastern Nile River floodplain formed of a Holocene-clayey silt layer (5-15m thick). It is underlain by the Pleistocene graded sand and gravel layer representing the main aquifer (Figure 2). The field investigations revealed that these wells are of 3-8 inches diameters and have depths ranging from 15-30m (shallow wells) in the urban area to 50-60m (relatively deep wells) in the industrial and agricultural areas. Depth to water (from the ground surface) in wells that tap the aquifer ranges from about 2.3m near Ismailia Canal in the west and northwest to 4.5m in the east and south.

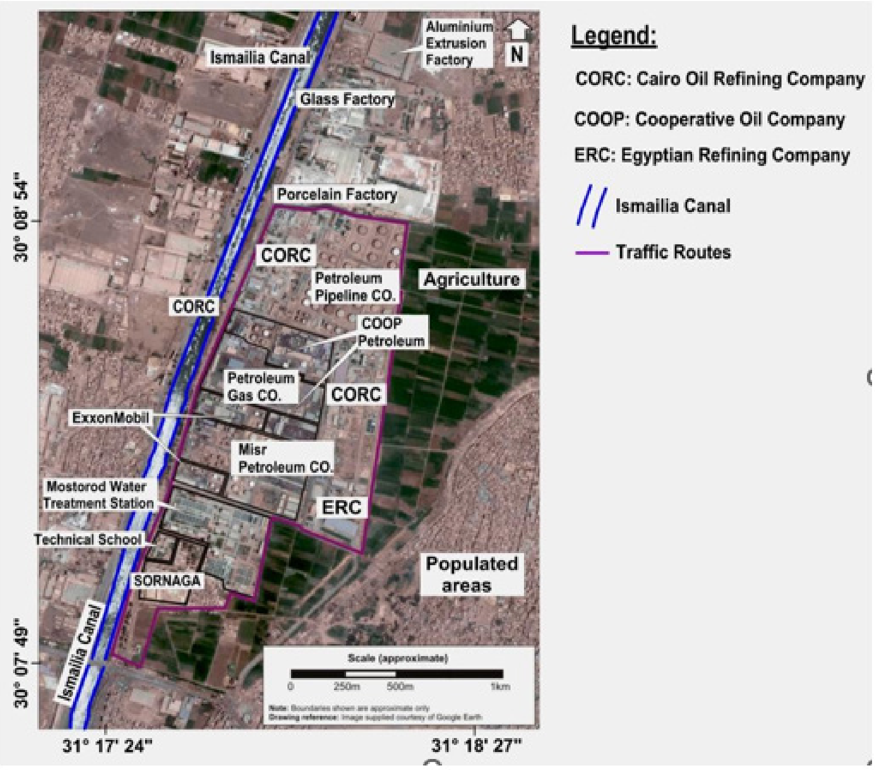

Figure 2: Existing Industries in Mostorod area (slightly modified after WorleyParsons, 2008b).

Existing industries in Mostorod area are numerous and strategic. The main industrial sectors are Cairo Oil Refining Company (CORC), Public Company for Ceramics and Porcelain, Sornaga Company for Ceramics, Mostorod Water Treatment Station, Petroleum Pipeline Company, Misr Petroleum Company, Petroleum Gas Company, Misr Glass Company, Al Saad for Aluminum Company, and Public Company for Ceramics and Porcelain (Figure 3). As oil product processing projects are among the emerging industries, the Egyptian Refining Company (ERC) is established by the Egyptian government in recent years in Mostorod area to meet the increasing demand for refined oil products in Egypt. The ERC aims to upgrade the range of products and comprises several new units (OPEC, 2016).

Sampling and Laboratory Analysis Techniques

It was observed that the representative thirty-five groundwater samples collected from production wells tapping the Pleistocene aquifer and two surfacewater samples taken from Ismailia Canal. Before sampling process, all wells purged for about 20 minutes to remove the standing water in casings (at least 3 to 5 times of the internal volume of the well water is removed). Concurrently, physicochemical parameters, including water pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Dissolved Oxygen (DO) carried out in-situ to observe the water chemical stability. After stabilization of these parameters, the groundwater samples collected in 2 liters-polyethylene bottles rinsed twice with the same water of a well. Filtration of surface water samples carried out using 0.45 µm pore-sized papers. For trace element analysis, drops of concentration. Nitric acid were added to the samples to decrease the pH value (<2 pH unit) in order to mitigate the metal precipitation. The bottles were closed firmly to prevent evaporation and contamination, and they were kept in a refrigerator (at ~ 4ºC), and in a short period transported to the laboratory to conduct the required analyses. Coordinates of sampling sites identified by the Global Positioning System device (GPS) model-eTrex, Personal Navigator Garmin Ltd. The collected water samples analyzed chemically for major ions and trace elements following the standard analytical protocol descried by [7] ASTM, 2024. The analysis carried at the water analysis unit of Desert Research Center, Cairo, Egypt. Dissolve d major ions for which concentrations determined in water from samples comprised bicarbonate (HCO3), chloride (Cl-), calcium (Ca++), magnesium (Mg), sodium (Na) and potassium (K). The major cations (Na, K, Mg and Ca) and major anions (HCO3, SO4, and Cl) were determined by ion chromatography (ICS-1100, Dionex, Sunnyvale, CA, USA). The concentrations of trace elements including cupper (Cu), iron (Fe), nicle (Ni), manganese (Mn) and lead (Pb) measured by inductively coupled argon plasma (ICAP, Thermo 6500). The content of the chemical constituents expressed in terms of mg/L. Other physical properties of water (pH, EC, TDS and DO) determined by a water- quality multiprobe device, Manta 2, Model Sub 3, USA. The anion-cation balance method presented here to determine the reliability of major ion analyses of fresh- or saline water assumes that major ions comprise most of the total dissolved solids in a water sample, and requires that all major ion concentrations measured.

