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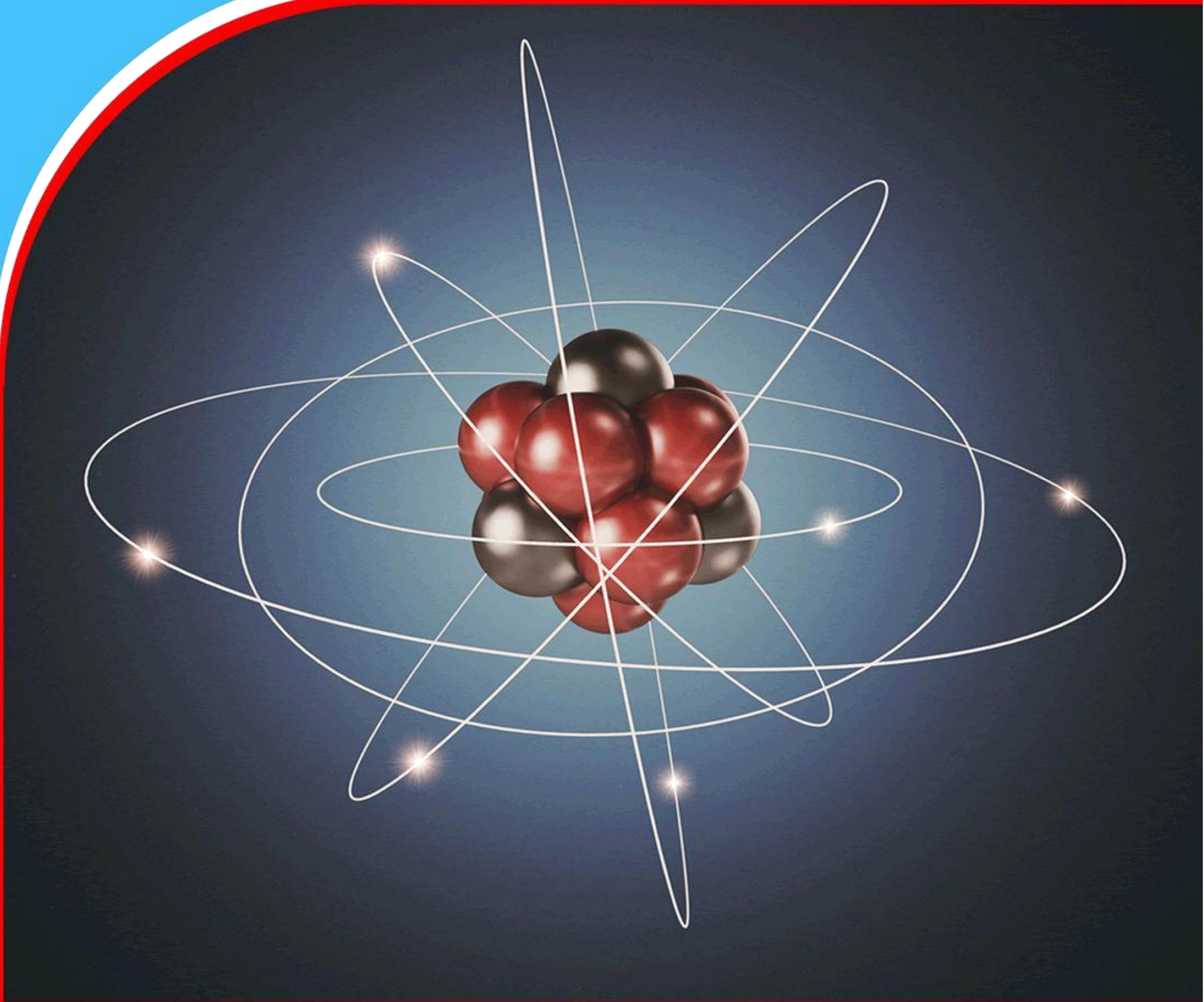

MATHEMATICAL MODELING OF WATER QUALITY WITH A DIFFERENT CHEMICAL STATE; NUTRIENTS AND ARID ENVIRONMENTAL CONDITIONS, SIWA OASIS, EGYPT

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MATHEMATICAL MODELING OF WATER QUALITY WITH A DIFFERENT CHEMICAL STATE; NUTRIENTS AND ARID ENVIRONMENTAL CONDITIONS, SIWA OASIS, EGYPT

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ABSTRACT

Purpose: A comprehensive monitoring and evaluation study was conducted on wells, water table and drainage water for water quality index. The study aimed to achieve a sustainable integrated management for water and soil at the study area.

Methodology: Assessment and evaluation of water samples were: Evaluate the physic-chemical properties; Discuss the Hydro chemical coefficient; Assessment of the appropriate use of water quality such as permeability index (PI) and Kelly's indicator (KI); Water quality identification and assessment through calculate of WQI; It was conducted various assessments of the elements within the water, such as the contamination factor (CFi); geoaccumulation index (I_{geo}) and the potential ecological risk index (RI).

Findings: The results shown that the dominance of Na^+ cation and Cl^- anions due to the influence of marine sediments on water elements which resulted in increased the mention ions in drainage water> water table> wells. TDS values of wells, water tables and drainage water were no detected, 2374 to 9088 and 3641.6 to 13952mg L^{-1}, respectively and RSC values of water samples were not significant. KI indicated that the well water is safe for drinking and the water table and drainage water are not acceptable for drinking. PI indicated that the suitability of water to be used in agriculture. WQI confirmed that the water is highly appropriated for Olive's tree and Palms cultivation. CFi indicated that the wells gave low to moderate contamination of Mn, Cu and B while, the Fe, Zn and Si concentrations were low. A very high degree of contamination by Fe, Mn, Zn, Cu and B were observed in water tables; however, Si concentration was low to considerable degree. Generally, drainage water gave a very high degree of contamination with Mn, Cu, and B, whereas the concentration of Fe, Zn and Si were low, moderate and considerable degree. Analytical modeling proved that the I_{geo} values for Mn, Zn, Cu and Si were assigned to Class 0 for water sources at study area. RI indicated the wells and water table samples (exception of Cu was moderate to high) were slightly risk as well as the RI of drainage water samples was low risk.

Contribution to theory, practice and policy: The results provided the relationships between the water resources assessment and water quality management, and to ensure their environmental reflections such as (contamination factor (CFi); geo-accumulation index (I_{geo}); the potential ecological risk (RI)), with the safe use of water based on its properties.

Keywords: *Hydro chemical coefficient; permeability index (PI); Kelly's indicator (KI); water quality index (WQI); contamination factor (CFi); geo-accumulation index (I_{geo}); the potential ecological risk (RI).*

INTRODUCTION

Water covers 71% of the Earth's surface **(**CIA, 2014**)**, which is vital for all known forms of life. Water quality refers to the physic-chemical and biological water properties. Through the Framework Directive Water (WFD), European countries began producing integrated management plans for the water with the basic objective is to achieve "good status" of water bodies by 2030 (Tsakiris and Alexakis, 2012).

