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Groundwater Suitability Assessment in Western Sohag Governorate, Upper Egypt

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ABSTRACT

Water from the Nile River is a fundamental water supply, while groundwater is a secondary source used for domestic, industrial, and agricultural uses in the Sohag region. Groundwater quality assessment requires additional focus due to the expanding urbanization, agriculture, and population in these dry regions, as well as the scarcity of water resources and water pollution. The evaluation of groundwater quality was implemented to determine suitable safety factors for different uses. Geographically, Araya and Gz.Shandwil regions relate to Sohag governorate and is important for residence and agriculture communities to supplement water for drinking, livestock, domestic, and irrigation uses, so great efforts were performed to evaluate water resources in the studied area. Even some large settlements use groundwater for irrigation and drinking purposes. Araya and Gz.Shandwilvillages have groundwater that founds in a Pleistocene aquifer. In all groundwater samples, the principal ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{2-}, and Cl^-) and minor chemical components (NO_3^-, NH_4^+) were analyzed. The investigation goals are to explain the potential impact of urbanization, and industrial and agricultural activities on groundwater characteristics and their purposes in different fields. The water quality is influence by natural and anthropogenic sources, which govern groundwater characteristics in the area. $Na+K+HCO_3$ facies predominance in Arya village and $Ca+Mg+HCO_3$ facies predominance in Gz.Shandwil village. Most of groundwater samples are suitable for drinking and Araya samples are low suitable for irrigation purposes and unsuitable for paper,fruits and vegetables industries, while Gz.Shandwil are suitable for irrigation, paper, fruits and vegetables industries.

Introduction

In many nations, groundwater is a significant and valuable resource that frequently fulfills a vital role as a source of water for both consumption and agriculture activities. The water demand has significantly increased over the past few decades, especially in developing countries, as a result of population expansion, rising living standards, industrialization, agricultural development, and urbanization (World Water Assessment Programme, 2009 and Llamas and Martnez-Santos, 2005). Groundwater quality has deteriorated, the water table has dropped, and ecosystems have been harmed as a result of the excessive groundwater abstraction that has been done over the years to meet these demands. It is clear that the issue of groundwater quality is just as crucial to meeting water needs as the issue of groundwater quantity (Karanth 1997; United Nations Environment Programme 2010; World Water Assessment Programme 2012).

In Sohag, the principal source of fresh water is groundwater in Quaternary aquifer next to Nile River. The Nile River and irrigation channel network serve as the main sources of surface water for its recharging, but substantial drainage, evaporation, and the use of the underlying water supply result in water loss (Ismail and El-Rawy, 2018; Embaby and Ali, 2021). The principal groundwater reservoir for the Pleistocene Quaternary era is found in the Sohag Governorate's Pleistocene river sediments, which unconformably rest a top marine Pliocene clay (Omar, 1996). For various reasons, groundwater management and evaluation were researched in Egypt by a number of authors (Embaby et al., 2016; Ismail and El-Rawy 2018; El-Rawy et al. 2019; Abdelhalim et al. 2020; Abdalazem et al. 2020; Ismail et al. 2020; Abu Heleika et al. 2021, Snousy et al., 2022). Northwest and southeast in Assuit governorate regions had the highest and lowest potential for drinking water use, respectively (Megahed and Farrag, 2019). Using the water quality index (WQI) and water quality measures, the groundwater quality for irrigation and drinking was evaluated (Gaber et al., 2021). The Pleistocene aquifer was discovered to be appropriate for drinking and irrigation while roughly half of the Eocene water samples were determined to be unfit (Ismail et al., 2021). Numerous studies have constantly focused on the

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groundwater quality and characteristics in Sohag Quaternary aquifer (Awad et al., 1995; Soltan, 1998; Omer and Abdel Moneim, 2001; Diab et al., 2002; Abdel Rahman, 2006; Ahmed, 2009; Rizk, 2010; Ahmed and Ali, 2011; Esam et al., 2012 ; Ismail and El-Rawy, 2018; and Embaby and Ali, 2021). Araya and Gz.Shandwilare the two study locations to manage groundwater suitability assessments for different purposes. In the area under examination, groundwater is significant and serves as the secondary supply of water used for drinking, residential usage, agriculture, and manufacturing. This study's objectives are to (1) locate the physicochemical parameters that provide data on groundwater quality, (2) evaluate the suitability of groundwater for drinking and agricultural use.

2. Background

2.1. Study area and climate

Upper Egypt's Sohag Governorate, with a total size of around 6.546 km2, is lies in Nile Valley Center, which is roughly 125 km long. Geographically, the research region is situated at 26.62°N and 31.65°E, respectively, which is 1.2 kilometers from western bank of the Nile and 1 kilometers from western desert margins (Fig. 1). Araya and Gz.ShandwilVillages are located 5 km and 8 Km, respectively, to southwest and northwest to center of Sohag City.