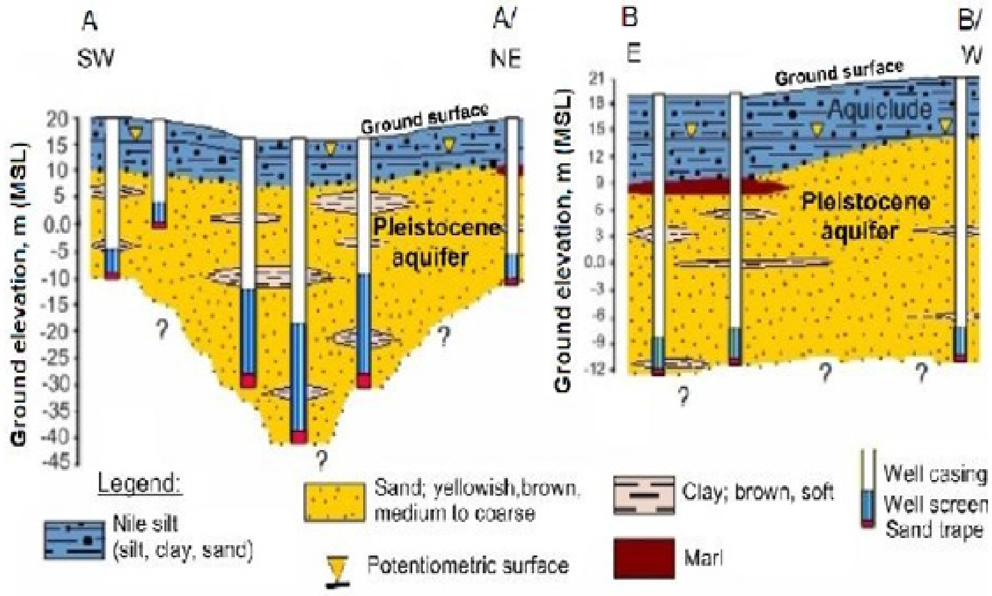

Figure 3: Hydrogeologic cross sections across the study area, the Pleistocene aquifer,Mostorod area, Egypt.

Using Different Scale Formation and Corrosion Indices

In order to assess the corrosion and scale formation that may result from using the groundwater in industries in the study area, the common indices of Langelier SaturationIndex (LSI), Ryznar Stability index (RSI), Puckorius Scaling Index (PSI), and Stiff-Davis Index (SDI), were calculated (Table 1). The LSI is an equilibrium model derived from the theoretical concept of saturation and provides an indicator of the degree of saturation of water with respect to calcium carbonate. The LSI approaches the concept of saturation using pH as a main variable. Bicarbonates (mg/l) concentration was used to express the water alkalinity as follows: The Bicarbonates (mg/l) concentration will be used instead of Alkalinity as will be used in LSI calculator, based on the relation: Bicarbonate (mg/l)=Total Alkalinity in mg/l as CaCO3 x 1.22 [8]. The RSI is an empirical method for predicting scaling tendencies of water based on a study of operating results with water of various saturation indices. This index is often used in combination with the Langelier index to improve the accuracy of predicting the scaling or corrosion tendencies. The RSI indicates the degree of saturation of CaCO3 in water and was calculated by pH, alkalinity (bicarbonate), calcium concentration, total dissolved solids. The PSI attempts to quantify the relationship between saturation state and scale formation by incorporating an estimate of buffering capacity of the water into the index [8]. It was calculated in a manner similar to the RSI. An equilibrium pH (pHeq) rather than the actual system pH was used to account for the buffering effects (Table 1). It was observed that Puckorius Scaling Index (PSI) attempts to quantify the relationship between saturation state and scale formation by incorporating an estimate of buffering capacity of the water into the index .The best review of the LSI, RSI and PSI methods was made independently by Cavano in an article published in The Analyst magazine in the fall of 1999.Cavano reported that the PSI method provided the most accurate values of the three methods. Total dissolved solids were between 500 and 1,000 parts per million (ppm), The calcium hardness (as CaCO3) was between 50 and 700 ppm, The total alkalinity (as CaCO3) was between 10 and 800 ppm, and The temperature was between 100 and 150°F (38 and 66°C). This index was the most complying with the study results (Table1), as 90% of the Mostord sampling sites measuring parameters were complying with PSI's chemical parameters ranges (Table2). The SDI method is one of the easiest ways to calculate calcium carbonate scaling tendencies. The Stiff-Davis index attempts to overcome the short comings of the Langelier Index with respect to high total dissolved solids' waters and the impact of "common ion" effects on the driving force for scale formation. Like the LSI, the Stiff-Davis index has its basis in the concept of saturation level. The solubility product used to predict the pH of saturation (pHs) for a water is empirically modified in the Stiff-Davis index. Stiff-Davis indices will predict that water is less scale forming than the LSI calculated for the same water chemistry and conditions. The deviation between the indices increases with ionic strength. Interpretation of the index is by the same scale as for the Langelier Saturation index, (Table 1). The LSI should be used for low TDS ranges (<10,000 ppm) and the stiff -Davis (S&DSI) is used for high TDS ranges (>10,000 ppm). In general, the Langelier Saturation Index (LSI) is used for brackish waters and the Stiff & Davis Stability Index (S&DSI) for seawater. At the pH of saturation (pHS), the water is in equilibrium with CaCO3. The novelty of our study being clearly showed by a comparive study of using different saturation indexes of groundinorder to select the suitable sites which will be used in industrial purposes with suggesting a flow chart of modified ground water treatment method usingdifferent alternatives of Polyphosphate, orthophosphatesor quatarnary ammnoium chloride corrosion inhibitors, this were not showed by other authors 's articles [9].

Table 1: Corrosion and scale formation indices (IwonaSkoczko et al,2019, Calford Odhiambo Otieno, et al, 2024).

Index	Used Formula	Explanation
Langelier saturation index(LSI)(24)	**LSI= pH-pHs** **pHs=A+B-log[Ca]-log[Alkalinity]**	**LSI < -0.5 → Corrosion** **-0.5 < LSI<0.5 → Equilibrium LSI > 0.5 → Scale formation** It is assumed that when the value of LI is negative (LI<-0.5), it indicates corrosiveness
Ryznar Stability index (RSI)[(25)]	**RSI= 2pHs - pH**	**RI<5.5 heavy scale will form** **5.5<RI<6.2 scale will form** **6.2<RI<6.8 no difficulties** **6.8<RI<8.5 water is aggressive RI>8.5 water is very aggressive**
Puckorius Scaling Index (PSI)[(26)]	**PSI=2(pHs)-pHeq** Where: -pH_s is the pH at saturation in calcite or calcium carbonate -pH_{eq} = 1.465 x log10[Total Alkalinity] - and [Alkalinity] = [HCO_3^-] + 2 [CO_3^{2-}] + [OH^-	The PSI index is calculated in a manner similar to the Ryznar stability index **PSI < 6 → Scale formation** **6 ≤ PSI ≤ 7 → little scaling or corrosive tendencies** **PSI > 7 → Significant corrosive tendency**
Stiff-Davis Index (SDI)	**LSI = pH – pHs**	**LSI = pH - pHs (TDS <10,000 mg/l) S&DSI = pH - pHs (TDS >10,000 mg/l**

Citation: Salah Abdelwahab El-Sayed, M STawfik*. Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt. Insi in Chem & Biochem. 3(3): 2026. ICBC. MS.ID.000563.
DOI: 10.33552/ICBC.2026.03.000563.

Table 2: Chemical consituent data of water samples from the Quaternary aquifer and Ismailia Canal, Mostorod area, Northeast Cairo, Egypt.