The authors of different agencies and integrating were the various and varied number of water quality standards for the development of their quality indicators for water (WQIs). Then most of them have been developed using a device advanced by the *US National Sanitation Comp. 2007* (Lermontov *et al.*, 2009 and Sanjoy *et al*., 2019). Thus, the information on water resources and their suitability for use is mandatory for spatial planning and sustainable development. This is particularly important in arid and semi-arid areas, where water resources are limited and average rainfall in the long-term decreases (Hajar, 2019**)**.

Monitoring and maintaining these essential water sources is urgently to a healthy life and a sufficient supply of safe water. Over the past few decades, the Water Quality Index (WQI) has been reflected an effective tool provided that WQ data for use by policy-makers **(**Yisa *et al*., 2012**)** and has been used in surface assessment; and groundwater quality around the world **(**Bora and Goswami 2017). WQI refers to water quality in terms of an index that epitomizes overall water quality in relative to specific criteria for specific usages **(**Etim *et al*., 2013). WQI has been defined as a classification that reflects the wide-ranging impact of several water quality standards.

This study was conducted on the waters of Siwa Oasis Lifeline in the North West, located in Egypt. Indeed, the oasis is of inter-provincial, interstate, and international significance without it Obtain sufficient information on water quality and benefit. Because it is an oasis of rich agriculture (olive & palm) as it is exporting olive products. For these reasons, the study should be made on this oasis of water.

MATERIALS AND METHODS

1. Studied area explanation:

- **Location:** Siwa Oasis is located in a deep low up to below sea level, to about 19 meters to the west, is located in an oasis Jaghbub similar low, and in the Big East dropper is also located low below sea level. It lies between latitudes 29°06′32″ N and 29°16′33″ N and longitudes 25°17′36″ E and 25°48′15″ E. In Siwa Oasis, there is virtually no rainfall during the year. This location is classified as BWh by Köppen and Geiger Fig. (1), the climate of Siwa exhibits extreme aridity from April to November.

- **Topography and geology:** Siwa Oasis is situated in a depression at the northern edge of Egypt's Western Desert, 80 km from the Egyptian border with Libya and 300 km south of the Mediterranean port town of Marsa Matrouh, the nearest town of any size within 500 km. At approximately 29° North and 25.5° east, the 800 km^2 Siwan Depression stretches 80 km in east-west direction; it is from 2 to 20 km wide, and lies as much as 18 m below. Bordered on the north cliff rises is more than 100 m above the floor of the low and the south slope faint of about 20-50 m, covered with sand dunes, (Fig. 2). The deeper part of the oasis is occupied by salt marshes and sabkhas. This very salty crust difficult to the extent that the residue of this material traditionally used to build houses (brick milk is known locally as karshif). The imposition of high inland mountains from the depression dates back to the Middle Miocene, while the sand deposits belong to the modern and Pleistocene epochs. Soil Siwa is mainly composed of sandstone and limestone particles derived from the walls of the gradient. It contains large proportions of small sand (60%) and quantities of mud (7%) and large amounts of dissolved substances, especially NaCl. Soil thickness is no more than 2 to 3m in most of the depressions; which are thinner in many places. Shallow water levels in most of the region with a lattice link between the water table and ground surface.

2. Sampling:

A total of 24 samples of water were collected eight from (wells; water table and ground water). Sampling was under taken during the dry season (Dec., 2019). Stopper- fitted polyethylene bottles (capacity 1000ml) were used for saving water samples, with favorable temperature (<4°C). After sampling, the samples were transported to *SWERI-ARC* for analysis.

a. **Analytical method:** Clarification in [Table No. 1]

RESULTS AND DISCUSSION

The chemical composition of the water samples studied: Our results (Table 2) specify that discontinuous changes in chemical properties within the water types can be due to variations in stable salts concentration, rather than to stratification of chemical composition. The changes between the chemical properties that have been obtained through various large chemical analyzes, especially in the surface, medium and low source. While, the EC dS/m in wells, water tables and drainage water they were (0.29 to 9.74; 3.71 to 14.20 and 5.69 to 21.80), respectively. At all levels of the water samples, it was the dominant cation Na^+ followed by Ca^{2+} followed Mg^{2+} followed by K^+ and at the same level as the dominant anions Cl^- followed by SO_4^{2-} and HCO_3^- and CO_3^{2-}. It shows an increasing tendency along the drainage water direction about the water table and wells. The effect of water often affects its role in transporting various elements of supply. Also, Heading results indicate that the pH value of the weak alkaline conditions.

A high TDS content generally indicates contamination of the water with harmful substances. On the other hand, when the percentage of soluble solids is very low, the water becomes tasteless. Thus, TDS content indicates in wells, water tables and drainage water they were (Null in value; 2374 to 9088 and 3641.6 to 13952 mg/L), respectively. It is evident that ESP, with a 15% minimum in which Na becomes a problem, is still generally used as a standard in many scientific discussions, (fig. 4).

The results show that the value of wells is appropriate in the samples of wells, and the ratio ranges (0.83 to 19.56). As for the samples of the water table level, it approaches the critical rate, and the ratio ranges (9.60 to 22.71). As well, drainage water samples at a high rate of containing Na^+ (14.22 to 23.55). Concentration of HCO_3 and CO_3 also affects the water suitability for irrigation purposes, all low RSC water samples in the study area.

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Descriptive statistics of different hydro chemical parameters: The main ionic relationship is the description to explain Hydro chemical evolution processes and the mechanism of water control samples. Let's clarify that:

In table (2), indicated that (rNa^++rK^+)/rCl^- on all samples Na^+ ions decrease relative to Cl^- ions, and this reflects the influence of water with marine sediments. This is due to the partial flow of marine sediments or ancient sea water through rainwater that infiltrated the movement horizontally or vertically and settled in the Crusader underground reservoir materials in the past time.

Most of the samples were indicated by (rSO_4^{2-}/rCl^-), a solution of Alfate such as Gypsum, local terrestrial source of Suepsomite ($MgSO_4 . 7H_2O$), Glauberite ($Na_2SO_4 . 10H_2O$) vs. anhydrite moreover other more rare sulfate salts.

The results indicated that most of the results for wells and water table were seriously contaminated water. Except for (well No. 3& 8) and (WT No. 6) were highly contaminated water. Moreover, drainage water is highly contaminated water. This means that the water is likely to be a source of pure meteoric, influenced by continental pollution from normal to dangerously contaminated as a result of the influence of ancient marine sediments.

The suitability index of use the studied water: The water-usability indicator is one of the pillars of maximizing its use. With it directed to the best use. However, several integrated indicators were used to judge water quality, continue in Table (3).