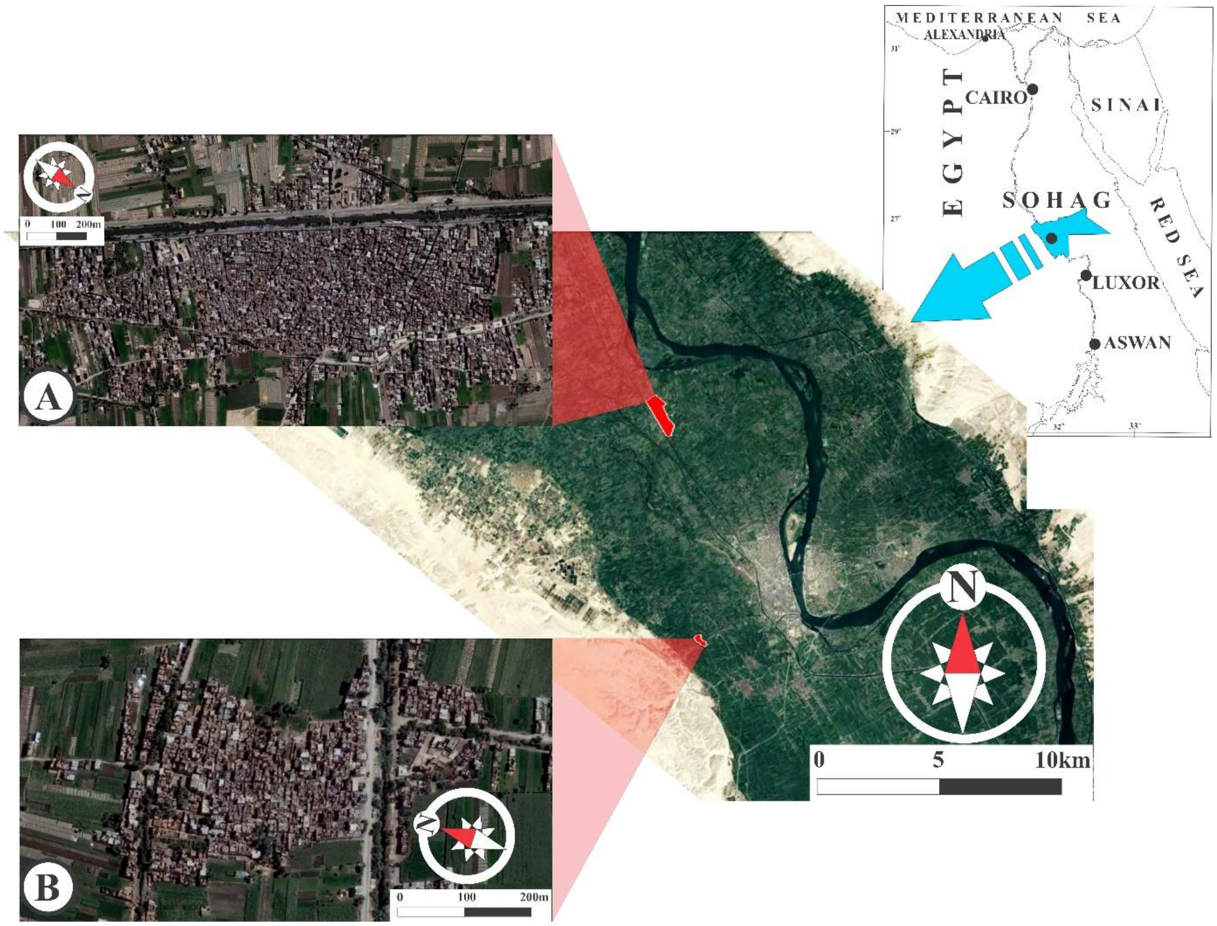

Fig. 1: Location maps of Sohag governorate, Upper Egypt, and the studied two villages Gazirat Shandwil (Gz.Sh.) (A) and Araya village (B); (Embaby and Ali, 2021).

Sohag is a part of North Africa's arid region, which is known for its hot summers and chilly winters (Embaby and Ali, 2021). The monthly average evaporation ranges from 96.1 to 325.5 mm from December to May (Egyptian Meteorological Authority, 2000; Embaby and Ali, 2021). With only 1.18 mm of rainfall per year a wide range of daily and yearly average temperatures (Allmetsat, 2008).

2.2. Geological and hydrogeological setting

The Nile valley aquifer unconformably rests on impervious Pliocene clay, is made up of sediments from the Pleistocene Nile basin (Table 1 and Fig. 2). Geology and hydrogeology are studied by many authors (Abu El Magd, 2008; Abu ElMagd etal., 2020; Awad et al., 1995; Soltan, 1998; Omer and Abdel Moneim, 2001; Ali, 2005 ; Ahmed and Ali, 2011; Esam et al., 2012 ; Ismail and El-Rawy, 2018; and Embaby and Ali, 2021). As the basis of the aquifer, An aquiclude is made of a Pliocene clay unit from the Muneiha Formation (Embaby and Ali, 2021). The Pleistocene deposits were appeared by fluviatile-graded sand-gravel intercalations, which are widely scattered along the surface and subsurface of the studied region (Farrag, 2005).