Well No.		Physicochemical parameters				Major Anions			Major Cations				Trace Elements				
	pH	T°C	EC	TDS	DO	HCO_3	SO_4	Cl	Ca	Mg	Na	K	Cu	Fe	Ni	Mn	Pb
			µS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	8.3	23.88	1145	611.2	6.39	304.4	199.2	102.5	43.4	52.55	105.47	62.08	0.009	0.243	0.018	0.061	0.024
2	7.2	24.19	1712	1113	7.62	105.4	488.1	302.2	200	69.7	83.8	19.4	0.014	0.482	0.023	0.049	0.027
3	8.1	23.77	729.1	490.4	6.11	123.2	119.1	68.44	50.1	17.22	38.9	15.72	0.006	0.145	0.019	0.799	0.022
4	8.4	23.42	1031	725	5.49	162.4	122.6	155	60.23	29.99	99.45	16.99	0.007	0.207	0.016	0.025	0.07
5	8.5	23.92	620.4	399.7	6.39	132.1	34.6	62.44	42.99	13.5	18.22	36.4	0.011	0.199	0.021	0.081	0.019
6	8.1	24.81	1000	650.1	6.39	190.1	200.3	92.45	52.44	37.8	78.3	26.9	0.012	0.331	0.021	1.362	0.022
7	7.8	24.37	1618	1052	7.11	110.6	382.4	222.1	160.4	48.62	70.49	16.8	0.013	0.224	0.018	21.45	0.019
8	9.5	23.86	596	388.4	5.77	56.46	176.3	47.32	22.31	32.5	49.78	15.8	0.008	0.194	0.019	0.651	0.023
9	8.6	24.55	728.6	389.8	6.82	109.9	122.9	98.24	60.7	27.31	46.25	9.1	0.007	0.291	0.017	1.46	0.029
10	8.2	24.78	617.8	401.6	7.65	137.7	134.1	35.92	51.42	15.62	34.81	8.85	0.008	0.292	0.022	1.47	0.026
11	7.8	23.5	637.2	414.5	4.66	199.8	32.5	42.61	53.9	13.4	32.7	9.2	0.006	0.115	0.023	0.077	0.016
12	8.6	23.91	1120	602.4	6.45	148	197.3	110.9	65.3	38.99	52.41	23	0.013	0.134	0.016	1.294	0.021
13	7.9	25.14	680	476	7.95	45.88	140.5	36.22	54.11	16.2	16.4	5.9	0.007	0.299	0.023	1.556	0.025
14	8.1	24.22	677.6	446.8	6.99	177.7	59.4	80.15	56	12.6	47.1	29.47	0.014	0.194	0.013	0.774	0.015
15	7.6	23.98	1025	689.9	6.71	157.6	186	124.82	110.4	21.4	47.9	5.99	0.006	0.104	0.021	1.331	0.026
16	8.7	23.74	923	646.2	5.45	104.9	183.2	147.75	56.2	39.6	63.5	22.4	0.006	0.133	0.017	0.099	0.018
17	7.9	24.96	1179	766.3	6.43	213.3	179.4	137.2	114.33	39.86	56.87	4.45	0.014	0.331	0.022	1.114	0.028
18	7.9	23.57	1220	808.8	5.88	127.9	183.7	190.4	76.7	38.9	82.3	6.2	0.011	0.145	0.014	0.098	0.017
19	7.4	23.61	1580	940.2	7.11	86.6	244.7	229.1	77.2	52.1	111.8	15.7	0.009	0.199	0.015	0.087	0.026
20	7.7	23.11	1797	1075	6.97	279.3	254.5	184.7	126.3	68.4	83.5	23	0.008	0.092	0.013	1.342	0.027
21	7.5	23.49	1946	1186	7.24	126	127.5	255.7	68.3	35.1	107.6	12.8	0.015	0.299	0.016	1.278	0.019
22	7.4	24.44	1866	1210	7.78	276.9	167	279.7	164.2	44.38	99.8	23.4	0.006	0.061	0.018	0.036	0.028
23	8.4	24.66	799	520.3	6.89	205.8	88.9	62.5	68.3	20.7	43.9	16	0.011	0.298	0.017	0.037	0.028
24	8.4	23.79	779	422.7	7.62	235.6	110.2	88.4	78.4	22.3	68.7	13.5	0.013	0.301	0.021	1.481	0.029
25	8.3	24.13	861	560.3	7.64	151.7	149.7	68.9	61.2	20.6	55.7	36.2	0.006	0.111	0.02	0.66	0.023
26	8.7	23.95	809	566.8	7.28	228.4	64.7	18.2	32.7	13.8	48.9	11.1	0.013	0.187	0.014	1.45	0.016
27	8.5	23.52	587	382.1	7.9	255.3	139.9	69.8	139.7	11.6	25.4	27.9	0.014	0.229	0.016	1.422	0.022

Citation: Salah Abdelwahab El-Sayed, M STawfik*. Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt. Insi in Chem & Biochem. 3(3): 2026. ICBC. MS.ID.000563.
DOI: 10.33552/ICBC.2026.03.000563.

28	8.6	23.87	798	511.4	5.98	197.2	160	105.7	39.4	41.2	70.1	26	0.0122	0.223	0.022	1.276	0.017
29	7.4	24.34	884	574.4	7.22	179.5	235.6	104.9	78.9	53	65	16	0.005	0.335	0.011	1.477	0.019
30	8.8	23.35	640	399.7	7.46	296.1	78.2	18.6	92.6	13.1	34.9	12.6	0.003	0.257	0.002	0.047	0.018
31	8.7	24.27	590	401.2	5.56	295.3	118.7	22.4	79.9	28.2	39.08	14.9	0.006	0.321	0.014	1.436	0.027
32	8.2	23.85	784	481.3	4.18	284.8	123	95.6	77.1	44.3	43.6	4.2	0.008	0.211	0.019	0.085	0.021
33	8.4	24.98	579	399.6	8.1	213.8	99.2	21.7	86.9	17.6	12.9	10.1	0.009	0.314	0.023	0.096	0.029
Minimum	7.2	23.11	579	382.1	4.18	45.88	32.5	18.2	22.31	11.6	12.9	4.2	0.003	0.06	0.002	0.025	0.015
Maximum	9.5	25.14	1946	1210	8.1	304.39	488.1	302.2	200	69.7	111.8	62.08	0.02	0.48	0.023	21.45	0.07
Average	8.17	24.06	986.63	627.37	6.7	179.38	160.7	111.59	78.85	31.88	58.65	18.12	0.01	0.23	0.018	1.393	0.024
Stdev	0.499	0.51	406.5	251.3	0.94	70.9	89.6	76.5	39.9	16.1	26.8	11.5	0.003	0.09	0.004	3.65	0.009
**S1 (Ismailia-Canal)	8.6	25.21	569	369.8	8.75	149.6	42.86	33.61	36.1	14.28	28.2	3.9	0.006	0.199	0.014	0.041	0.016
S2(Ismailia Canal)	8.3	26.11	576	374.2	7.84	153.5	44.1	38.72	40.93	12.1	35.7	4.1	0.007	0.289	0.022	0.024	0.024

*S: Surface water samples of Ismailia Canal *Stedv.: Standard deviation

Citation: Salah Abdelwahab El-Sayed, M STawfik*. Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt. Insi in Chem & Biochem. 3(3): 2026. ICBC. MS.ID.000563.
DOI: 10.33552/ICBC.2026.03.000563.

