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Soil, Water Chemistry and Sedimentological Studies of Al Asfar Evaporation Lake and its Inland Sabkha, Al Hassa Area, Saudi Arabia

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Abstract: The present study aims to study the environment of Evaporation Al Asfar Lake, Al Hassa area, eastern province, Saudi Arabia. Remote sensing, sedimentological, hydrogeological, chemical studies and Geographical Information Systems (GIS) are implemented to achieve the objectives of this study. The processed landsat-5 TM and SPOT Imageries indicated, there is a general increment in both the sabkha and water ponds areas extent with the passage of time. The origin and the various sediments types are recognized through the sedimentological aspects of this study. Different sabkha grades are identified. These different sabkha grades have various degrees of salt content as it is indicated from the TDS spatial distribution at Al Asfar area. This study revealed that the surface water of Al Asfar lake is characterized by a relatively low salinity and then re-treating and reusing of this water in agricultural purposes will lead to minimize the sabkha extension, to mitigate its impact on the nearby farms of Al Hassa oasis, to mitigate aquifer recharge with high saline water and to optimize the water use of this available surface water body in this arid environment. The results of this study are important in any future development of this area of the Al Asfar and in planning of how to reuse the water lakes in the agricultural purposes. Chemical results are very important to be taken in consideration by Saudi Aramco, as the different sabkha grades have their various corrosion levels that may impact the pipelines crossing this sabkha area.

Key words: Evaporation lakes, inland sabkha, water reuse, remote sensing, GIS, soil chemistry, water quality, Al Hassa Oasis

INTRODUCTION

Water resources are essential and play a significant role in the development processes. The Kingdom of Saudi Arabia (KSA) is known by its arid conditions and limited renewable freshwater resources. Surface water in KSA is very limited and of a little significance in the water budget of KSA. To meet the increasing water demands in domestic, industrial, and agricultural sectors, various alternative supplies are surface water, renewable groundwater resources, treated wastewater, desalinated water, and non-renewable groundwater.

Fresh water supply in arid regions is limited due to scarce precipitation and high evapotranspiration. When the limited supply is coupled with increasing demand for fresh water in these regions due to rapid population growth, it necessitates optimal development and management of water resources.

Al Hassa Oasis is one of the main and old agricultural centers in Saudi Arabia. Al Hassa oasis with an area of 20,000 ha is located 70 km west of the Arabian Gulf (Fig. 1). An irrigation network of 1,450 km of concrete canals and drainage network were put into operation in 1971 (Abderrhman and Bader, 1992). This irrigation project delivers 328 million m^3 of groundwater for about 22, 000 farms. Nowadays this amount of water is increased due to use of the treated wastewater from Al Hofouf sewage station.

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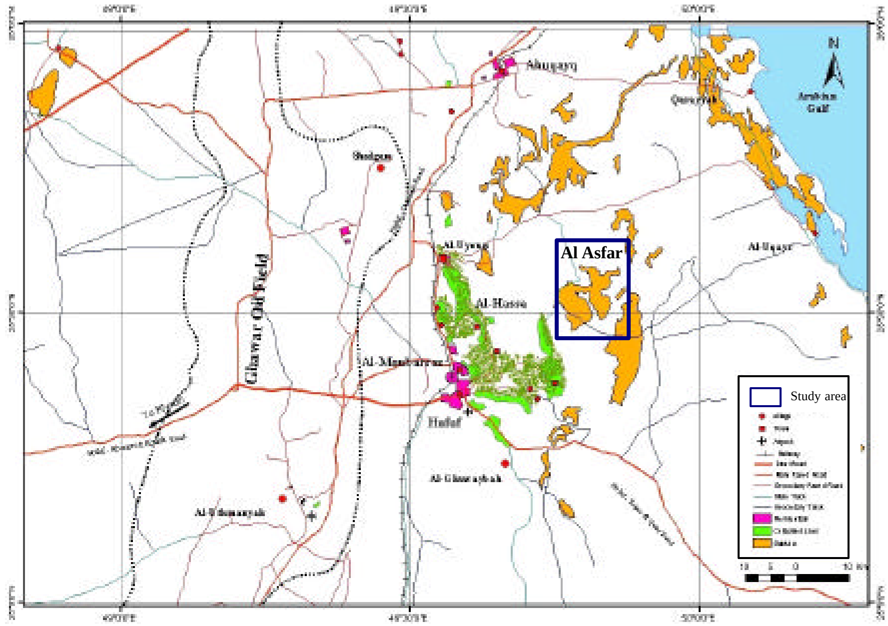