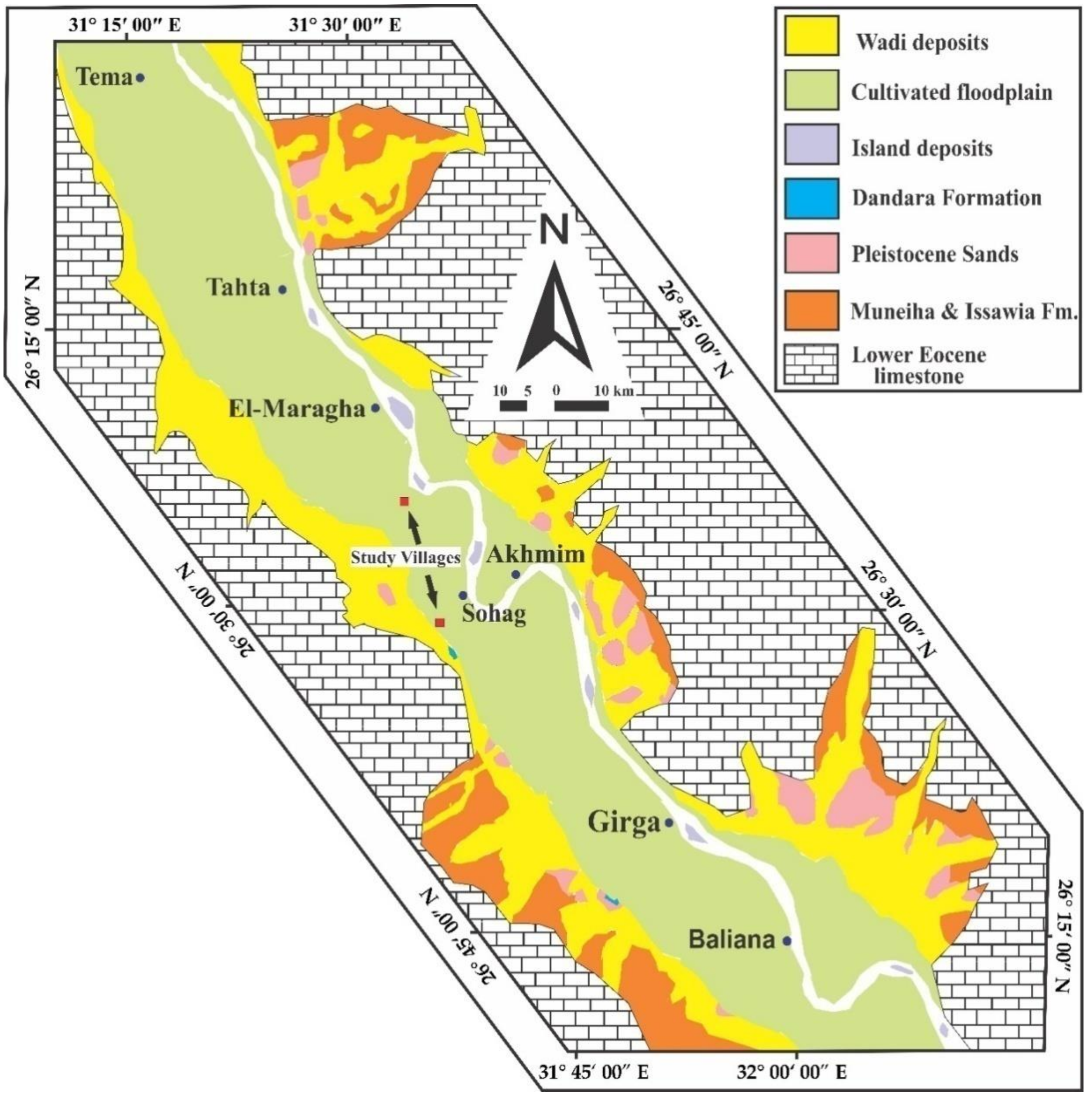

Fig. 2: Geological map showing the main stratigraphic units in Sohag, modified after (Ali 2005; Embaby and Ali, 2021).

Table 1: Main geological units in Sohag area (Embaby and Ali, 2021).

Age		Formation	Description	Ref
Neogene *and* Quaternary	*Recent (Holocene)*	*Wadi deposits*	Disintegrated product of the nearby Eocene carbonate, in addition to the reworked material from the pre-existing sediments	Said, 1975
		Alluvial deposits (Nile floodplain)	Clays and silts with sandstone intercalations	
	Pleistocene	*Dandara*	Fluviatile fine sand–silt intercalations and accumulated at low-energy environment	Omer and Issawi 1998
		Ghawanim	Nile sandy sediments exhibiting the first appearance of the heavy mineral	Omer 1996
		KomOmbo	Sand and gravel sediments containing abundant coarse fragments of igneous and metamorphic parentage	Butzer and Hansen 1968
		Qena	Quartozose sands and gravels lacking igneous and metamorphic fragments	Said 1981
	Late Pliocene / Early Pleistocene	*Issawia*	Clastic facies at the lake margins and carbonate facies in the central zones	Said 1975
	Early Pliocene	*Muneiha*	Bedded brown and gray clays intercalated with thin beds and lenses of silt and fine sand, and fluviatile-dominated sediments made up of sand, silt, and mud intercalations	Omer and Issawi 1998
Lower Eocene		*Drunka*	Medium to thick-bedded succession of limestone, which is highly bioturbated in some horizons, with siliceous concretions of variable sizes	Said 1960
		Thebes	Massive to laminated limestone with flint bands or nodules and marl rich with Nummulites and planktonic foraminifera	

The two components of the Pleistocene aquifer are the unconfined and the semi-confined aquifers (Embaby and Ali, 2021). The former alluvial plains (sandy gravel beds), which border the desert on two sides, are covered by permeable Wadi deposits that cover the unconfined aquifer. (Embaby and Ali, 2021). The silty clay layer of the alluvial floodplain has low permeability rests on top of the semi-confined aquifer (Embaby and Ali, 2021).

3. Methodology

The sampling procedures are carried out during sample collecting and are established by the quantity of foreign academics (Claasen 1982; Barcelona et al. 1985). The samples were retrieved physically by the investigators from a pump's discharge line that was flowing. Plastic 500 ml vials were used to collect the groundwater samples. They were stored in an icebox and subsequently, a refrigerator at 4°C until they were transported to the Applied and Environmental Geochemistry Laboratory (EAG) at Sohag University to undergo the necessary chemical analyses. Digital meters (WPA cm 35 and Cole Parmer models, respectively) were used to measure pH and Electric Conductivity (EC). Calcium, sodium and potassium were detected by a Flame Photometer (Jenway PFP7), magnesium was detected using the Buck Scientific 210 VGP Flame Atomic Absorption Spectrophotometer. Chloride and bicarbonate were volumetrically detected, While Sulfate, nitrate, and ammonia were detected by Spectrophotometry (Table 2).

Table 2: List of Chemical parameters and their test methods (Embaby and Ali, 2021).

	Parameters	Unit	Test Methods
1	pH	---	pH meter
2	Conductivity	ms/cm	Conductivity meter
3	Total dissolved Solids	mg/L	Digital conductivity meter
4	Chloride	mg/L	Titration
5	Calcium	mg/L	Flame Photometer
6	Sodium	mg/L	Flame Photometer
7	Potassium	mg/L	Flame Photometer
8	Magnesium	mg/L	FAAS
9	Chloride	mg/L	Titration
10	Sulfate	mg/L	Spectrophotometric
11	Bicarbonate	mg/L	Titration
12	Nitrate -Nitrogen (NO_3 — N)	mg/L	Spectrophotometric
13	Ammonia-Nitrogen (NH_3 — N)	mg/L	Spectrophotometric
14	Iron	mg/L	FAAS
15	Manganese	mg/L	FAAS

Results and discussion

4.1. Groundwater Classification

The Chadha diagram is simulated from the piper diagram (1944) to distinguish the groundwater types (Chadha, 1999). This diagram depends on equivalent percentages of (CO_3+HCO_3)-(SO_4+Cl) versus (Ca+Mg)-(Na+K). The Chadha diagram shows two main types of groundwater including Na+K-HCO_3 water type occurs in Araya samples, while Ca+Mg-HCO_3 presents in Gz.Shandwil samples (Fig.3). The two primary types of water are Na-HCO_3 and Ca-HCO_3 according to the principal ions (Embaby and Ali, 2021).

4.2. Physical parameters of groundwater

The groundwater samples are colorless and have a pH values range between (7.4-7.8) indicating recharge from Nile River and Nile channels. The EC value are (532 - 732) ms/cm in Gz.Shandwil groundwater samples, while, The EC value range from (968 - 1198) ms/cm in Araya groundwater samples reflect a decrease toward the Nile river direction and an increase toward limestone hill. The groundwater samples of Gz.Shandwil and Araya indicate fresh groundwater based on electrical conductivity classification (Mandel and Shiftan, 1981). The total salinity of samples varies from (341-765) ppm, where, lowest TDS values in Gz.Shandwil samples and highest TDS value recorded in Araya wells. The physical and chemical groundwater parameters are shown in (Table 3).