The Kelly index (KI) indicates the relative amount of Na vs. Ca and Mg help determine the suitability of water for agricultural purposes. The clearest indicator (KI) indicates that well water (Na^+ deficiency in water) is safe for drinking. The water table and drainage water are not suitable for drinking.

The results of permeability index (PI) all the water samples indicated that their level is of average use for agriculture. This means that it needs to be mixed with good quality water. The Water Quality Index (WQI) confirmed that the water is largely suitable for the crops used there (olives and palms). **Doneen, (1964)** explained that the suitability of water for irrigation does not depend on the total concentration of salts soluble, where salts are deposited on the low solubility of soil and deposited each year. In fact, water with a low salt content is suitable for irrigation purposes.

Various assessments of the elements within the water: In order to systematically understand the contamination of elements in the sediments of the water studied, the contamination factor (CFi), the value of geo-accumulation index (I_{geo}), and the potential ecological risk index (RI) were applied to evaluate the pollution ranks in the current study.

The contamination factor (CFi): In (Table 4 and figure 4), the mean CFi values for Fe, Mn, Zn, Cu, B and Si were in the wells (0.74: 1.26); (8.45: 21.60); (0.46: 1.78); (2.15: 17.75); (0.0: 10.27) and (0.08: 1.39), respectively. The results mostly indicated that the water wells were low to moderate contamination by Mn, Cu and B. In contrast, showed Fe, Zn and Si concentration is low.

The results also indicated that the mean CFi values for Fe, Mn, Zn, Cu, B and Si were in the water table (1.07: 1.49); (16.85: 37.15); (1.19: 2.63); (10.25: 113.50); (6.13: 64.23) and (0.13: 6.21), respectively. The results generally showed that the water

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tables in the study area were very high degree of contamination by Fe, Mn, Zn, Cu and B. In contrast, showed Si concentration is low to considerable degree.

In addition to the analytical calculation results the mean CFi values for Fe, Mn, Zn, Cu, B and Si were in the drainage water (0.48: 1.27); (11.05: 17.80); (0.39: 1.44); (3.95: 14.40); (10.07: 45.17) and (0.82: 2.62), respectively. Results in general specified that the wastewater in the study area was very high degree of contamination with Mn, Cu, and B. On the other hand, showed that the concentration of Fe, Zn and Si low to a moderate and considerable degree.

It can reduce the risk of deterioration of soil fertility by building organic matter to the soil, add lime to the soil and maintain the alkaline soil with water management according to the quality and evaluation at the level of the environmental impact on the system. Which expounded **(**Mahmoud *et al*., 2019**)**, that one of the deteriorations of soil fertility is a reflection of a group of recent environmental changes (the Climate properties of the soil quality of human practices ... that of water, *etc.*).

The value of geo-accumulation index (I_{geo}): In figure (4) and table (4) analytical computational results the mean I_{geo} values for Mn, Zn, Cu and Si (-0.24: -0.65); (0.09: 0.68); (-0.32: -1.24) and (0: -1.92) were in the wells are existing falling into Class 0 at all locations, which means that well water was not contaminated with these elements. Except for the Fe results, they fell into Class 1 (1.09: 1.32), which means that the well water was moderately polluted. In adding, the B element in all site classification between classes 0 to 1; the result was B (0.15: 1.88).

On the other hand, arithmetic model was produced for the following geo-accumulation of water table, the mean I_{geo} values for Mn, Zn, Cu and B (-0.24: -0.53); (0.02: 0.58); (-0.16: 0.48) and (-0.36: 0.59) were in the samples are prevailing falling into Class 0 at all sites, which means that water table was not contaminated with these elements. Except for the Fe results, they fell into Class 1 (1.25: 1.39), which means that the water table was moderately polluted. The Mathematical model output for Si was heading into several classes in amid class 0 and 3; the result was B (0.32: 2.01).

At the level of the rest of the outputs of the results it was the mean I_{geo} values for Mn, Zn, Cu and B (-0.24: -0.53); (0.02: 0.58); (-0.42: -0.98) and (0: 0.43) were in the drainage water are existing falling into Class 0 at all localities, which means that water samples was not contaminated with these elements. But the results of elemental Fe and Si headed to a class 1 (unpolluted to moderately pollute); the result was Fe (1.15: 1.33) and Si (1.13: 1.70).

The potential ecological risk index (RI): The RI for well water samples is of slightly risk, where the results go according to the follows (Fe 3.69: 6.32); (Mn 8.45: 21.60); (Zn 0.46: 1.78); (Cu 0.75: 88.75); (B 0: 3.08) and (Si 0.08: 4.57). In a nutshell, the element of studied under investigation in the sediment doesn't reflect the environmental risks to water.

The results also to water table indicated the follows (Fe 4.30: 5.94); (Mn 16.85: 37.15); (Zn 1.19: 2.63); (B 1.84: 19.27) and (Si 0.13: 6.21). It is a standard that is considered the case of water samples is slightly risk. With the exception of the Cu results that were subtracted, the risks were moderate to high for the entire study area, (Cu 5125: 567.50).

Furthermore, RI of drainage water samples in the sediment observed was low risk, according to European reference **(**Hakanson, 1980**)**. Where, the results go according to the following (Fe 3.37: 5.08); (Mn 16.58: 32.63); (Zn 0.31: 1.14); (Cu 19.75: 72.0); (B 3.02: 13.55) and (Si 0.64: 2.34).

CONCLUSION

Mathematical modeling of WQI confirmed that CFi of wells indicate low to moderate contamination of Mn, Cu and B on the other hand, a very high degree of contamination by Fe, Mn, Zn and Cu was found in water table; however, Si concentration was low to considerable degree. Generally, drainage water gave a very high degree of contamination with Mn, Cu, and B. The water is highly appropriated for Olive's tree and Palms cultivation. Analytical modeling proved that the I_{geo} values for Mn, Zn, Cu and Si were assigned to Class 0 for water sources at study area. RI indicated the wells and water table samples (exception of Cu was moderate to high) were slightly risk as well as the RI of drainage water samples was low risk. Based on the obtained results can be recommended that:

- The mathematical modeling techniques are very effective to evaluate the water risk assessment and assign water quality indices, which allocate the most optimal use of water.
- The modeling outputs emphasized that the significant role of water quality indicators for sustainable water use, appropriate management of soil as well as environmental integrity.
- The water quality indices obtained using modeling support decision makers and long term agro- strategies.