Fig. 1: Base map of Al Hassa region and the location of the study area

Al Hassa drainage water is collected by 1641 earthen lateral open canals having depths of about 1 m. The collected drainage water in the eastern sector of the project flows from the laterals to three sub main drainage canals which are connected to main drainage canal D2 (Fig. 2). The collected water in this drainage flows towards Al Asfar Evaporation Lake at 13 km (Fig. 2) to the east of Al Hassa Oasis. The drainage water in the northern sector flows from the laterals to six sub main drainage canals which are connected to main drainage canal D1. Drainage water in D1 flows towards Al Uyoun Evaporation Lake outside Al Hassa Oasis, 52 km north of Al Hofuf. The water remains in the evaporation lakes during winter season to be used to supply cattle with drinking water and for aquifer recharge. From December until April each year, the agricultural drainage water overflows from the northern lake through small waterways into the Arabian Gulf (Abderrhman and Bader, 1992).

The main salient morphologic features of Al Asfar Lake are wet lands, sabkhas and sand dunes. There are salt tolerant vegetation (halophyte) found in some of the less salt affected sabkha areas. The area is characterized by widespread growth of halophyte shrubs associated with a very thin salt crust on the sabkha surface (Fig. 3). In desert environments sabkha is one of the least investigated environments. That is most probably due to its subtle nature. However, due to its potential economic value and/or its direct or indirect impact on the environment; particularly groundwater, interest in the sabkha deposits increased in recent years. Information on the location and area of various grades of sabkha will provide valuable information about these phenomena and to know its environmental impacts on the surrounding areas and to investigate its dynamics.

The Eastern province of Saudi Arabia has many sabkha; the coastal sabkha has been studied by Barth and Böer (2002), Mah (2004) and Barth (2006).

A very distinct vegetation type which occurs at both inland and coastal sabkhat is the *Phoenix dactylifera/Tamarix* sp. type. These sites are highly valued by recreation seeking people because they providen shade and green in the otherwise unspectacular landscape. Generally there are much more locations along the sabkha edges where the environmental conditions would support Phoenix/Tamarix communities. It is strongly suggested that these communities be cultivated in order to provide more recreational possibilities especially near urban settlements (Barth, 2006).