4.3. Assessment for drinking purposes

The colorless, odorless water used for drinking and human consumption purposes excessive amount of dissolved mineral, free from turbidity and absence of harmful micro-organisms. The groundwater classification according to (Chebotarev, 1955) for drinking water on the studied groundwater samples, reflected that the Araya and Gz.Shandwil groundwater samples belong to the fresh water type with TDS less than 2000 mg/l (Tab.4 & Fig. 4). TDS is below 1000 mg/l, and all the groundwater samples are suitable and permissible for drinking purposes (WHO, 2006), (Tab.5). The maximum permissible limits according to (WHO, 1996 and EHCW, 2007), indicate that all the Gz.Shandwil and Araya groundwater wells in the area of fresh water (Tab.6 & Fig. 5).

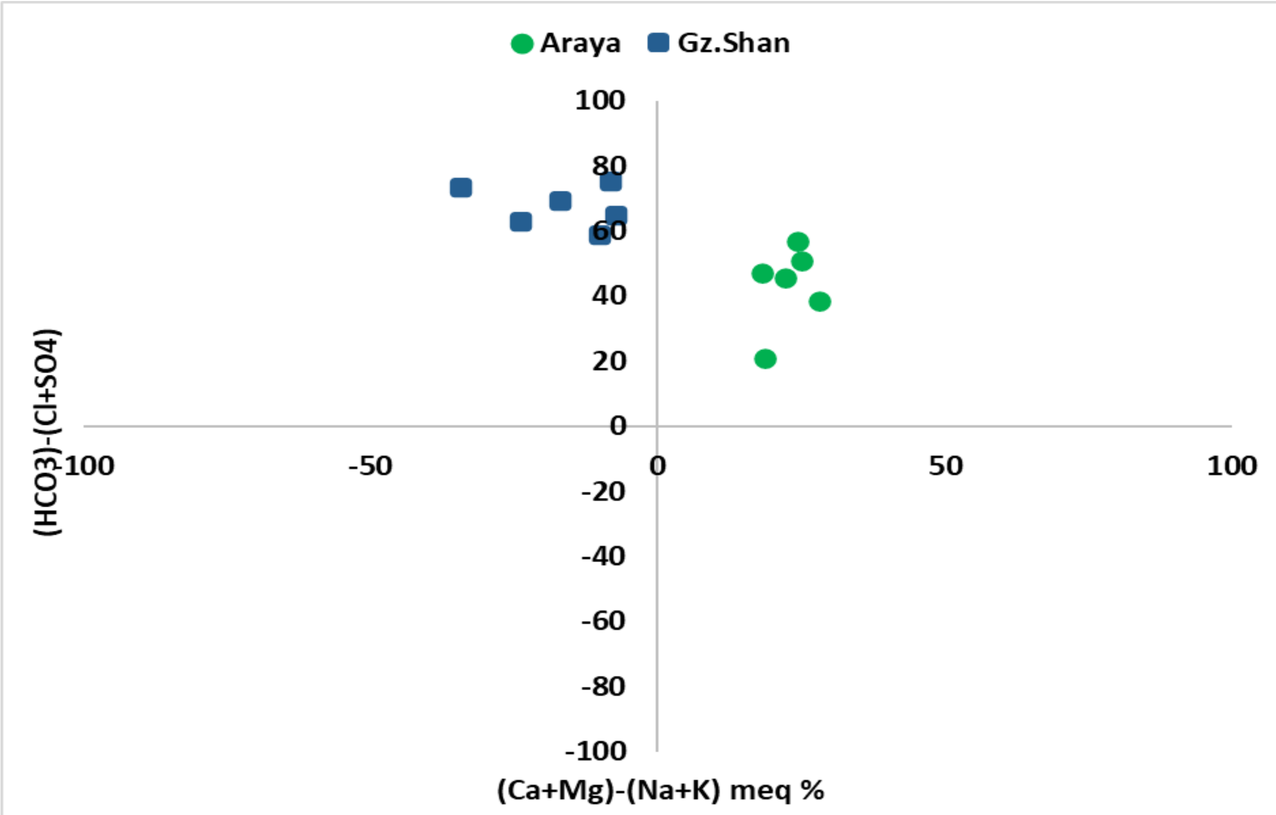

Fig.3: Chadha diagram shows groundwater classification.

Table 3: Summary statistics of physical and chemical groundwater parameters in the study area. Ion concentrations and TDS are in mg/L. SD: Standard Deviation. CV: Coefficient of Variation (Embaby and Ali, 2021).

Variable	Village	Mean	StDev	Variance	CV%	Min.	Median	Max.	Sk.	Kur.	Nile*
pH	Araya	7.67	0.05	0.00	0.67	7.60	7.70	7.70	-0.97	-1.87	8.13
	Gz.Sh.	7.67	0.15	0.02	1.96	7.40	7.70	7.80	-1.27	1.53	
TDS	Araya	684.00	56.60	3208.00	8.28	620.00	684.50	765.00	0.24	-1.29	226.00
	Gz.Sh.	383.00	49.20	2424.70	12.87	341.00	370.00	469.00	1.22	1.12	
Ca	Araya	80.17	3.60	12.97	4.49	75.00	80.00	85.00	-0.09	-0.64	30.00
	Gz.Sh.	23.17	3.76	14.17	16.25	19.00	22.50	30.00	1.33	2.49	
Mg	Araya	37.33	5.28	27.87	14.14	31.00	37.00	45.00	0.32	-1.17	9.00
	Gz.Sh.	19.33	2.66	7.07	13.75	16.00	19.00	24.00	1.00	2.18	
Na	Araya	98.83	10.89	118.57	11.02	88.00	96.50	116.00	0.73	-0.70	21.00
	Gz.Sh.	86.17	18.53	343.37	21.51	71.00	81.00	123.00	2.15	5.03	
K	Araya	6.05	0.30	0.09	4.88	5.70	5.95	6.50	0.67	-0.61	4.00
	Gz.Sh.	5.72	0.45	0.20	7.86	5.20	5.70	6.30	0.13	-2.08	
HCO_3	Araya	485.20	36.10	1303.80	7.44	445.00	481.00	527.00	0.17	-2.45	127.00
	Gz.Sh.	333.70	51.90	2690.70	15.55	289.00	319.00	431.00	1.67	3.00	
Cl	Araya	48.50	14.43	208.30	29.76	29.00	51.50	67.00	-0.32	-1.18	28.00
	Gz.Sh.	14.67	3.01	9.07	20.53	11.00	14.50	19.00	0.28	-1.02	
SO_4	Araya	86.20	28.00	782.20	32.46	69.00	74.00	142.00	2.23	5.07	18.00
	Gz.Sh.	29.33	5.05	25.47	17.20	20.00	30.50	34.00	-1.54	2.66	
NO_3	Araya	0.67	0.39	0.15	58.44	0.21	0.62	1.37	1.14	2.18	0.74
	Gz.Sh.	0.89	0.68	0.47	77.25	0.42	0.58	2.21	1.98	3.92	
NH_4	Araya	1.71	0.33	0.11	19.45	1.23	1.71	2.21	0.15	0.59	0.19
	Gz.Sh.	1.34	0.85	0.72	63.09	0.61	0.98	2.67	1.00	-0.87	
Fe	Araya	0.30	0.12	0.01	40.32	0.20	0.24	0.43	1.12	-0.51	0.01
	Gz.Sh.	0.22	0.07	0.01	33.11	0.14	0.22	0.41	0.13	-1.97	
Mn	Araya	0.63	0.14	0.02	23.16	0.41	0.61	0.79	0.04	-1.02	0.01
	Gz.Sh.	0.48	0.09	0.01	17.78	0.39	0.50	0.61	-0.26	-1.40	