ACKNOWLEDGMENT

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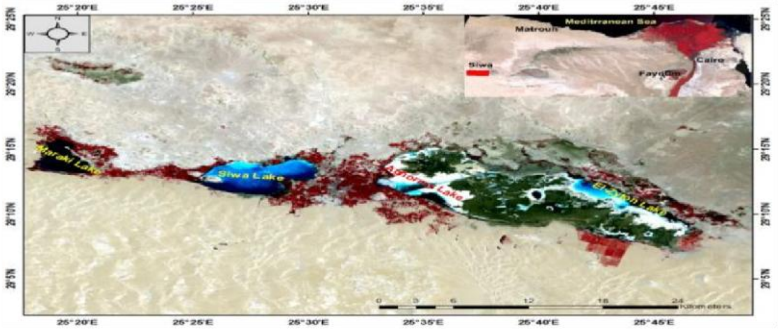

SIWA OASIS WEATHER BY MONTH // WEATHER AVERAGES

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	11.7	13.4	16.5	21	25.3	28.4	29.5	28.9	26.3	23.2	18.4	13.1
Min. Temperature (°C)	4	5.2	8	12	16.4	19.1	20.7	20.1	17.9	14.5	10.2	5.2
Max. Temperature (°C)	19.4	21.7	25	30	34.2	37.7	38.3	37.7	34.8	32	26.6	21.1
Avg. Temperature (°F)	53.1	56.1	61.7	69.8	77.5	83.1	85.1	84.0	79.3	73.8	65.1	55.6
Min. Temperature (°F)	39.2	41.4	46.4	53.6	61.5	66.4	69.3	68.2	64.2	58.1	50.4	41.4
Max. Temperature (°F)	66.9	71.1	77.0	86.0	93.6	99.9	100.9	99.9	94.6	89.6	79.9	70.0
Precipitation / Rainfall (mm)	1	1	1	1	0	0	0	0	0	0	1	2

Fig. (1): **Siwa oasis Location and weather averages**

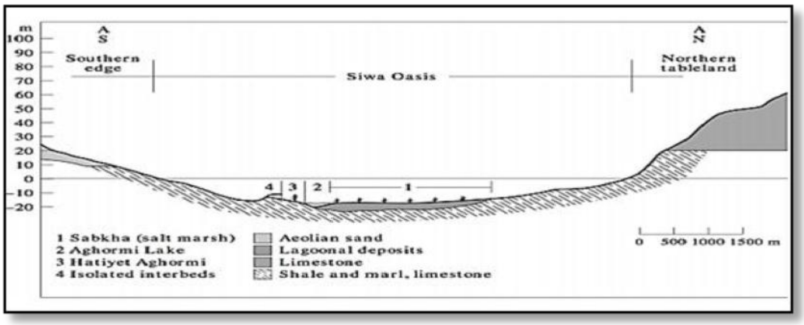

Fig. (2): **North–south section of Siwa Oasis.** **(Source: Misak *et al.*, 1997).**

Table (1): Explanations of the analytical methods of the studied samples:

<table>
<tr><td colspan="2">⅄ Chemical and elements analysis: The samples were analyzed for pH, EC, Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Cl^{-}, CO_3^{2-}, HCO_3^{-}, SO_4^{2-}, SAR, ESP and RSC following the techniques described in (APHA, 2012 and Rakotondrabe et al., 2018).As well, Fe, Mn, Zn, Cu, B and Si following the techniques in Ballinger (1989).</td></tr>
<tr><td>⅄ Hydro chemical coefficient of water samples: The measured hydro-chemical parameter was interpreted using equations, based on chemical analyses (Hem, 1985) as following:

$rCl^{-}/(rHCO_3^{-}+CO_3^{2-})$, according to the study of this parameter in the direction of separation salinization from areas affected by the ancient marine sediments or corrosive sea water, (Tood, 1980) classification according to this ratio as follows: normal good water (<1); slightly contaminated water (1>and <2); moderate contaminated water (2-6); seriously contaminated water (<15) and highly contaminated water (>15)</td><td>$$\frac{rNa + rK}{rCl}$$
$$\frac{rSO4}{rCl}$$
$$\frac{rCl}{r(HCO3 + CO3)}$$
$$\left(\frac{rSO4}{ranions}\right) - \left(\frac{rNa}{rcations}\right) * 100$$</td></tr>
<tr><td>⅄ Water suitability quality for usage:
<u>Kelly Indicator (KI)</u> is water quality suitable for usage; also it is determined on the base of purpose KI. In KI, Ca^{2+} and Na^{+} versus measured Mg^{2+} (Kelly, 1940). It's calculated with the following equation (Srinivasamoorthy et al., 2014).
<u>Permeability index (PI)</u> is also used to determine the suitability of irrigation water. Soil permeability is affected by long-term exposure of irrigation water that contains a high amount of Na, Ca, Mg and HCO_3 ions (Ravikumar et al., 2011; Srinivasamurthy et al. 2014). Donen (1964) The PI was introduced to assess the suitability of irrigation water and it is calculated with the following formula (Arumugam and Elangovan 2009).</td><td>$$KI = \frac{Na}{Ca + Mg}$$
Where ion concentrations are expressed in meq/L. KI indicates an excess quantity of Na^{+} in water. Thus, water with KI value less than one (KI<1) is acceptable for irrigation, while value greater than one (KI>1) indicates excess Na^{+} in water and value less than two (KI<2) indicates Na^{+} deficiency in water.
$$PI = \frac{(Na + \sqrt{HCO3}) * 100)}{(Ca + Mg + Na + K)}$$
It is expressed in concentrations meq/ L. Water classified into 3 categories based on the PI values. Class I (PI>75%) is considered suitable for irrigation, class II (PI = 25-75%) is considered somewhat appropriate irrigation uses, the third category (PI<25%) is not suitable (Das and Nag, 2015)</td></tr>
<tr><td>⅄ <u>Water quality index (WQI)</u>
- WQI was calculated for each sample using the equation according to (Yisa and Jimoh, (2010) and Tyagi et al., (2014). Where, qi, ci, and si indicated quality rating scale, concentration of i parameter, and standard value of i parameter, respectively. Relative weight was calculated by:</td><td>$$qi = \left(\frac{ci}{si}\right) * 100$$
$$wi = \frac{1}{si}$$
$$WQI = \frac{\sum qi\ wi}{\sum wi}$$
Where, the standard value of i parameter is inversely comparative to the relative weight. To conclude, general WQI was calculated according to the following expression: WQI classified based on computed, <50excellent; 50-100 good water; 101-200 poor water; 201-300 very poor water and >300 water unsuitable for use.</td></tr>
<tr><td>⅄ Various assessments of the elements within the water:
- The contamination factor (CFi) is the nutrient concentration ratio (C^i_s); the background value (C^i_b). CFi was calculated by:
- The geo- accumulation index (I_{geo}) can be</td><td>$$CFi = \frac{Cis}{Cib}$$
Where, (C^i_s) symbolizes the measured nutrient value, (C^i_b) represents the equivalent related value. CFi was classification according to (Pandey et al., 2019), low degree (CFi<1), moderate degree (1≤CFi<3), considerable degree (3≤CFi<6) and very high degree (CFi≥6).</td></tr>
</table>