Results and Discussion

Chemistry of Groundwater

Physico-chemical parameters and concentrations of major ions and some trace elements determined for water samples collected from the Pleistocene aquifer and the Nile water in Ismaila Canal are listed in Table 3-2. In addition, a statistical summary of the chemical constituents is also presented in Table 3-1. Ion balance analysis was performed on each sample; the results indicated that the percentage differences between the sum cations and anions were less than ±4%. The chemical results reveal that the physicochemical parameters of the Pleistocene groundwater show a wide range and are generally higher than those of Nile water of Ismailia Canal. The high standard deviations Table 3-1 can be attributed to the influence of evaporation and hydrogeochemical processes such as dilution, water-rock interaction, mixing, etc. The groundwater in the study area is slightly alkaline to alkaline where the pH varies from 7.2 to 9.5 standard unit (average= 8.17). The EC and salinity (as TDS) have values ranging from 579-1964µS/cm (average= 986.6 µS/cm) and 382-1210 mg/L (average= 627.4 mg/L). Both the EC and TDS values are found to increase towards the east, away of the Ismailia Canal that contains fresh water. The dissolved oxygen (DO) concentration in the examined groundwater samples is lower than that in the water of the Ismailia Canal. The DO has values ranging from 4.18 mg/L to 8.10 mg/L (averge= 6.10 mg/L). It was observed that the dissolved major ions in the studied groundwater samples are generally higher than those in the water of Ismailia Canal, as showed in table 2. The concentrations of the major ions in the groundwater decrease generally due the charchtersitices of west region (i.e. towards the Ismailia Canal). The HCO3, SO4 and Cl ions have concentration values ranging from 45.9-304.4 mg/L (average= 179.4 mg/L), 32.5-488.1mg/L (average= 160.7 mg/L) and 18.2-302.2 mg/L (average = 111.6 mg/L), respectively. The Ca, Mg, Na and K ions have values varying between 22.3 mg/L and 200 mg/l, 11.6 mg/l and 69.7 mg/L, 12.9 mg/l and 111.8 mg/L , and 4.2 mg/l and 62.1 mg/L with respective averages of 78.9 mg/L, 31.9 mg/L, 58.7 mg/L and 18.1 mg/L, respectively. The surface water of Ismailia Canal has larger contents (meq/L) of calcium and bicarbonate ions and, therefore, this water typically is a calcium bicarbonate water. On the other hand, the content of major ions varies spatially in the Pleistocene aquifer in the study area. Generally, the groundwater from the aquifer is predominantly bicarbonate and sulphate types and is distinctive in the study area because of its large calcium component The concentrations of trace elements in the examined groundwater samples differ from place to place, and they are generally greater than those of the Ismailia Canal water (Table 2). The range and (average) values of the Cu, Fe, Ni, Mn, and Pb in the groundwater samples are 0.003-0.02 mg/L (0.01 mg/L), 0.06-0.48 mg/L (0.23 mg/L), 0.002-0.023 mg/L (0.018 mg/L), 0.025-21.5 mg/L (1.4 mg/L), and 0.015-0.07 mg/L (0.024 mg/L), respectively. The occurrence of the these elements with high concentration levels in the Pleistocene-groundwater samples may be the result of the mixing with agricultural, municipal and industrial effluents [9].

Table 3: Using scale and corrosion water saturation indexes.

Groundwater Sample No.	Langelier saturation Index LSI	Stiff Davis stability Index SDS	Ryznar Stability Index RSI	Puckorious Stability Index PSI
1	0.7437	0.8692	6.812	7.0180
2	-0.1739	-0.1622	7.547	7.34
3	0.2205	0.5873	7.659	8.23
4	0.696	0.8796	7.0062	7.6937
5	0.5962	1.1018	7.307	8.2457
6	0.436	0.6423	7.22	7.567
7	0.357	0.418	7.085	7.453
8	0.941	1.4193	7.616	10.093
9	0.77	1.049	7.04	8.22
10	0.408	0.866	7.38	8.028
11	0.171	0.595	7.456	7.404
12	0.9091	1.106	6.781	7.74
13	-0.3481	0.2585	8.5963	9.6550
14	0.4406	0.7832	7.21	7.57
15	0.1599	0.3374	7.28	7.208
16	0.786	0.934	7.126	8.405
17	0.699	0.712	6.5002	6.573
18	0.1973	0.3433	7.505	7.85
19	-0.476	-0.3764	8.3530	8.4485
20	0.5371	0.6006	6.625	6.2716
21	-0.2788	-0.1359	8.057	8.009

Citation: Salah Abdelwahab El-Sayed, M STawfik*. Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt. Insi in Chem & Biochem. 3(3): 2026. ICBC. MS.ID.000563.
DOI: 10.33552/ICBC.2026.03.000563.

22	0.352	0.4033	6.6960	6.097
23	0.8923	1.1755	6.6153	7.200
24	1.0035	1.196	6.39	6.8580
25	0.599	0.8962	7.1011	7.76
26	0.9006	1.43	6.89	7.689
27	1.388	1.53	5.72	6.227
28	0.8206	1.029	6.95	7.74
29	-0.114	0.0154	7.62	7.28
30	1.569	1.8214	5.661	6.364
31	1.423	1.636	5.8574	6.4970
32	0.874	1.0221	6.45	6.598
33	1.032	1.34	6.337	6.9101
*S1 (Ismailia Canal)	0.7024	1.319	7.195	8.2036
*S2 (Ismailia Canal)	0.4856	1.048	7.32	4.24