Table 4: Chebotarev classification according to groundwater salinity, (Chebotarev,1955).

TDS (ppm)	Quality	Water type	Water samples
Less than 500	Good potable	Fresh water	Gz.Shandwil samples
500-700	Fresh		Araya-3, Araya-11,, Araya-5,
700-1500	Fairly fresh		Araya-1, Araya-2, Araya-school
1500-2000	Possible fresh		
2000-3200	Slightly brackish	Brackish water	
3200-4000	Brackish		
4000-5000	Definitely brackish		
5000-6000	Slightly salty	Saline water	
6000-7000	Salty		
7000-10000	Very salty		

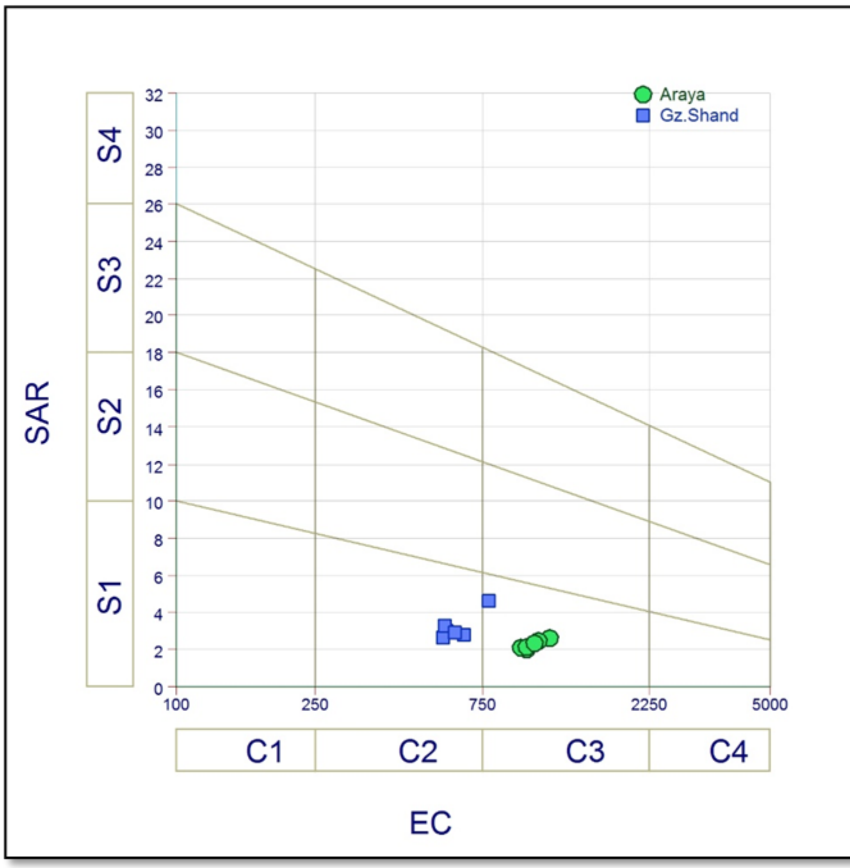

Fig. 4: Wicox›s Classification for evaluation of water irrigation.

Table 5: Groundwater suitability for drinking and domestic use based on TDS.

TDS	Sample No.	Evaluation for drinking purposes
<500	Gz.Shandwil samples	Excellent
500- 1500	Araya samples	Permissible
>1500		Unsuitable to satisfactory

Table 6: Maximum permissible limits according to (WHO, 1996 and EHCW, 2007).

Parameters	Unit	WHO (1996)	EHCW (2007)	Accepted water samples	Suitable For drinking
pH		6.5- 8.5	-	All samples	All groundwater samples are suitable for drinking purposes
TDS	mg/l	1000	1000	All samples	
TH ($CaCO_3$)	mg/l	-	500	All samples	
Na	mg/l	200	200	All samples	
K	mg/l	12	-	All samples	
Ca	mg/l	200	-	All samples	
Mg	mg/l	125	-	All samples	
Cl	mg/l	250	250	All samples	
SO_4	mg/l	400	250	All samples	
HCO_3	mg/l	350	-	Gz.Shandwil samples except Gz.Shandwil-4	
NO_3	mg/l	50	45	All samples	
NH_4	mg/l	-	0.5	Unsuitable samples	
PO_4	mg/l	-	-	All samples	