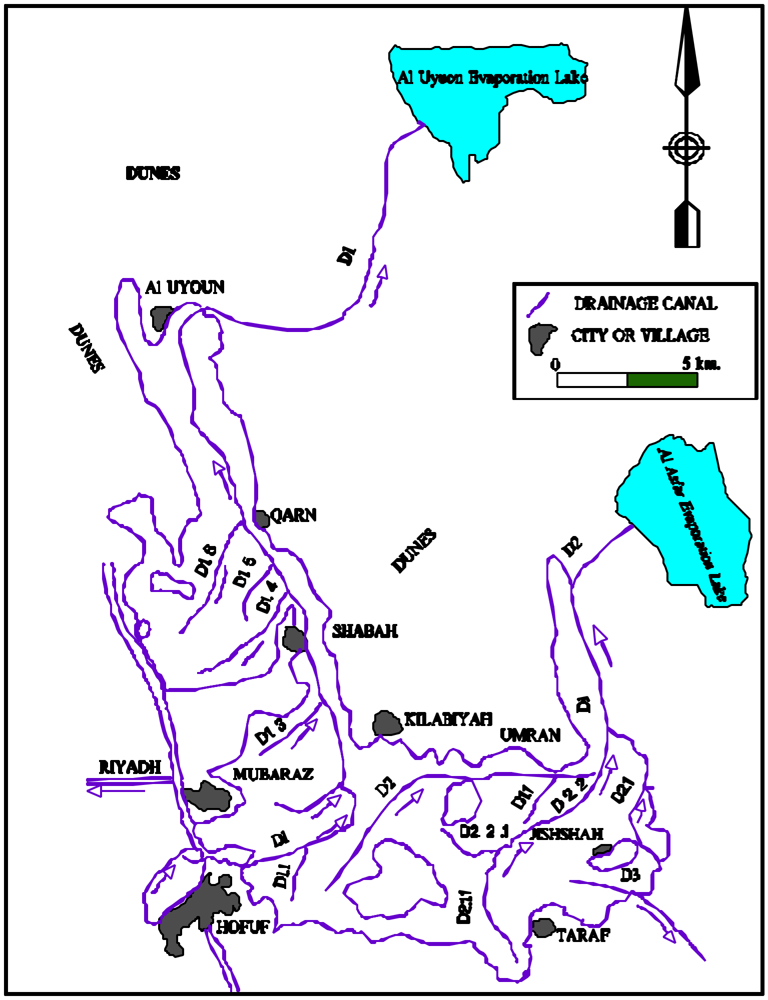


Fig. 2: Main drainage system of Al Hassa irrigation and drainage project

Fig. 3: Different types of salt tolerant vegetation (halophyte) at Al Asfar area

Hydrogeology of Al Hassa area have been reported in a number of studies by Etewy *et al*. (1983), Al-Mahmoud (1987), Abdurrahman (1988), Edgell (1989), Al Dakheel and Al Safarjalani (2005) and Al Safarjalani and Almadini (2007).

The present study aims to study the environment of Evaporation Lake of Al Asfar, Al Hassa area. Remote sensing, sedimentological, hydrogeological, chemical studies and Geographical Information Systems (GIS) are implemented to achieve the objectives of this study. The main concern of this study is the presentation of some quantitative data on the geochemistry of sabkha soil water and on the geochemistry of the solid constituents of the crustal layer of Al Asfar sabkha and ascertain the maturity class of Al Asfar sabkha in reference to the classification proposed by Bahafzallah *et al*. (1993).

MATERIALS AND METHODS

Multi-date landsat-5 TM imageries of years 1987, 1993, 1998 and 2000 and SPOT imageries of year 2007 of the study area have been processed and analyzed to investigate the dynamics of both water ponds and the associated sabkha with time at Al Asfar lake area. One hundred and eight surface soil samples representing each soil series from Al Asfar sabkha were collected. The sampling of sabkha was sometimes hindered by small water bonds or local vegetations. Fourteen samples from surface water and the isolated water bonds and twenty samples of soil water (from the area characterized by shallow water table ($\approx$20 cm depth) have been collected in May to June, 2007. The latitude and longitude of the soil and water samples coordinates was measured by using high accuracy differential GPS. The collected soil samples were raised from pits 20-30 cm deep. The soil samples were then air dried and sieved through a 2 mm sieve.

The sabkha soil samples were studied in detail to determine the textural and sedimentological characteristics of sabkha sediments in the study area. Different techniques were used for the sediment analyses. For the grain size analysis, the dry sieve method was used. The grain size analysis has been done using the standard set of sieves for dry and wet sieving, manufactured by Eijkelkamp. The sieving of the samples was done by applying an electromagnetic sieve shaker. The sieve shaker keeps the sample continuously in motion in order to obtain the best possible sieving results. The grain size statistical parameters (Graphical Mean Grain Size Mz, Inclusive Graphic Standard Deviation Sorting, σ_I, Skewness SK_I and Graphic Kurtosis K_G) were calculated using the graphical-computational methods according to Folk (1965).

A paste of sabkha soil in deionized water was prepared and filtered. Extracts of soil samples were prepared and tagged for chemical analysis. The pH and total soluble salts were measured in the soil paste extract (Rhoades, 1982). Sodium and potassium was determined by flame photometry according to (Jackson, 1973). Calcium and magnesium were determined by atomic absorption spectrophotometer according to Carter (1993). Soluble carbonates and bicarbonates were determined volumetrically in the soil paste extract by titration against 0.01 N Hydrochloric acid using phenolphthalein and methyl orange as indicators according to Jackson (1967). Soluble chlorides were determined by titration with 0.01 N silver nitrate solution and potassium chromate as indicator according to Richards (1954). Sulphate was determined turbidmetrically with barium chloride as described by Jackson (1973). Organic matter content was determined according to Walkley-Black rapid titration method (Jackson, 1967). The concentrations of NO_3^- were determined in soil paste extract and water samples according to Norman *et al*. (1985) method. ArcGIS software and satellite image processing software (ERDAS Imagine) were used for the integration of the output parameters of this study and for visualizes their spatial distribution.