calculated by the equation **(Muller, 1969):** - **The potential ecological risk index (RI)** was mentioned by European references **Hakanson, (1980),** which measured toxicity level, the synergistic effect and ecological sensitivity of several potentially toxic elements. The calculation formulation by:	$$Igeo = log2\left[\frac{Cis}{1.5Cib}\right]$$ Where, 1.5 is a back ground matrix correction factor which was used to characterize sedimentary features, petro geology and other impacts. Hence, the pollution degree was classified: $I_{geo} \leq 0$ unpolluted (class 0); $0 < I_{geo} \leq 1$ unpolluted to moderately polluted (class 1); $1 < I_{geo} \leq 2$ moderately polluted (class 2); $2 < I_{geo} \leq 3$ moderately to heavily polluted (class 3); $3 < I_{geo} \leq 4$ heavily polluted (class 4); $4 < I_{geo} \leq 5$ heavily to extremely polluted (class 5); $I_{geo} \geq 5$ extremely polluted (class 6). $$RI = \sum E^i_r = \sum T^i_r * CFi = \sum T^i_r * (C^i_s * C^i_b)$$ Where, T^i_r is the toxicity response coefficient. E^i_r is the potential ecological risk index. RI is the comprehensive potential ecological risk index of several metals in sediments, which consists of 4 classes: RI< 150 slightly risk, 150≤RI<300 moderate risk, 300≤RI<600 high risk and RI≥600 very high risk.

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Table (2): Chemical composition and hydro-chemical coefficient for water resources samples in the studied area.

Wells No.	The chemical composition and hydro chemical coefficient of samples of water wells in Siwa Oasis													
	pH	EC dS/m	TDS ppm	Soluble cations & anions (mg/l)								SAR	ESP	RSC meq/l
				Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}			
W1	7.60	2.32	--	8.19	4.51	12.76	0.84	17.00	1.30	1.60	6.40	5.06	5.85	-9.80
W2	7.71	0.29	--	1.89	1.20	1.77	0.68	3.00	0.60	1.20	0.74	1.42	0.83	-1.29
W3	6.89	9.70	--	18.91	24.30	72.30	2.39	85.00	0.60	3.20	29.70	15.55	17.82	-39.40
W4	7.02	3.58	--	14.02	7.67	32.66	1.05	20.00	1.80	2.60	34.00	9.30	11.07	-20.29
W5	7.21	9.28	--	22.07	8.79	68.10	1.65	82.00	1.40	2.20	15.01	17.34	19.56	-27.30
W6	7.35	4.78	--	119.98	9.62	32.70	1.12	40.00	0.80	3.40	11.22	9.95	11.83	-17.40
W7	7.70	2.66	--	8.83	4.13	20.41	0.86	22.00	1.20	2.40	8.63	8.02	9.56	-9.36
W8	7.04	9.74	--	17.02	15.08	63.96	1.51	70.00	0.60	1.20	25.77	15.97	18.23	-30.30
Water Table No.	**The chemical composition and hydro chemical coefficient of samples of water table in Siwa Oasis**													
	pH	**EC dS/m**	**TDS ppm**	**Soluble cations & anions (mg/l)**								**SAR**	**ESP**	**RSC meq/l**
				Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}			
WT1	7.14	8.78	5619	21.17	23.04	23.04	2.04	72.00	0.80	5.00	27.17	12.99	15.19	-37.41
WT2	7.46	13.31	8518	66.83	19.59	19.59	2.95	10.40	1.60	5.20	85.77	16.31	18.56	-79.62

WT3	7.76	4.99	3193	17.65	8.27	8.27	1.83	45.00	1.00	4.60	10.05	9.14	10.89	-200.3
WT4	7.38	7.38	4723	30.26	34.55	34.55	3.09	40.00	1.20	4.60	73.10	8.96	10.68	-59.01
WT5	7.21	14.20	9088	67.35	37.85	37.85	4.49	114.0	0.80	7.40	111.69	17.12	19.35	-97.00
WT6	7.16	9.33	5971	37.83	37.83	28.84	4.28	56.00	0.40	2.40	135.35	11.64	13.72	-63.78
WT7	7.36	9.95	6368	20.81	94.57	2.29	2.60	83.00	0.00	4.60	99.83	20.77	22.71	-294.9
WT8	7.36	3.71	2374	10.72	10.72	12.12	1.54	25.00	0.50	4.20	21.90	8.02	9.60	-18.14
drainage Water No.	**The chemical composition and hydro chemical coefficient of samples of drainage water in Siwa Oasis**													
	pH	**EC dS/m**	**TDS ppm**	**Soluble cations & anions (mg/l)**								**SAR**	**ESP**	**RSC meq/l**
				Ca^{2+}	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**Cl^{-}**	**CO_3^{2-}**	**HCO_3^{-}**	**SO_4^{2-}**			
DW1	7.61	21.80	13952	80.71	22.99	156.5	5.76	220.0	1.80	5.20	38.96	21.73	23.55	-56.70
DW2	7.39	12.70	8128	30.26	31.46	100.4	3.30	130.0	1.40	5.00	29.92	18.07	20.25	-55.30
DW3	7.35	12.72	8140	31.52	35.14	96.97	3.23	108.0	2.00	4.20	52.92	16.80	19.04	-60.50
DW4	7.27	12.80	8192	31.52	35.51	98.70	2.11	106.0	1.40	3.80	168.54	17.05	19.28	-61.83
DW5	7.26	12.56	80384	39.09	51.03	88.50	2.81	104.0	2.00	3.60	71.83	13.18	15.39	-84.52
DW6	7.33	12.25	7840	37.83	30.07	90.20	2.74	112.0	2.00	3.40	43.44	15.48	17.75	-62.50
DW7	7.43	5.69	3641.6	8.20	10.32	36.80	1.26	24.00	1.60	4.80	26.18	12.09	14.22	-12.12

DW8	7.58	14.20	9088	32.78	49.94	86.76	3.23	120.0	1.20	3.40	48.11	13.49	15.71	-78.12

 EC: Electric Conductivity; **TDS:** Total Dissolved Salts; **SAR:** Sodium Adsorption Ratio; **ESP**: Exchangeable Sodium Percentage and **RSC:** Residual Sodium Carbonate.

Table (2): Cont.