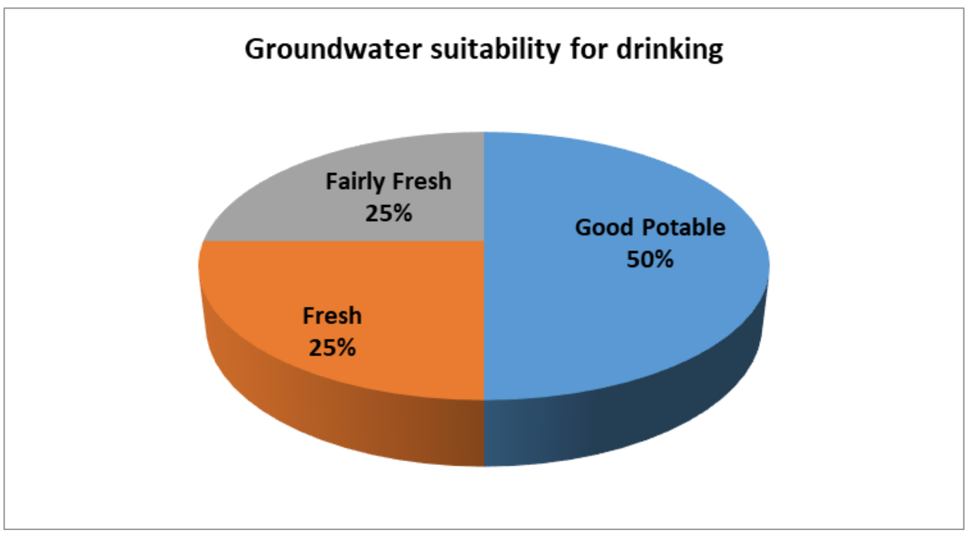

Fig. 5: Pie chart of groundwater suitability for drinking based on salinity.

4.4. Assessment for domestic purposes

One of the most significant problems with the use of water is the hardness of the groundwater, and contributing to dense scale formation or corrosion of boilers, cooling water equipment, and industrial process systems, in cleaning processes. The soap reacts firstly with hardness salts in water before forming a lather to compose insoluble Ca and Mg. The hardness of groundwater causes precipitation of ordinary soap, because existence of dissolved Ca^{2+} and Mg^{2+} in integration with carbonate and bicarbonate ions. Water for households anticipates must have a hardness of less than 100 (U.S. Salinity Laboratory Staff, 1954). The Hardness (H) is calculated as: Hardness= [(Ca^{++}+Mg^{++} epm)×50], (Hem, 1985). Hardness is classified into four categories based on the amount of dissolved Ca and Mg in groundwater (Hem, 1985). As stated in the computed values for total hardness levels for the analyzed water samples according to (Hem, 1989) and (Durfor and Beeker, 1964) classifications (Tab.7). Araya groundwater samples are classified as hard and moderately hard in Gz.Shandwil groundwater samples reflect that are not suitable for laundry purposes. The hardness can be greatly reduced by boiling water that drives carbon dioxide off and precipitates calcium carbonate. Plotting of TDS versus Total Hardness (TH) containing 6 classes (Xiao et al., 2015), all the groundwater samples plotted in fresh and hard classes (Fig. 6).

Table 7: Hardness ranges with water classification type (Hem, 1985).

Water classes	Hardnes Ranges ($CaCO_3$ ppm)	
Soft	0-75	……
Moderatly	>75-150	Gz.Shandwil-1, 2, 3, 4
Hard	>150-300	Gz.Shandwil-5, 8
Very Hard	>300	Araya groudwater samples

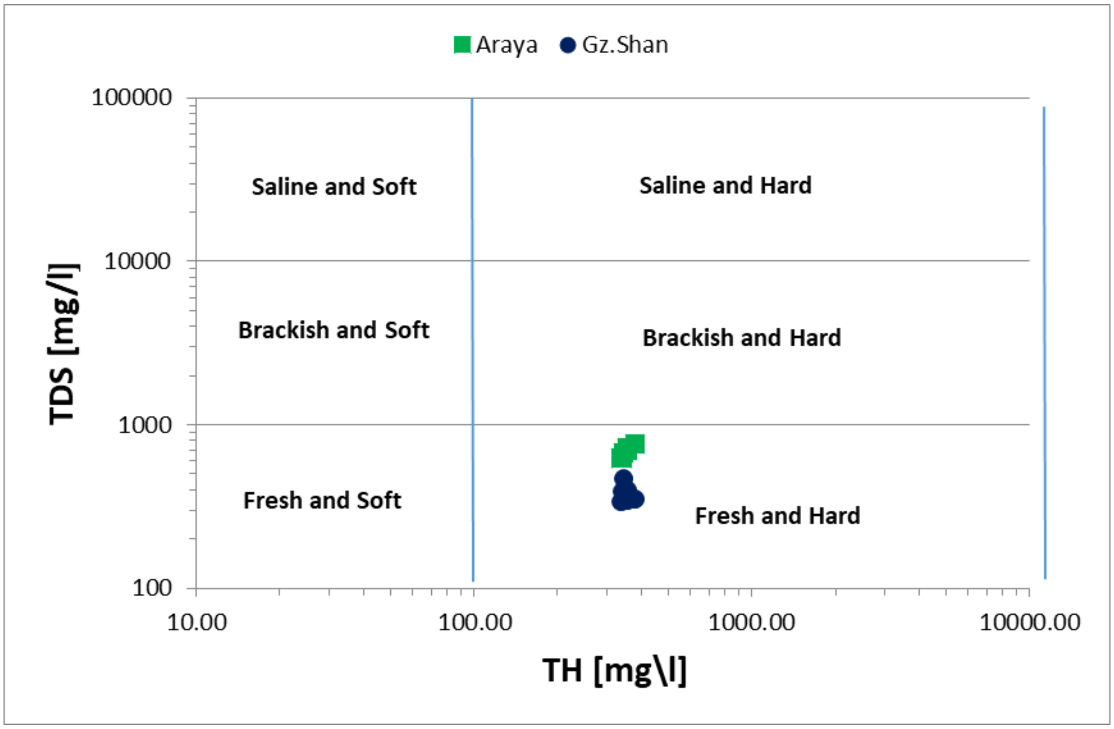

Fig. 6: TDS versus Hardness [TH] in groundwater.

4.5. Assessment for Livestock and poultry purposes

Groundwater consumed in farms for livestock and poultry purposes depending on quality restrictions of the same kinds as those relating to the quality of drinking and domestic. The properties of groundwater samples compared with the limits are excellent and suitable for all animals (Tab.8). Classification for utilizing saline water for livestock and poultry depending on the TDS concentration (NASNAE, 1972), are shown in (Tab.9). The Excellent groundwater for all classes of livestock and poultry (TDS<1000 mg/l) includes Araya and Gz.Shandwil groundwater samples belong to Class I, indicating that all types of livestock and poultry can successfully use the examined groundwater (NASNAE, 1972).