RESULTS AND DISCUSSION

Remote Sensing Investigations

In this study, Landsat -5 TM imageries with seven bands of years 1987, 1993, 1998 and 2000 beside SPOT imageries of year 2007 of the study area have been geo-referenced, visually interpreted and analyzed to identify different geomorphic units of Al Asfar Lake environment. The digital elevation model (DEM) of the study area was also processed and analyzed. The elevation data collected using the GPS system has been used for constructing a digital elevation model (DEM) for Al Asfar area (Fig. 4). This map facilitated the interpretation of the result of the grain size distribution and the result of the chemical analysis. The processed landsat-5 TM and SPOT Imageries indicated, there is a general increment in both the sabkha and wet land areas extent with the passage of time (sabkha and wetlands in 1987) vs. (sabkha and wetlands in 2000) (Fig. 5). The direction of increment is related to relief where increased sabkha areas have taken place in low relief areas where groundwater rose and pushed salt to the surface. Sabkha spectral signature in imagery taken at different wavelengths is complex. It is related to salt content in soil, low relief, moisture content, groundwater table, surface water in sabkha areas, salt tolerant halophytic vegetation, texture, color and composition of soil and soil profiles. However, different sabkha grades are recognized. These different sabkha grades have various degrees of salt content as it is indicated from the TDS spatial distribution map gained from the chemical analysis task of this study.

Sedimentological Results

Forty one representative samples out of the 108 collected sabkha soil samples, were selected and the following analysis were carried out: grain size analysis, determination of carbonate, sand and mud contents and organic matter content. In the following is the discussion of the result of each analysis.

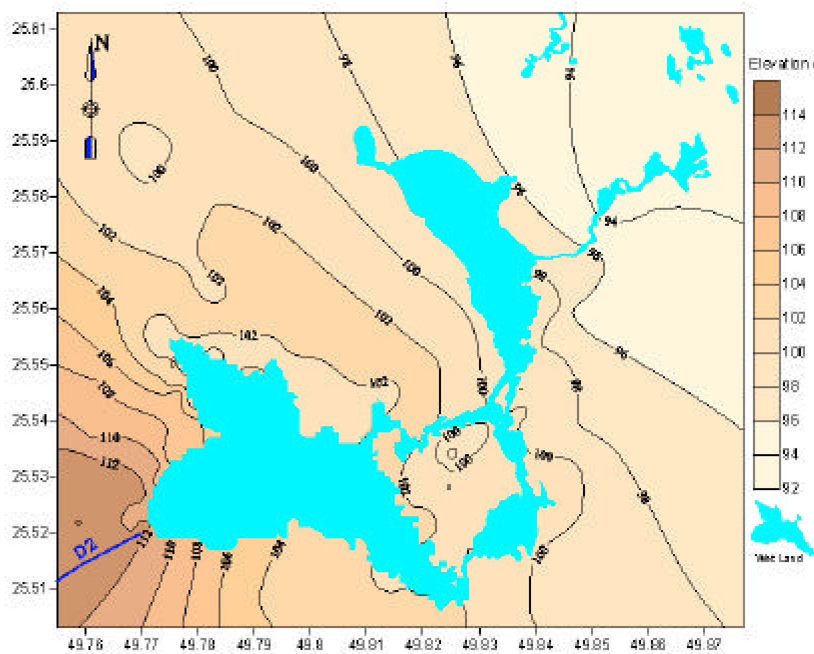


Fig. 4: Digital elevation model map of Al Asfar area, Al Hassa, KSA

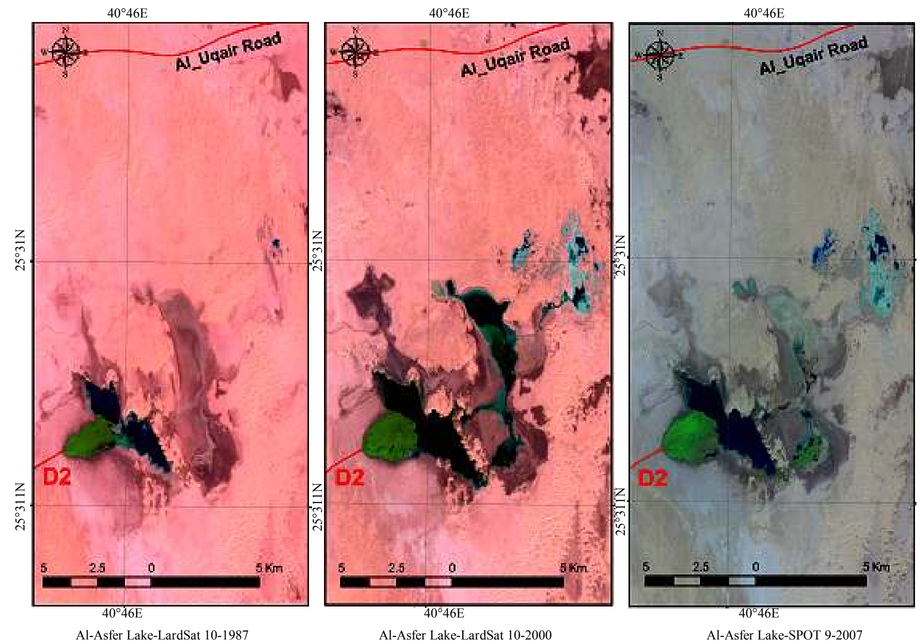


Fig. 5: The processed landsat-5 TM imageries (in years of 1987, 2000) and SPOT (in year 2007) for Al Asfar area