Wells No.	**The chemical composition and hydro chemical coefficient of samples of water wells in Siwa Oasis**			
	$\frac{rNa+rK}{rCl}$	$\frac{rSO4}{rCl}$	$\frac{rCl}{r(HCO3+CO3)}$	$(\frac{rSO4}{ranions}) - (\frac{rNa}{rcations}) * 100$
W1	0.80	0.38	5.86	-1957.12
W2	0.82	0.25	1.67	-455.86
W3	0.88	0.35	22.37	-10247.49
W4	1.69	1.70	4.55	-4330.85
W5	0.85	0.18	22.78	-8143.77
W6	0.85	0.28	9.52	-4355.55
W7	0.97	0.39	6.11	-2758.52
W8	0.94	0.37	38.89	-8402.86
Water Table No.	**The chemical composition and hydro chemical coefficient of samples of water tables in Siwa Oasis**			
	$\frac{rNa+rK}{rCl}$	$\frac{rSO4}{rCl}$	$\frac{rCl}{r(HCO3+CO3)}$	$(\frac{rSO4}{ranions}) - (\frac{rNa}{rcations}) * 100$
WT1	0.35	0.38	12.41	-4887.49

WT2	2.17	8.25	1.53	-4,141.50
WT3	0.22	0.22	8.04	-1867.98
WT4	0.94	1.83	6.90	-7252.45
WT5	0.37	0.98	13.90	-7954.33
WT6	0.59	2.42	20.00	-7030.67
WT7	0.06	1.20	18.04	-9851.37
WT8	0.55	0.88	5.32	-2523.58
drainage Water No.	**The chemical composition and hydro chemical coefficient of samples of drainage water in Siwa Oasis**			
	$\frac{rNa+rK}{rCl}$	$\frac{rSO4}{rCl}$	$\frac{rCl}{r(HCO3+CO3)}$	$(\frac{rSO4}{ranions}) - (\frac{rNa}{rcations}) * 100$
DW1	0.74	0.18	31.43	-18672.77
DW2	0.80	0.23	20.31	-13,811.24
DW3	0.93	0.49	17.42	-13782.04
DW4	0.95	1.59	20.38	-13769.80
DW5	0.88	0.69	18.57	-14382.28
DW6	0.83	0.39	20.74	-12490.21
DW7	1.59	1.09	3.75	-5253.11

DW8	0.75	0.40	26.09	-14204.56

Table (3): Kelly's Index (KI), Permeability Index (PI) and Water Quality Index (WQI) for suitability of use water samples.

Wells No.	Kelly's Index (KI)	(KI) Classes	Permeability Index (PI)	(PI) classes	Water Quality Index (WQI) based on weighted arithmetic	(WQI) classes
W1	14.32	Na deficiency in water	53.33	Moderate suitable irrigation uses	8.82	Excellent
W2	2.71	Na deficiency in water	51.72	Moderate suitable irrigation uses	15.75	Excellent
W3	76.12	Na deficiency in water	62.84	Moderate suitable irrigation uses	9.93	Excellent
W4	34.99	Na deficiency in water	61.86	Moderate suitable irrigation uses	19.67	Excellent
W5	71.19	Na deficiency in water	69.16	Moderate suitable irrigation uses	35.25	Good
W6	32.97	Na deficiency in water	21.14	Unsuitable irrigation uses	10.06	Excellent
W7	22.72	Na deficiency in water	64.15	Moderate suitable irrigation uses	12.89	Excellent
W8	67.72	Na deficiency in water	66.68	Moderate suitable irrigation uses	13.99	Excellent
Water Table No.	**Kelly's Index (KI)**	**(KI) Classes**	**Permeability Index (PI)**	**(PI) classes**	**Water Quality Index (WQI) based on weighted arithmetic**	**(WQI) classes**
WT1	24.13	Unsuitability of water quality	36.48	Moderate suitable irrigation uses	10.16	Excellent
WT2	19.88	Unsuitability of water quality	20.07	Unsuitable irrigation uses	21.13	Excellent

WT3	8.74	Unsuitability of water quality	28.91	Moderate suitable irrigation uses	21.81	Excellent
WT4	35.69	Unsuitability of water quality	35.82	Moderate suitable irrigation uses	31.03	Good
WT5	38.41	Unsuitability of water quality	27.50	Moderate suitable irrigation uses	28.76	Good
WT6	29.60	Unsuitability of water quality	27.94	Moderate suitable irrigation uses	11.79	Excellent
WT7	2.40	Unsuitability of water quality	3.69	Unsuitable irrigation uses	0.63	Excellent
WT8	13.25	Unsuitability of water quality	40.37	Moderate suitable irrigation uses	5.93	Excellent
drainage Water No.	**Kelly's Index (KI)**	**(KI) Classes**	**Permeability Index (PI)**	**(PI) classes**	**Water Quality Index (WQI) based on weighted arithmetic**	**(WQI) classes**
DW1	158.44	Unsuitability of water quality	59.70	Moderate suitable irrigation uses	30.31	Good
DW2	103.72	Unsuitability of water quality	62.05	Moderate suitable irrigation uses	20.25	Excellent
DW3	100.05	Unsuitability of water quality	59.34	Moderate suitable irrigation uses	26.28	Good
DW4	101.83	Unsuitability of water quality	59.97	Moderate suitable irrigation uses	21.76	Excellent
DW5	90.76	Unsuitability of water quality	49.82	Moderate suitable irrigation uses	26.51	Good
DW6	92.58	Unsuitability of water quality	57.23	Moderate suitable irrigation uses	22.13	Excellent
DW7	41.29	Unsuitability of water quality	68.91	Moderate suitable irrigation uses	18.27	Excellent
DW8	89.41	Unsuitability of water quality	51.30	Moderate suitable irrigation uses	24.55	Excellent

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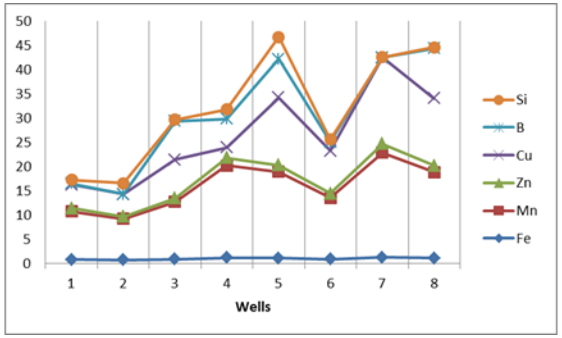
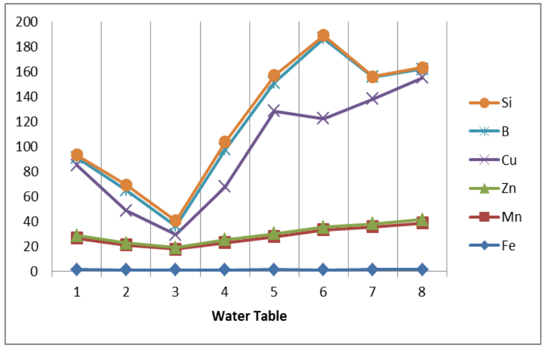
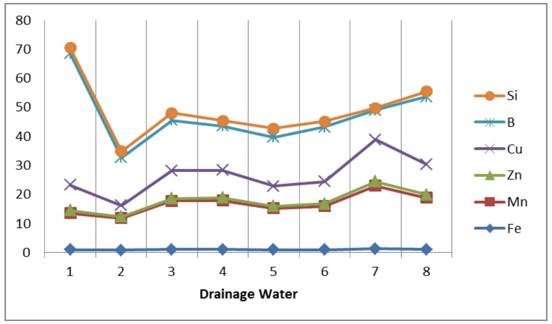
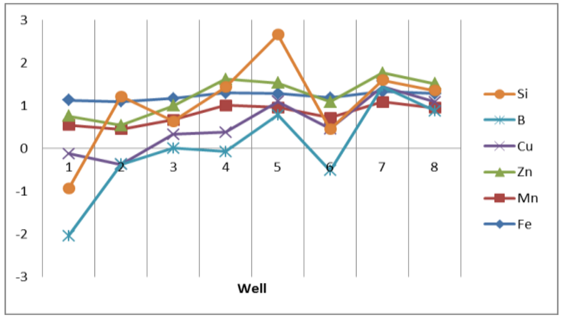
CFi