The effects of different anions and cations concentrations in industrail water

It was reported that HCO3− influences the acidity of water, which in turn makes it corrosive. The concentration of bicarbonate in the examined ground water (Table3-2) was with average =179.38 mg/l which ranged from 45.9-304.4 mg/L. Similarly, the presence of sulfate in water could facilitate its corrosion activities. Table 2. showed that sulfate concentrations were ranged from 32.5-488.1mg/L with (average= 160.7 mg/L), the metallic materials in water distribution channels are easily exposed to major corrosion risks due to the conversion of sulfate in water to corrosive sulfides by anaerobic sulfate-reducing bacteria. An increment in the number of sulfur-producing bacteria increases the amount of hydrogen sulfide gas that reacts with metallic surfaces of the distribution system to cause corrosion. High chloride concentrations can increase the tendency of water to cause corrosion in distribution systems. Table 2, showed that the chlorides values are ranged (18.2-302.2 mg/L) with average 111.6 mg/L. Nearly all metals will corrode to some degree. The rate and extent of the corrosion depend on the degree of dissimilarity of the metals and the physical and chemical characteristics of the media, metal, and environment. In water that is soft, corrosion occurs because of the lack of dissolved cations, such as calcium and magnesium in the water. In scale forming water, a precipitate or coating of calcium or magnesium carbonate forms on the inside of the piping. This coating can inhibit the corrosion of the pipe because it acts as a barrier, but it can also cause the pipe to clog. Table 2. showed that calcium and magnesium and sodium mean average results were 78.9 mg/L, 31.9 mg/L and 58.7 mg/L, respectively. Water with high levels of sodium, chloride, or other ions will increase the conductivity of the water and may promote corrosion. High dissolved solids, such as salts and can induce chemical corrosion. Table 2, showed that the both EC and salinity (as TDS) have values ranging from 579-1964 µS/cm (average= 986.6 µS/cm) and 382-1210 mg/L (average= 627.4 mg/L). The Iron release from corroded iron pipes is the principal cause of “colored water” problems in drinking water distribution systems. The corrosion scales present in corroded iron pipes restrict the flow of water, and could deteriorate the water quality. Table 2, showed that iron values were ranged from 0.06-0.48 mg/L and with average (0.23 mg/L). The effect of dissolved oxygen (DO), as key water quality parameter, on iron release from the old corroded iron pipes. It was reported that the interaction of DO with iron pipes covered with naturally aged scales (several decades old), as are present in most unlined iron/steel pipes being in use in drinking water distribution systems [7]. On the other hand, table 2, showed that the DO values, ranging from 4.18 mg/L to 8.10 mg/L with averge value = 6.10 mg/L for the groundwater samples. It was reported that copper can enter into the water through natural deposits in rock and soil, but more often, as a result of corrosion in household plumbing. As the result measured concentrations with different anions, cations and trace elements as: Sulfate, Chlorides, TDS, Ca, Mg, Na, K and Fe etc. [10,27]. Table 2. showed that copper values were ranged from 0.003-0.02 mg/L with average value (0.01 mg/L). As the result copper showed lower tendency for scale formation in the ground water samples used in study.

Using Scale and Corrosion Water Saturation Indexes as Indicators for Industrial Water Quality

The using LSI in industrial water assessment was considered as one of the most frequently used indices used to assess the corrosive impact of CaCO3 concentrations on the water distribution systems and industries. Table 3 and Fig 5. showed that the highest LSI values were found in sites (30, 31, 27, 33, 24, 8, 12, 26, 23, 32, 28, 16, 9, 1, S1 ,17 ,4 ,16, 5 and 20) with values (1.5,1.423 and 1.38, 1.032, 1.003, 0.94, 0.909, 0.906, 0.89, 0.87, 0.82, 0.78, 0.77, 0.74, 0.702, 0.699, 0.696, 0.59,and 0.53) which means the water tendes to precipitate a scale layer of CaCO3 (Table1), which also showed that 57.1 % of the selected 35 ground water sampling sites, had the tendency to form scale layer of CaCO3 which lead to cause scale blocking layer inside the water tubes when using these ground water sites as a water source for the selected Mostord industrial region. Table 3 and Fig 5 Also showed that the rest of sampling sites (42.8%) niether precipating nor dissolving a scale layer of CaCO3(water

Citation: Salah Abdelwahab El-Sayed, M STawfik*. Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt. Insi in Chem & Biochem. 3(3): 2026. ICBC. MS.ID.000563.
DOI: 10.33552/ICBC.2026.03.000563.

is in equilibrium) (Table1), As the result, these sampling sites (42.8%) were suitable for using as a source of industrial water in Mostord area. On the other hand Table 2. And Fig 6 showed that the highest pH values were found in sampling sites (8, 30,16, 26, ,31,S1) with values (9.5, 8.8, 8.7, 8.7, 8.7, and S1) these will support the increasing probability of scale formation at these sites as being detected by using LSI. Using Stiff-Davis index as showed in Fig 7, when its TDS values were <10,000 mg/l (Table 1). Table 3 and Figure 7 showed that the highest SDI values were found in sites (30, 31, 27, 8 , 24, 5,12, 32,23) with values (1.8,1.63 ,1.53, 1.41, 1.17, 1.101,1.06, 1.022,0.403) which means that the water tendes to precipitate a scale layer of CaCO3 as showen in (Table 1). It was observed that Fig 7 showed that 26.4 % of the selected 35 ground water sampling sites, had the tendency to form scale layer of CaCO3 which lead to cause scale blocking layer inside the water tubes when using these ground water sites as a water source for the selected Mostord industrial region. Table 3 and Fig 7, showed that the rest of sampling sites (74.28%) niether precipating nor dissolving a scale layer of CaCO3(water is in equilibrium) (Table 1), As the result, these sampling sites(74.28%) were suitable for using as a source of industrial water in Mostord area. In case of using Ryznar index the Table3. and Figure 8, showed that the highest RSI values were found in sites (13, 19, 21, 3, 8, 2, 11, 10, S2, 5, 15, 6, 14, 16, 25, 9, 28, 26, 1, 22, 23,17, 24, 32, 33, 31) with values (8.59,8.35, 8.05, 7.65, 7.61, 7.54,7.45,7.38, 7.32, 7.30, 7.28,7.22,7.21, 7.12, 7.10, 7.04, 6.95, 6.89, 6.81, 6.78, 6.69, 6.61, 6.5, 6.43, 6.33 and 5.83). These values showed that 54.28% of these values were corrosively aggressive as, 6.8<RSI<8.5 (Table 1), while the rest of sampling sites with 20% with values (6.78,6.69, 6.61, 6.5, 6.43, 6.33, and 5.83) were showed no diffuclties of corrosion as their RSI was 6.2<RSI<6.8 (Table 1). As the result, these sampling sites (20%) were suitable for using them as a source of industrial water in Mostord industrial . In case of using Puckorious Stability Index. Table 3 and Figure 9, showed that the highest PSI values were found in sites (8, 13, 19, 16, 5, 3, S2, 9, 10, 18, 26, 12, 28, 4, 6, 14, 7, 2, 29, 23, 33, 24, 17, 30, 27). With PSI values (10.09, 9.65, 8.44, 8.40, 8.25, 8.24,8.23, 8.20, 8.02, 7.85, 7.68, 7.74, 7.73, 7.69, 7.56, 7.45, 7.34, 7.28, 7.200, 6.91, 6.85, 6.57, 6.49, 6.36 and 6.22). These values showed that 71.42 % of these values showed little scaling and corrosion tendencies as all of these values were in range 6 ≤ PSI ≤ 7 (Table 2-1), while the rest of sampling sites with 28.57 % showed no diffuclties of corrosion but tendecy of little scale formation as 6 < PSI (Table2-1). As the result, the rest of sampling sites (28.57%) were not suitable for using them as a source of industrial water in Mostord indusreial untill adition of antiscale formation (ortho or polyphates adittion).