Grain Size Analysis

The main purpose of grain size analysis is to get an idea about the size spectrum of the sabkha samples under investigation. It is also gives information on the energy of the medium of deposition, where coarse particles are usually transported in higher energy environment, whereas, low energy environment transports finer sediments. It is also worthy to add that the statistical parameters of grain size and their mutual relationships provide us with information on agents of transportation as well as the environment of deposition.

Grain size statistical parameters form the basis of many schemes for classifying sedimentary environments. The size distribution of coarse clastic sediments reflects the fluidity (viscosity) factor of the depositing medium and the energy factor of the environment (site) of deposition (Sahu, 1964; Vincent, 1998; Al-Sharhan and El-Sammak, 2004). Sedimentologists are particularly concerned with three aspects of particle size: (a) techniques for measuring grain size and expressing it in terms of a grade scale; (b) methods for quantifying grain size data and presenting them in a graphical or statistical form and (c) the genetic significance of these data (Boggs, 1995). Every environment of deposition may be assumed to have a characteristic range of energy conditions and energy fluctuations as functions of location and time (Sahu, 1964). Many techniques have been proposed which use grain size data to interpret depositional environments (Boggs, 1995). More sophisticated multivariate statistical techniques, such as factor analysis and discrimination function analysis, have also been explored.

Grain size parameters include graphic mean size (Mz), inclusive graphic standard deviation (σ_I), inclusive graphic skewness (SK_I) and graphic kurtosis (K_G) are calculated. The estimation of the statistical grain-size parameters was accomplished using the mathematic formulas of Folk and Ward (1957). Table 1 shows the descriptive statistics of the different grain size parameters for the analyzed sabkha soil samples. Surfer contouring software has been used to draw spatial distribution maps for these parameters, these maps will generally used to estimate the relation between grain size distribution and the sedimentological and geomorphologic features of the area.

The average value of Mz is 1.5 Φ (medium sand). The Mz values indicate that most of the samples of sabkha deposits are composed of medium sand. Figure 6a represents the spatial distribution of Mz for the analyzed samples in the study area. This map indicates that the fining is getting towards the north and to the west of the area of study. This distribution is related to the sources of sediments and the geomorphologic features including the drainage system and the topography of the study area (Fig. 4). The dominance of the fine sediments at the western part of the study area are coming from the mouth of the main Drain (D2) and the floods of the main lake of Al Asfar.

The average value of sorting (σ_I) is 0.96 Φ (moderately sorted). The samples of poorly sorted are located to the west of the study area Fig. 6b, this may be attributed to the different sources of the sediments having different sediment characteristics (i.e. sabkha, alluvial deposits and aeolian sediments, and dust storms) and the effect of geomorphology. While moderately sorted and moderately well sorted are located to the east of the study area.

The average values of SK_I is 0.08 Φ (near symmetrical). The data obtained showed that the most sediment of all the studied sabkha deposits are near symmetrical in the middle and to the north of the area while the southern part samples are fine skewed Fig. 6c. It is worth to mention that there is a good

Table 1: Descriptive statistics of the different grain size parameters for the analyzed sabkha soil samples, Al Asfar lake area, Al Hassa, KSA

Variables	Mz (ϕ)	σ_I (ϕ)	SK_I	K_G
Range	0.81:2.31	0.56:1.53	-0.22:-0.28	0.73:-1.27
Average	1.50	0.96	0.08	1.03
Standard deviation	0.31	0.24	0.12	0.12