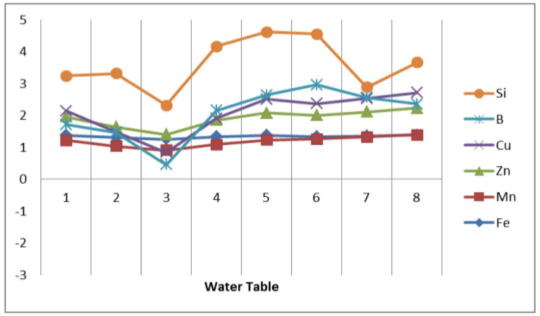


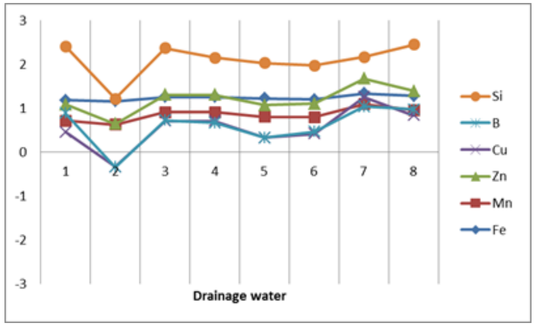




I_{geo}







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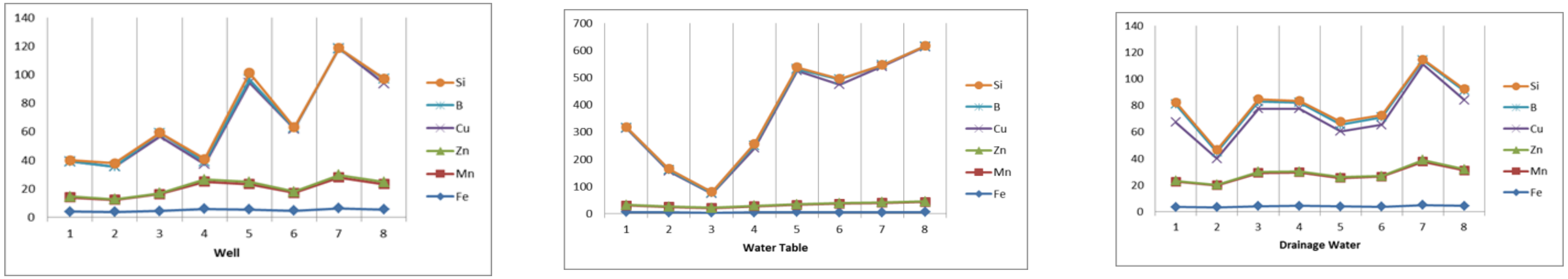
RI	

Fig. (4): **Simegraphics to CFi, Igeo and RI identify to elements for the water studied**

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Table (4): Essential nutrients analysis of major constituents of water resources in the studied area

Wells No.	The character of the water elements in wells and metal contamination														
	Fe	CFi	CFi Grade	$I_{geo.}$	RI	Mn	CFi	CFi Grade	$I_{geo.}$	RI	Zn	CFi	CFi Grade	$I_{geo.}$	RI
W1	4.00	0.80	LD	1.12	4.00	1.99	9.95	VHD	-0.58	9.95	1.23	0.62	LD	0.21	0.62
W2	3.69	0.74	LD	1.09	3.69	1.69	8.45	VHD	-0.65	8.45	0.92	0.46	LD	0.09	0.46
W3	4.36	0.87	LD	1.16	4.36	2.36	11.8	VHD	-0.50	11.80	1.59	0.80	LD	0.33	0.80
W4	5.81	1.16	MD	1.29	5.81	3.81	19.05	VHD	-0.29	19.05	3.04	1.52	MD	0.61	1.52
W5	5.55	1.11	MD	1.27	5.55	3.55	17.75	VHD	-0.32	17.75	2.78	1.39	MD	0.57	1.39
W6	4.52	0.90	LD	1.18	4.52	2.53	12.65	VHD	-0.47	12.65	1.76	0.88	LD	0.37	0.88
W7	6.32	1.26	LD	1.32	6.32	4.32	21.60	VHD	-0.24	21.60	3.55	1.78	MD	0.68	1.78
W8	5.54	1.11	LD	1.27	5.54	3.54	17.70	VHD	-0.33	17.70	2.77	1.39	MD	0.57	1.39
Water Table No.	The character of the water elements in water table and metal contamination														
	Fe	CFi	CFi Grade	$I_{geo.}$	RI	Mn	CFi	CFi Grade	$I_{geo.}$	RI	Zn	CFi	CFi Grade	$I_{geo.}$	RI
WT1	7.21	1.44	MD	1.38	5.77	5.02	25.10	VHD	-0.17	25.10	4.23	2.12	MD	0.75	2.12
WT2	6.00	1.20	MD	1.30	4.80	4.00	20.00	VHD	-0.27	20.00	3.02	1.51	MD	0.60	1.51
WT3	5.37	1.07	MD	1.25	4.30	3.37	16.85	VHD	-0.35	16.85	2.38	1.19	MD	0.50	1.19