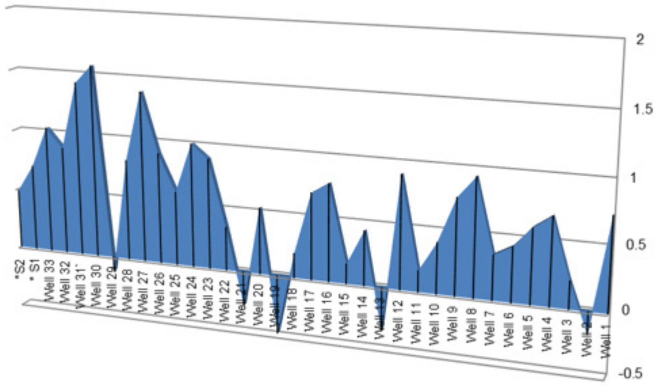

Figure 5: Langelier Saturation Index.

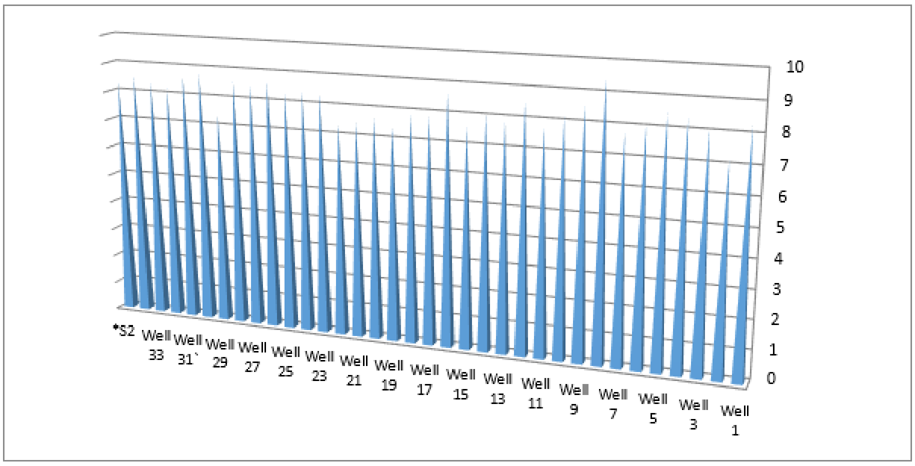

Figure 6: Measured pH at different selected sites.

Citation: Salah Abdelwahab El-Sayed, M STawfik*. Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt. Insi in Chem & Biochem. 3(3): 2026. ICBC. MS.ID.000563.
DOI: 10.33552/ICBC.2026.03.000563.

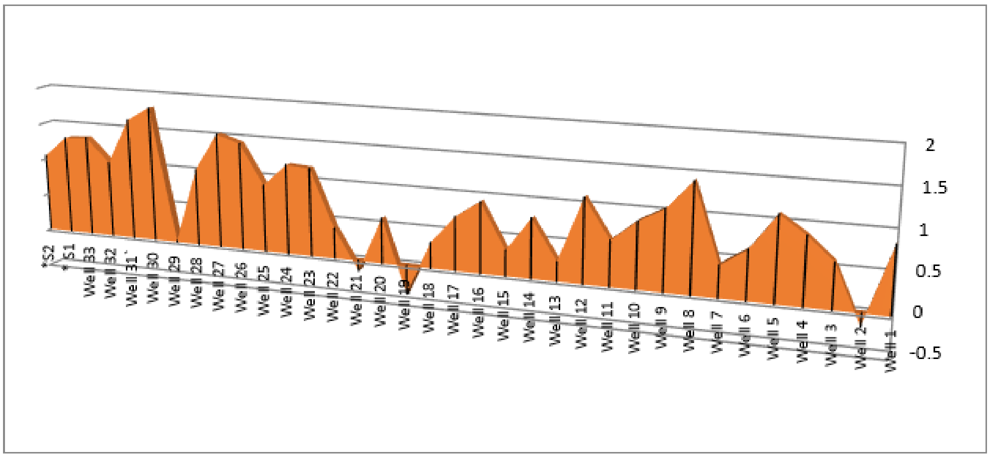

Figure 7: Stiff Davis Index.

Study the using of advanced ground water treatment system

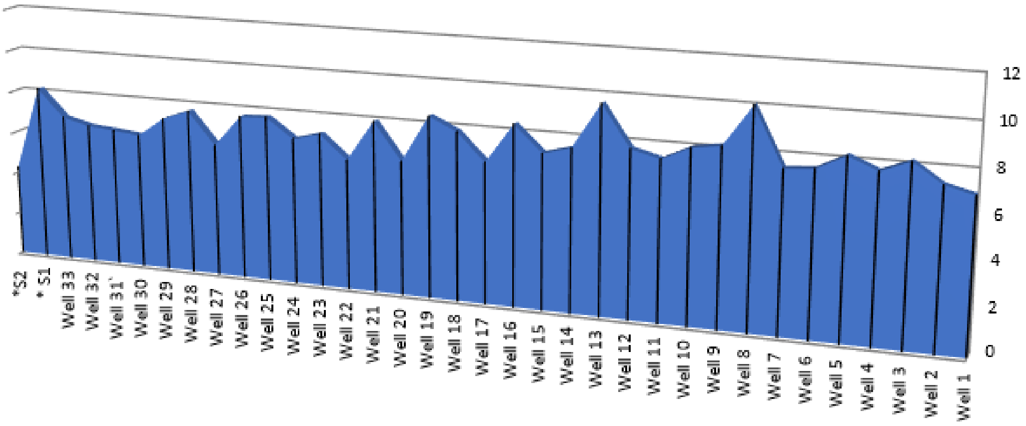

Figure 8: Ryznar Stability Index.