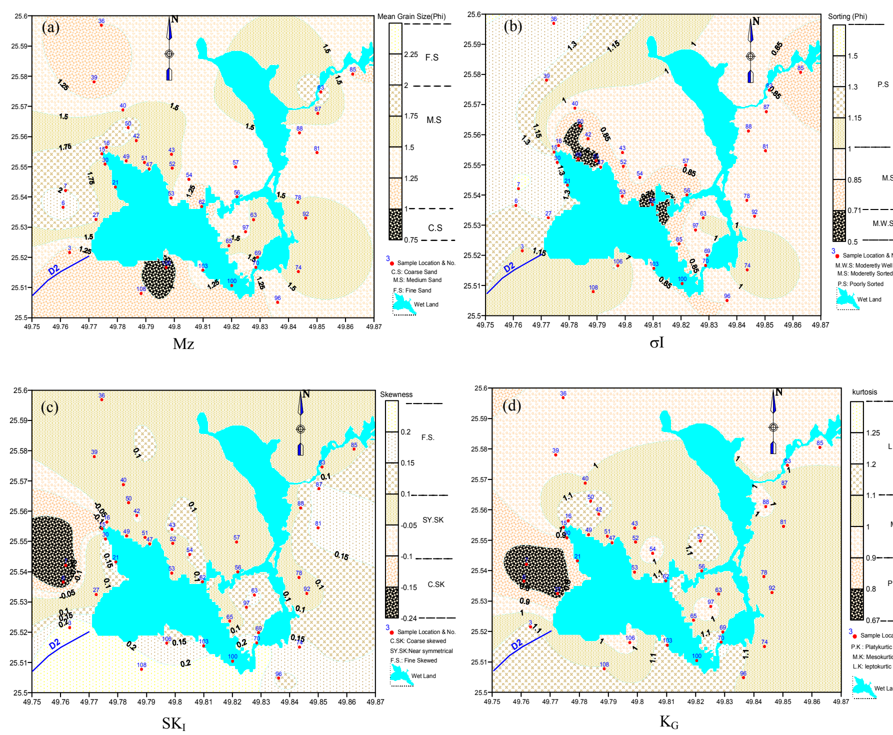


Fig. 6: Distribution of grain size statistical parameters in the study area, (a) mean grain size, (b) sorting, (c) skewness and (d) kurtosis

match between the map of Mz distribution (Fig. 6 a) and the map of SK_I (Fig. 6c), see for example the patch off the negative skewed around the location of samples 6 and 7 which means fine particles and that is clearly indicated in the map of Mz (Fig. 6a). Also, the southern part of the map is characterized by positive values of SK_I which means coarse particles and this in a good match with map of Mz (Fig. 6a). Areas with positively skewed sediments are formed in association with the tidal flats and sabkhas (Al Hurban *et al*., 2007).

The sediment samples in the study area are inclined towards the mesokurtic (average value of kurtosis is kG 1.03 Φ, ranging between platykurtic (0.73) to leptokurtic (1.29), Fig. 6d. The data obtained for KG indicates that the Al Asfar sabkha sediments are mesokurtic (60.97%), leptokurtic (24.39%) and platykurtic (14.63%). This may also be attributed to the variety of sediment sources and the complexity of surface geomorphology of the area. Platykurtic sediments are mostly associated with the poorly sorted sediments and this is clear if you compare the western part (poorly sorting) of map shown in Fig. 6b with the western part (platykurtic)of map shown in Fig. 6d.

In general, the grain size statistical analyses indicate that most of the areas are composed of two or more classes of sediments transported and deposited from different sources; these are aeolian sand, sabkhas and drain input and coastal features. The variability in the grain size statistical parameters may be attributed to the complexity of surface morphology as well as the diversity in the type of depositional environment in Al Asfar area.

Determination of Carbonate, Sand and Mud Contents

Figures 7a-c show the spatial distribution of the carbonate, sand and mud, respectively. From the grain size analysis and from these maps, it is clear the Al Asfar sabkha are in general sand and sandy silt. Also, It could be noticed the clearly that both carbonate and mud contents are generally increase