Table 8: The upper limits of total dissolved solids for livestock (Mackee and Wolf, 1963) and (Hem, 1970).

Animal types	TDS [mg/l]	Sample No.
Poultry	2860	All groundwater samples
Horse	6435	All groundwater samples
Cattle (dairy)	7150	All groundwater samples
Cattle (beef)	10100	All groundwater samples
Sheep (adults)	12900	All groundwater samples

Table 9: The guide lines of using saline water for livestock and poultry (National Academy of Science, 1972).

	TDS (mg/l)	Characters	Sample No.
Class I	Less than 1000 mg/l	Relatively low level of salinity. Excellent for all classes of livestock and poultry.	All groundwater samples
Class II	1000 - 2999 mg/l	Very satisfactory for all classes of livestock and poultry. May cause temporary and mild diarrhea in livestock not accustomed to them or watery dropping in poultry.	
Class III	3000 - 4999 mg/l	Satisfactory for livestock but may cause temporary diarrhea or be refused at first by animals not accustomed to them. Poor water for poultry, often causes water faces, increased mortality, and decreased growth, especially in Turkey.	
Class IV	5000 - 6999 mg/l	Can be used with reasonable safety for dairy and beef cattle, sheep, swine, and horses. Avoid use for pregnant or lactating animals. Not acceptable for poultry.	
Class V	7000 – 10000 mg/l	Unfit for poultry and probably for swine. Considerable risk in using for pregnant or lactating cows, horses, or sheep or for young these species. In general, use should be avoided although older ruminants, horses, poultry, and swine may subset on them under certain conditions.	
Class VI	More than 10000 mg/l	Risks with this highly saline water are so great that they cannot be recommended for use under any conditions.	

4.6. Assessment for irrigation purposes.

Groundwater for irrigation purposes rely on parameters including TDS, sodium ion percent (Na%), and sodium adsorption ratio.

4.6.1. Classification according to salinity content

The salinity concentration excess leads to hurtful growth of plants and plant destruction, therefore, compared to field crops, vegetables are more sensitive to salinity. The irrigation water can be utilized without any problem when TDS < 480 ppm, the problems are displayed when TDS is varying from [480-1920 ppm], while the problems become severe when, TDS > 1920 ppm (**Ayer, 1975**). Gz.Shandwil groundwater samples are less than 480 ppm, while, Araya groundwater samples range between 620-765 ppm. The groundwater samples of Gz.Shandwil is suitable for irrigation purposes, while Araya groundwater samples are marginal suitability for irrigation purposes and represent 50% suitable and 50% marginal.

4.6.2. Classification according to sodium ion percent (Na%)

The sodium ion percent (Na%) is anticipated for groundwater assessment for irrigation and can be computed by equation:

$$Na^{+}\% = \frac{Na^{+}+K^{+}}{Ca^{++}+Mg^{++}+Na^{+}+K^{+}} \times 100 \text{ epm}$$

(Araya-1 and Araya-11) are permissible for irrigation and the rest of Araya are good and suitable for irrigation, while (Gz.Shandwil-3 and Gz.Shandwil-4) are bad and the rest of groundwater samples are permissible for irrigation based on sodium ion percent (Tab.10). The suitability depend on sodium ion percent represents 33% good, 50% permissible and 17% bad.

4.6.3. Classification according to sodium adsorption ratio

The sodium adsorption ratio (SAR.) substantially toxic to plants especially fruits and it frequently leads to problems in soil structure, infiltration, and permeability rates. The sodium concentrations excess in soils cause the emergence of alkaline. This technique helps to assess the unhealthy effect of high sodium content in irrigation water (U.S. salinity laboratory Staff, 1954).

$$SAR = \frac{Na}{\frac{1}{2}\sqrt{Ca+Mg}} \text{ [epm]}$$

The (SAR) values of studied samples are vary based on acceptable limits for use as irrigation water for most plants and all soil types (U.S. Salinity Lab. Staff, 1954). The standard samples are excellent and good water classes and acceptable for farming in all soil kinds without any trouble. The irrigation suitability is based on Electrical Conductivity (EC) as a function of salinity against (SAR), (U.S. Salinity Laboratory Staff, 1954) as shown (Tab.11&12). The Wilcox classification (1955) explained that Araya samples and Gz.Shandwil-10 belongs to C_3-S_1 class and satisfactory for irrigation, While the rest of Gz.Shandwil samples plot in C_2-S1 reflects suitability for all crops and sodium-sensitive crops as shown in (Tab.13 & Fig. 6).

Table 10: Type of water based on (Na %) parameter.

Wilcox, 1948 and Standard U.S. salinity Lab. Staff, 1954		Groundwater samples in studied area		
Class	(Na %)	Sample symbole	Na %	Purpose for irrigation
Excellent	<20	Araya-1	40.62	Permissible
Good	20-40	Araya-2	35.83	Good
Permissible	>40-60	Araya-3	37.44	Good
Bad	>60-80	Araya-11	40.83	Permissible
Unsituable	>80	Araya-5	37.77	Good
		Araya school	38.87	Good
		Gz.shandwil-1	58.39	Permissible
		Gz.shandwil-2	54.06	Permissible
		Gz.shandwil-3	61.87	Bad
		Gz.shandwil--4	67.03	Bad
		Gz.shandwil-5	53.56	Permissible
		Gz.shandwil-8	55.02	Permissible

Table 11: Groundwater classification based on S.A.R., (U.S. Salinity Lab. Staff, 1954)

Range	Class	order	Suitability	Usage
<10	Excellent	low	Suitable	Can be used for all soils
10-18	Good	Medium	Moderate	Preferably used for coarse textured soil of good permeability.
18-26	Fair	High	Fair	Can produce harmful effects and good soil managements is essential.
>26	Poor	Very high	Unsuitable	Not satisfactory for irrigation

Table 12: Suitability of groundwater for irrigation based on EC and SAR for groundwater samples in the study area.