An modified treatment method is being sugested to overcome the corrosive potiential resulted from the previous studied groundwater corrosion indixes calculations, as showed in Figure 10. The intake well is suggested to be in the inlet opening, where a screen is suggested to separate the floating material, then Aerators used to remove the gases from the water, where the outlet water passed to coagulant tank where the coagulant is add into the water. Then the water inter flash mixer unit where the coagulator are mixed. Then the clarification process (Flocculation and sedimentation), where flocs being formed then getting settled down in sedimentation step. The outlet water then suggested to be passed to filter beds where fine and colloidal matter being removed and finally the disinfection of treated well water is suggested to kill microorganisms and also destroy organic impurities This suggested treated ground water become suitable for household as reached the distribution system. Injection of polyphosphate (corrosion inhibition) or quatarnary ammnoium chlorideare necessary for corrosion protection of different distribution water tubes in case of using selected well water in the industrial purposes. In brine phases results showed that “quaternary ammonium chloride would not efficiently inhibitedcarbon dioxide corrosion for up 20 ppm of inhibitor concentration. At higher concentrations, such as

60 to 100 ppm were required to reduce carbon dioxide corrosion to 90% inhibition efficiency. On the other hand reverse Osmosis unit added in case of using the selected ground water as demineralized industrial source with costbenefit analysis stud, bsed on the kind of industry. Figure 10. Suggested modified treatment flowchart of intake well water used in industry

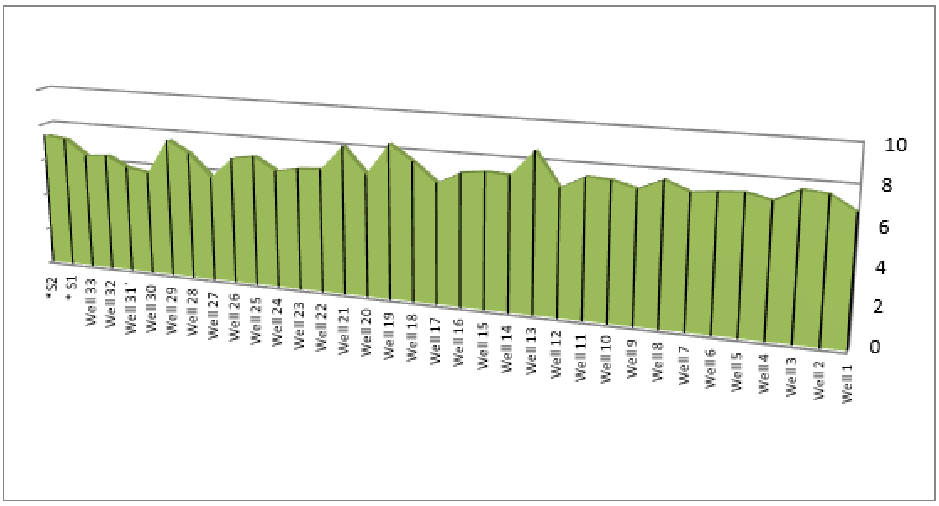

Figure 9: Puckorious Stability Index.

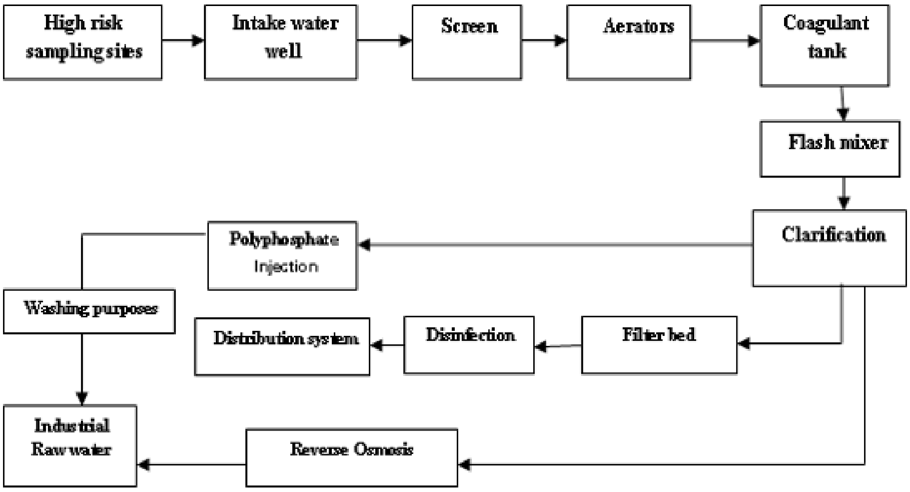

Figure 10: Suggested modified treatment flowchart of intake well water used in industry.

Conclusion and Recommendation

The study results showed that, the highest LSI values were found in sites (30, 31, 27, 33, 24, 8, 12, 26, 23, 32, 28, 16, 9, 1, S1 ,17 ,4 ,16, 5 and 20), this showed that 57.1 % of the selected 35 ground water sampling sites, had the tendency to form scale layer of CaCO3, leading to cause scale blocking layer inside the water tubes when using these ground water sites as a water source for the selected mostord industrial region, where the rest of sampling sites (42.8%) are niether precipating nor dissolving a scale layer of CaCO3(water is in equilibrium), As the result, 42.8% of these sampling siteswere suitable for using as a source of industrial water in Mostord area. In case of using Stiff-Davis index, the study results showed that the highest SDI values were indicated in sites (30, 31, 27, 8 , 24, 5,12, 32,23) with values(1.8,1.63 ,1.53, 1.41, 1.17, 1.101,1.06, 1.022,0.403), where these results showed that 26.4 % of the selected 35 ground water sampling sites, had the tendency to form scale layer of CaCO3, lead to cause scale blocking layer inside the water tubes, where 74.28% of the rest of sampling sites are niether precipating nor dissolving a scale layer of CaCO3(water is in equilibrium), As the result were recommended to be used as a source of industrial water in Mostord area. In case of using Ryznar index, the study results showed that the highest RSI values

Citation: Salah Abdelwahab El-Sayed, M STawfik*. Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt. Insi in Chem & Biochem. 3(3): 2026. ICBC. MS.ID.000563.
DOI: 10.33552/ICBC.2026.03.000563.

were indicated in sites (13, 19, 21, 3, 8, 2, 11, 10, S2, 5, 15, 6, 14, 16, 25, 9, 28, 26, 1, 22, 23,17, 24, 32, 33, 31). As the result, there will be corrosively aggressive as, 6.8<RSI<8.5 while the 20% of the sampling sites with values (6.78,6.69, 6.61, 6.5, 6.43, 6.33, and 5.83) are showing no diffuclties in corrosion, as their RSI values were in range 6.2<RI<6.8. As the result, there will be suitable for using as a source of industrial water in Mostord indusreial. In case of usingPuckorious Stability Index, the high calculated PSI values were showed in sites (8, 13, 19, 16, 5, 3, S2, 9, 10, 18, 26, 12, 28, 4, 6, 14, 7, 2, 29, 23, 33, 24, 17, 30, 27). These values showed that 71.42 % of these values showed little scaling and corrosion tendencies , because the PSI limit is 6 ≤ PSI ≤ 7, while 28.57 % of samples showed no diffuclties of corrosion but tendecy of little scale formation. It was concluded that 28.57% of the samples will be not suitable for using as a source of industrial water in Mostord indusreial untill adition of antiscale formation. The Study recommendes modified advanced water treatment method to mitigate the corrositivity potential of the studied groundwater samples,based on different processes; (sedimentation, coagulation, filtration, and Reverse Osmosis), to remove different suspended and dissolved solids, which may affect the industrial process (Scale formation). Where the recommended addition of Polyphosphate, orthophosphates and quatarnary ammnoium chloride doses as (corrosion inhibitors) were suggested to be added to the desalinated ground water flow. Depending on the flow rate and the degree of corrosion formed at the Mostorod industrial sector, where this advanced treatment tool will be helpful to overcome the predicated corrosion impacts which might be occurred when using the studied desalinated groundwater as a source for industrial water in Mostorod industrial area.