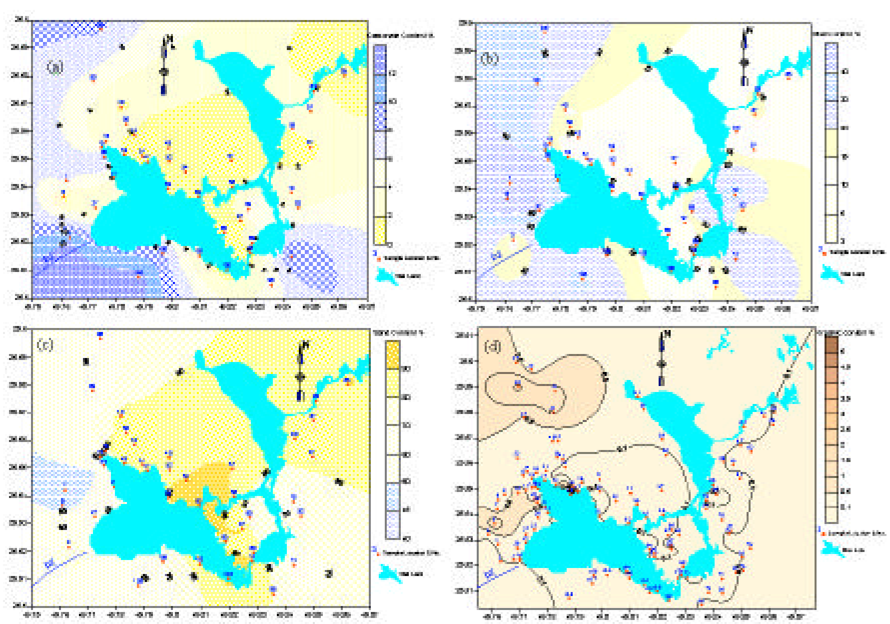


Fig. 7: The spatial distribution of carbonate, sand, mud and organic matter contents in the inland sabkha samples of Al Asfar area, Al Hassa, KSA. (a) Carbon, (b) Mud, (c) Sand and (d) Organic content

in the west of the study area. The increase of mud content in the west of the area is attributed to fine sediments associated with the discharged water from the main drain network, mainly D-2 (Fig. 2). The increase of carbonate content is attributed to the dissolution of the scattered carbonate Neogene ridges existing at the west of the study area to sabkha soil.

Organic Matter Content

The organic matter content for these sabkha soil samples is analyzed. The high values of the organic matter content are belonging to samples located quite near to the periphery of the main lake of Al Asfar (Fig. 7d) and this is attributed to the accumulation of the decayed vegetation with depth at these locations.

Chemical and Hydrochemical Investigations

The samples were analyzed for their chemical properties; hydrogen ion concentration (pH), electrical conductivity (EC), and then total dissolved salts (TDS) is calculated and for major constituents (Na^+, Ca^{++}, K^+ , Mg^{++}, Cl^-, SO_4^-, HCO_3^- and NO_3^-). Table 2 shows the statistical analysis of chemical properties and for major constituents of the collected sabkha soil, surface water and pore water samples. From this table it could be noticed, the major cations are in order Na^+, K^+, Ca^{++} and Mg^{++}, while the major anions are in order: Cl^-, SO_4^-, HCO_3^- and NO_3^-. The carbonate content is so small that it was undetected as the maximum value of pH is not more than 8.3 which is the threshold this ions start to form for both soil and water samples (Stumm and Morgan, 1981).

pH was measured for all sediment and water samples. Figure 8a and b shows the spatial distribution map of pH values for soils and water along the study area. The soil samples having pH

Table 2: Statistical analysis for chemical analysis for the major cations and anions for Al Asfar sabkha soil, surface water and for pore water samples

					Major cations (ppm)				Major anions (ppm)			
Type	Analysis value	pH	EC (dS m^{-1})	TDS (ppm)	Na^+	Ca^{++}	K^+	Mg^{++}	Cl^-	SO_4^-	HCO_3^-	NO_3^-
Soil samples	Minimum	7.22	5.6	4464.0	561.0	188.2	229.2	92.7	1014.6	718.7	31.1	2.5
	Maximum	8.28	70.9	56720.0	7262.1	2308.3	2775.4	1178.2	15146.1	12891.7	863.3	95.0
	Mean	7.653	27.7	22166.1	2841.3	900.7	1085.9	459.0	6130.7	4243.9	112.2	12.1
	SD*	0.188	15.8	12635.7	1619.1	513.9	618.7	261.8	3513.6	2578.3	82.3	13.0
Water samples	Minimum	7.0	9.5	7624.0	1008.9	235.8	159.7	536.3	1827.2	1349.9	70.0	0.9
	Maximum	8.3	102.3	81840.0	10829.6	2531.5	1714.3	5756.7	27335.0	8809.8	1742.4	41.0
	Mean	7.8	40.5	32383.5	4285.2	1001.7	678.4	2277.9	10717.7	4321.9	318.7	9.1
	SD*	0.3	28.7	22973.4	3040.0	710.6	481.2	1616.0	8079.9	2447.0	287.0	9.4