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WT4	6.35	1.27	MD	1.33	5.08	4.35	21.75	VHD	-0.24	21.75	4.35	2.18	MD	0.76	2.18
WT5	7.25	1.45	MD	1.38	5.80	5.25	26.25	VHD	-0.15	26.25	5.25	2.63	MD	0.85	2.63
WT6	6.37	1.27	MD	1.33	5.10	6.37	31.85	VHD	-0.07	31.85	4.13	2.07	MD	0.74	2.07
WT7	6.88	1.38	MD	1.36	5.50	6.88	34.40	VHD	-0.04	34.40	4.65	2.33	MD	0.79	2.33
WT8	7.43	1.49	MD	1.39	5.94	7.43	37.15	VHD	0.00	37.15	5.19	2.60	MD	0.84	2.60
drainage Water No.	**The character of the water elements in drainage water and metal contamination**														
	Fe	**CFi**	**CFi Grade**	**$I_{geo.}$**	**RI**	**Mn**	**CFi**	**CFi Grade**	**$I_{geo.}$**	**RI**	**Zn**	**CFi**	**CFi Grade**	**$I_{geo.}$**	**RI**
DW1	4.54	0.91	LD	1.18	3.63	2.53	12.65	VHD	-0.47	18.98	1.77	0.89	LD	0.37	0.70
DW2	4.21	0.84	LD	1.15	3.37	2.21	11.05	VHD	-0.53	16.58	0.78	0.39	LD	0.02	0.31
DW3	5.32	1.06	MD	1.25	4.26	3.33	16.65	VHD	-0.35	24.98	1.90	0.95	LD	0.40	0.75
DW4	5.37	1.07	MD	1.25	4.30	3.36	16.80	VHD	-0.35	25.20	1.89	0.95	LD	0.40	0.75
DW5	5.01	1.00	MD	1.22	4.01	2.85	14.25	VHD	-0.42	21.38	1.38	0.69	LD	0.26	0.55
DW6	4.67	0.93	LD	1.19	3.74	3.01	15.05	VHD	-0.40	22.58	1.54	0.77	LD	0.31	0.61
DW7	6.35	1.27	MD	1.33	5.08	4.35	21.75	VHD	-0.24	32.63	2.88	1.44	MD	0.58	1.14
DW8	5.56	1.11	MD	1.27	4.45	3.56	17.80	VHD	-0.32	26.70	2.08	1.04	MD	0.44	0.82

 CFi: Contamination Factor**; Igeo**: geo-accumulation; **RI:** The Potential Ecological Risk Index**; LD**: Low Degree; MD: Moderate Degree; **CD:** Considerable Degree; **VHD**: Very High Degree.

Table (4): cont.

Wells No.	The character of the water elements in wells and metal contamination														
	Cu	CFi	CFi Grade	$I_{geo.}$	RI	B	CFi	CFi Grade	$I_{geo.}$	RI	Si	CFi	CFi Grade	$I_{geo.}$	RI
W1	0.98	4.90	CD	-0.88	24.50	0.06	0.20	LD	-1.92	0.06	3.89	0.78	LD	1.11	0.78
W2	0.92	4.60	CD	-0.91	23.00	0.00	0.00	LD	0.00	0.00	11.6	2.32	MD	1.59	2.32
W3	1.59	7.95	VHD	-0.67	39.75	2.38	7.93	VHD	-0.32	2.38	1.28	0.26	LD	0.63	0.26
W4	0.43	2.15	MD	-1.24	10.75	1.78	5.93	MD	-0.45	1.78	9.64	1.93	MD	1.51	1.93
W5	2.78	13.9	VHD	-0.43	69.50	2.38	7.93	VHD	-0.32	2.38	22.83	4.57	CD	1.88	4.57
W6	1.76	8.80	VHD	-0.63	44.00	0.54	1.80	MD	-0.97	0.54	2.72	0.54	LD	0.96	0.54
W7	3.55	17.75	VHD	-0.32	88.75	0.00	0.00	LD	0.00	0.00	0.42	0.08	LD	0.15	0.08
W8	2.77	13.85	VHD	-0.43	69.25	3.08	10.27	VHD	-0.21	3.08	0.91	0.18	LD	0.48	0.18
Water Table No.	The character of the water elements in water table and metal contamination														
	Cu	CFi	CFi Grade	$I_{geo.}$	RI	B	CFi	CFi Grade	$I_{geo.}$	RI	Si	CFi	CFi Grade	$I_{geo.}$	RI
WT1	11.25	56.25	VHD	0.18	281.25	1.84	6.13	VHD	-0.43	1.84	10.16	2.03	MD	1.53	2.03
WT2	5.2	26.00	VHD	-0.16	130.00	4.92	16.40	VHD	-0.01	4.92	21.13	4.23	CD	1.85	4.23
WT3	2.05	10.25	VHD	-0.56	51.25	2.03	6.77	VHD	-0.39	2.03	21.81	4.36	CD	1.86	4.36

WT4	8.50	42.50	VHD	0.05	212.50	8.86	29.53	VHD	0.25	8.86	31.03	6.21	VHD	2.01	6.21
WT5	19.60	98.00	VHD	0.42	490.00	6.82	22.73	VHD	0.13	6.82	28.76	5.75	CD	1.98	5.75
WT6	17.40	87.00	VHD	0.37	435.00	19.27	64.23	VHD	0.59	19.27	11.79	2.36	MD	1.59	2.36
WT7	19.95	99.75	VHD	0.42	498.75	5.3	17.67	VHD	0.03	5.30	0.63	0.13	LD	0.32	0.13
WT8	22.70	113.50	VHD	0.48	567.50	2.16	7.20	VHD	-0.36	2.16	5.93	1.19	MD	1.30	1.19
drainage Water No.	**The character of the water elements in drainage water and metal contamination**														
	Cu	**CFi**	**CFi Grade**	**$I_{geo.}$**	**RI**	**B**	**CFi**	**CFi Grade**	**$I_{geo.}$**	**RI**	**Si**	**CFi**	**CFi Grade**	**$I_{geo.}$**	**RI**
DW1	1.76	8.80	VHD	-0.63	44.00	13.55	45.17	VHD	0.43	13.55	9.94	1.99	MD	1.52	1.55
DW2	0.79	3.95	CD	-0.98	19.75	4.92	16.40	VHD	-0.01	4.92	10.85	2.17	MD	1.56	1.69
DW3	1.90	9.50	VHD	-0.60	47.50	5.18	17.27	VHD	0.02	5.18	13.08	2.62	MD	1.64	2.04
DW4	1.89	9.45	VHD	-0.60	47.25	4.57	15.23	VHD	-0.04	4.57	9.15	1.83	MD	1.48	1.43
DW5	1.38	6.90	VHD	-0.74	34.50	5.05	16.83	VHD	0.00	5.05	15.01	3.00	MD	1.70	2.34
DW6	1.54	7.70	VHD	-0.69	38.50	5.62	18.73	VHD	0.05	5.62	9.64	1.93	MD	1.51	1.50
DW7	2.88	14.40	VHD	-0.42	72.00	3.02	10.07	VHD	-0.22	3.02	4.08	0.82	LD	1.13	0.64
DW8	2.08	10.40	VHD	-0.56	52.00	6.98	23.27	VHD	0.14	6.98	8.92	1.78	MD	1.47	1.39

CFi: Contamination Factor; **Igeo:** geo-accumulation; **RI**: The Potential Ecological Risk Index; **LD**: Low Degree; **MD**: Moderate Degree; **CD:** Considerable Degree; **VHD**: Very High Degree