Funding: No Funds Ethics approval

All of the experimental protocols were not need to get ethic approval as there were no experimental animals used.

Consent to Publish

All of authors consent that this manuscript was published in this journal.

Consent to Participate

No consent to participate.

Conflict of interest

The authors declare no competing interests.

Data availability: All data generated or analyzed during this study are included in this published article

Declarations

Conflict of Interest: The authors declare no competing interest.

References

1. Gleeson T, Cuthbert M, Ferguson G, Debra Perrone D (2020) Global Groundwater Sustainability, Resources, and Systems in the Anthropocene. Annu Rev Earth Planet Sci 48: 431-463.
2. Abdel Moneim AA, Zaki S, Diab M (2014) Groundwater conditionsand the geoenvironmental impacts of the recent developmentin the south estern part of western desert of Egypt. journal of water resourcesand protection 6: 381-401.
3. H.I.Abdel-Shafy, Aziz.Kamel (2016) Groundwater in Egypt issue: Location, amount, contamination, renewable, future overview. Egypt J Chem 59(3): 321-362.
4. El-Sayed SA, Morsy SM (2018) Hydrogeological assessment of Moghra aquifer, North Western Desert, Egypt. Annals Geol Surv Egypt pp. 110-130.
5. Shams M, Mohamadi A Sajadi SA, (2012) Evaluation of corrosion and scaling potential of water in rural water supply distribution networks of tabas, Iran. World Appl Sci J 17(11): 1484-1489.
6. Valdez B, Schorr M, Quintero M, García R, Rosas N, (2010) Effect of climate change on durability of engineering materials in hydraulic infrastructure: an overview. Corrosion Engineering Science and Technology 45(1): pp. 34-41.
7. Hassan Taghipour, Mohammed Shakerkhatibi, Mojtaba Pourabar, Medi Belvasi, (2012) Corrosion and scaling potential in drinking water distribution system of tbrize, Northwestern Iran, Health promotion perspective 2: 103-111.
8. IwonaSkoczko, EwaSzatyłowicz (2019) Treatment Method Assessment of the Impact on the Corrosivity and Aggressiveness for the Boiler Feed Water. Journal of Water 11: 1-14.
9. Bouslah S, Djemili L, Houichi L, (2017) Water quality index assessment of Koudiat Medouar reservoir, North Algeria using weighted arithmetic index method. Journal of water and land development, 35: 221-228.
10. ASTM (2024) Standard specification of reagent water. ASTM D1193-06. United States. 11.01.
11. Abbasi T, Abbasi SA (2012) Water quality indices. Elsevier, Amsterdam, Netherlad pp. 384.
12. Brown RA, Kumar (2011) A New Perspective on Eratosthenes' Measurement of the Earth. The Physics Teacher 49: 445-447.
13. Calford Odhiambo Otieno, Alice Makonjo Wekesa (2024) Assessment of groundwater stability using corrosion and scaling trendenvy indices on selected springs in Menga region in Nyamira country, Kenya. Open Journal of Microphysics 14: 79-88.
14. CERS (Center for Environmental Research and Studies) (2014) Method Statement of Groundwater Quality Baseline Study of ERC Refinery Project, Mostorod, Cairo, Egypt. Center for Environmental Research and Studies (CERS), Cairo University, Egypt 19.
15. Environics (2010) EIA Study for Greater Cairo Metro Line No. 4 Phase 1-Final Report. National Authority for Tunnel, 297.
16. Ibrahim M (2001) Earth and Environment Science. 69012089: 1-6.
17. Lin L, Jiang W, Xu X, Xu P (2020) A critical review of the application of electromagnetic fields for scaling control in water systems: mechanisms, characterization, and operation: npj Clean Water 3: 25.
18. Mirzabeygi M, Naji M, Yousefi N, Shams M, Biglari H et al. (2016) Evaluation of corrosion and scaling tendency indices in water distribution system: a case study of TorbatHeydariye. Iran: Desalination and Water Treatment.
19. Palazzo J, van der Merwe, G Combrink (2016) The accuracy of calcium-carbonate based saturation indices in predicting the corrosivity of hot brackish water towards mild steel. journal of south America institute of Mining and metallergy 115: 1229-1238.
20. Tavanpour N, Noshadi M (2016) Scale Formation and Corrosion of Drinking Water Pipes: A Case Study of Drinking Water Distribution System of Shiraz City: Modern Applied Science. 10(3): 166-177.
21. Worley Parsons (2008) Environmental and Social Impact Assessment, ERC Hydro- Cracking Complex Project at Mostorod, Appendix 12.2, Clearance and Land Contamination Study Plan for North Plot and South

Citation: Salah Abdelwahab El-Sayed, M STawfik*. Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt. Insi in Chem & Biochem. 3(3): 2026. ICBC. MS.ID.000563.
DOI: 10.33552/ICBC.2026.03.000563.

Plot 1. Worley Parsons Infrastructure and Environment Limited, Maadi, Cairo, Egypt, 18.

22. Worley Parsons (2008a) Egyptian Refining Company Environmental and Social Impact Assessment Erc Hydro-Cracking Complex Project at Mostorod, Final Version, Appendix 1.1–Upgrade Works Agreement: WorleyParsons Infrastructure and Environment Limited.
23. WorleyParsons (2008b) Environmental and Social Impact Assessment Erc.
24. Hydro-Cracking Complex Project at Mostorod, FINAL VERSION, Chapter 1 – Introduction: WorleyParsons Infrastructure and Environment Limited. Brown, R. A. and Kumar, 2011, A New Perspective on Eratosthenes' Measurement of the Earth. The Physics Teacher 49: 445-447.
25. UNIP (2023) Quality assurance for freshwater quality monitoring-technical guidance document. United Nations Environment Programme 1-76.
26. USGS (2024) Potential corrosivity of untreated groundwater in Louisiana, Scientific investigation report 2024-5035, Department of transportation and development, U.S. Department of the Interior, Geological Survey 1-48.
27. UNESCO (United Nations Educational, Scientific and Cultural Organization) (2004) Groundwater resources of the world and their use, Zektser, I. S. and Everett, L. G.eds, UNESCO, IHP-VI, series on groundwater

    6:1- 346.

Citation: Salah Abdelwahab El-Sayed, M STawfik*. Prediction of Scale Formation and Corrosion Problems Associated with the Use of Groundwater in Industry: A Case Study in Northeast Cairo, Egypt. Insi in Chem & Biochem. 3(3): 2026. ICBC. MS.ID.000563.
DOI: 10.33552/ICBC.2026.03.000563.