No.	Well Name	Ec	S.A.R.	Order	Class
1	Araya-1	1195	low	Excellent	Suitable
2	Araya-2	1130	low	Excellent	Suitable
3	Araya-3	969	low	Excellent	Suitable
4	Araya-11	1042	low	Excellent	Suitable
5	Araya-5	980	low	Excellent	Suitable
6	Araya school	1097	low	Excellent	Suitable
7	Gz.shandwil-1	544	low	Excellent	Suitable
8	Gz.shandwil-2	541	low	Excellent	Suitable
9	Gz.shandwil-3	533	low	Excellent	Suitable
10	Gz.shandwil--4	733	low	Excellent	Suitable
11	Gz.shandwil-5	613	low	Excellent	Suitable
12	Gz.shandwil-8	625	low	Excellent	Suitable

Table 13: Classification of irrigation water based on SAR (Richards, 1954).

Well No.	Class	Description
All Gz.Sahnd samples except Gz.Shandwil-10	C2-S1	Low saline water with low SAR, suitable for most crops on most soils and suitable in Sodium sensitive crops.
Gz.Shandwil-10 and all Araya samples	C3-S1	Medium to high saline water, with low SAR, is satisfactory for plants having moderate salts to leaching on soils of moderate permeability (good water class).

4.6.4. Classification according to Kelly index (KI)

Kelly index is important parameter used for groundwater classification for irrigation purpose based on sodium measured against calcium and magnesium (Kelly, 1940&1951). KI is calculated by using the formula:

$$KI= [\frac{Mg^{++}}{(Ca^{++}+Mg^{++})}\ x100]$$

Groundwater with (KI) (>1) reveals an excess level of sodium in waters and unsuitable for irrigation but groundwater with a KI (<1) is suitable for irrigation (Narsimha et al., 2013). The Kelly index in Araya area are suitable for irrigation and range from (0.54-0.67), while Kelly index in Gz.Shandwil area range from (1.11-1.97) are unsuitable for irrigation.

4.6.5. Magnesium ratio (MR)

The Magnesium ratio is important for evaluation of groundwater for irrigation to show the effect of magnesium ion in irrigation groundwater. The magnesium ion in water affects the soil quality converting it to alkaline and decreases crop yield (Narsimha et al., 2013). The magnesium ratio formula (Szabolcs and Darab, 1964):

$$MR =\frac{Mg^{++}}{Ca^{++}+Mg^{++}}\ x100$$

Magnesium ratio (<50) is suitable for irrigation and magnesium ratio (>50%) is unsuitable for irrigation purposes, and all ionic concentrations are expressed in meq/l. (Paliwal, 1972). MR in Araya area vary from (37.55-48.75), and suitable for irrigation. MR in Gz.Shandwil vary from (51.08-62.25), and unsuitable for irrigation.

4.6. Evaluation for building purposes

The quality of cement is influenced by high sulfate ions, thus, when sulfate concentration exceeds 300 ppm, it interacts with cement materials and form gypsum, Therefore the only treatment is to form dense concrete and utilize ion-cemented materials (Water treatment, 1979). Araya and Gz.Shandwil groundwater samples are suitable for building purposes because SO_4^{--} is lower than 300 ppm based on the standard limits of (Water Treatment ,1979).

4.7. Evaluation for Industrial purposes

The limits of the international standard used in industry (National Academy of Engineering, 1972 and Hem, 1989). The Araya samples are not suitable for paper, textile, fruits, and vegetables industries due to the values of TDS and hardness being more than the standard limits, While Gz.Shandwil samples are suitable. The Araya and Gz.Shandwil samples are suitable for Petroleum and Mining (Tab.14).

Table 14: The groundwater quality for industrial purposes by (National Academy of Science and National Academy of Engineering, 1972).

Characters	Industry							
	Paper		Textile		Fruit and vegetable		Petroleum and Mining	
PH	-	Gz.Shandwil groundwater samples are suitable	-	Gz.Shandwil groundwater samples are suitable	6.5-8.5	Gz.Shandwil groundwater samples are suitable	6-9	Araya and Gz.Shandwil groundwater samples are suitable
T.D.S.	200-500		100-200		500		3500	
Hardness	100-200		0-50		250		900	
Alkalinity	75-150		50-200		250		500	
$Na^{+}+K^{+}$	-		0-50		-		230	
Ca^{++}	Industry water		-		100		220	
Mg^{++}	-		-		-		85	
Cl^{-}	0-200		100		250		1600	
SO_4^{--}	-		100		250		900	
$HCO_3^{-}+CO_3^{--}$	-		100		-		480	
Iron	0.1 - 1.1		0 - 0.3		0.2		15	
SiO_2	20-100		25		50		85	

Conclusion

The evaluation of groundwater quality was implemented to determine suitable safety factors for different uses. The area belongs to Sohag governorate and is important for residence and agriculture communities to supplement water for drinking, livestock, domestic, and irrigation uses, so great efforts were performed to evaluate water resources in the studied area. Even some large settlements use groundwater for drinking and irrigation. The two villages (Araya and Gz.Shandwil) have groundwater that appears in a Pleistocene. In all groundwater samples, the principal ions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, and HCO_3^-) and minor chemical components (NH_4^+, NO_3^-) were analyzed. To identify the suitability assessment of the research sites, groundwater samples were collected from two villages located 10 km apart in Sohag, Egypt.

Groundwater samples in Arya villages have:

- Na+K+HCO_3 facies predominance.
- Highest TDS
- are fresh and fairly fresh based on TDS and all groundwater samples are suitable for drinking purposes.
- are very hard hardness for domestic purposes.
- are belong to Class I, TDS less than 1000 mg/l, and excellent for all classes of livestock and poultry purposes.
- are good to permissible based on Na%, and suitable for irrigation purposes.
- are low excellent suitable irrigation purposes based on SAR, and belong to C3-S1 based on Wicox,s classification.
- have SO_4 less than 300 mg/l, and suitable for building purposes
- are unsuitable for paper, textile, fruits, and vegetables industries; and suitable for petroleum and mining purposes

Groundwater samples in GZ.Shandwil villages have:

- Ca+Mg+HCO_3 facies predominance.
- lowest TDS
- are good potable freshwater based on TDS and all groundwater samples are suitable for drinking purposes.
- are moderately to hard hardness for domestic purposes.
- are belong to Class I, TDS less than 1000 mg/l, and excellent for all classes of livestock and poultry purposes.
- are permissible to bad based on Na%, and suitable for irrigation purposes.
- are low excellent suitable irrigation purposes based on SAR and belong to C2-S1 based on Wicox,s classification.
- have SO_4 less than 300 mg/l, and suitable for building purposes
- are suitable for paper, textile, fruits and vegetables industries; and suitable for petroleum and mining purposes

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