*Standard Deviation

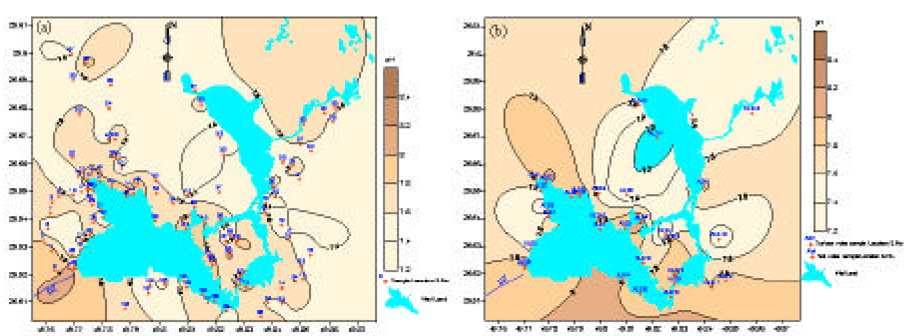


Fig. 8: Distribution map of the pH content for the soil and water of Al Asfar inland Sabkha, Al Hassa area, KSA

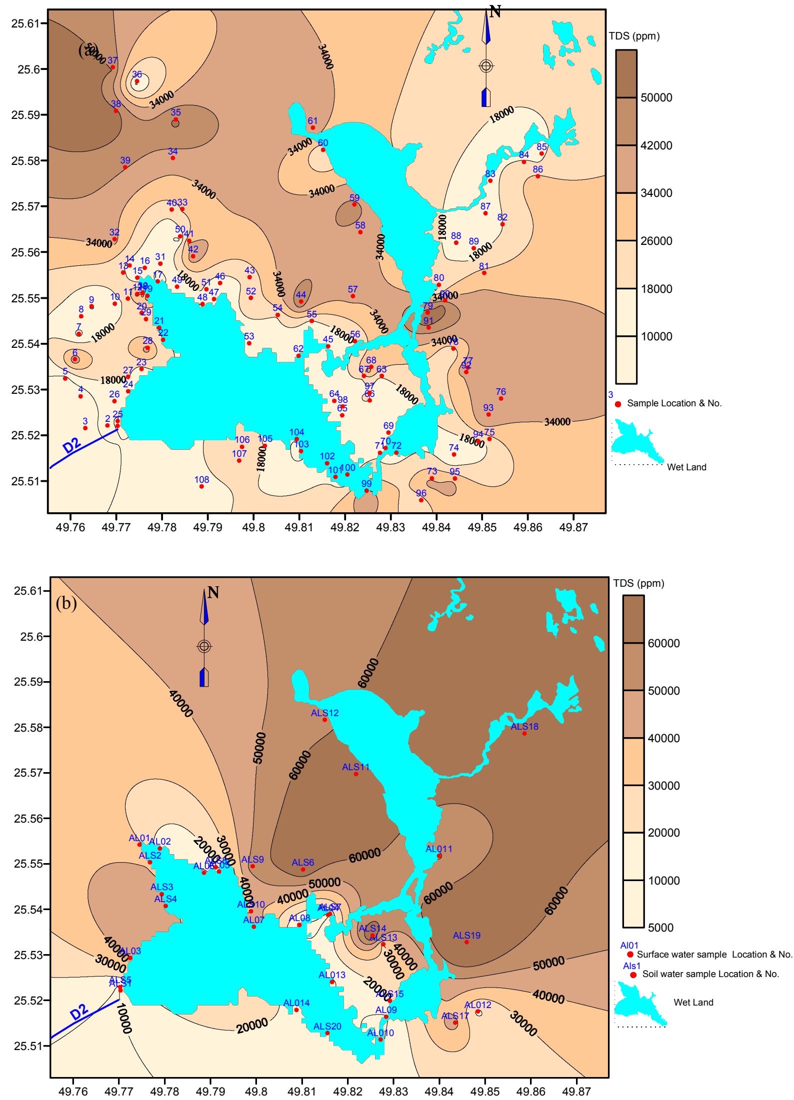


Fig. 9: Spatial Distribution map of the total salinity (a) for the soil and (b) for the surface water and soil water of Al Asfar area, Al Hassa area, KSA

values varying between 7.22 and 8.28, while the water samples having pH values 7 and 8.3. From these two maps, it could notice that pH values are increasing southwestward in opposite trend of TDS distribution map (Fig. 9 a, b). Obviously all the samples indicate a slightly alkaline character with very narrow pH ranges.

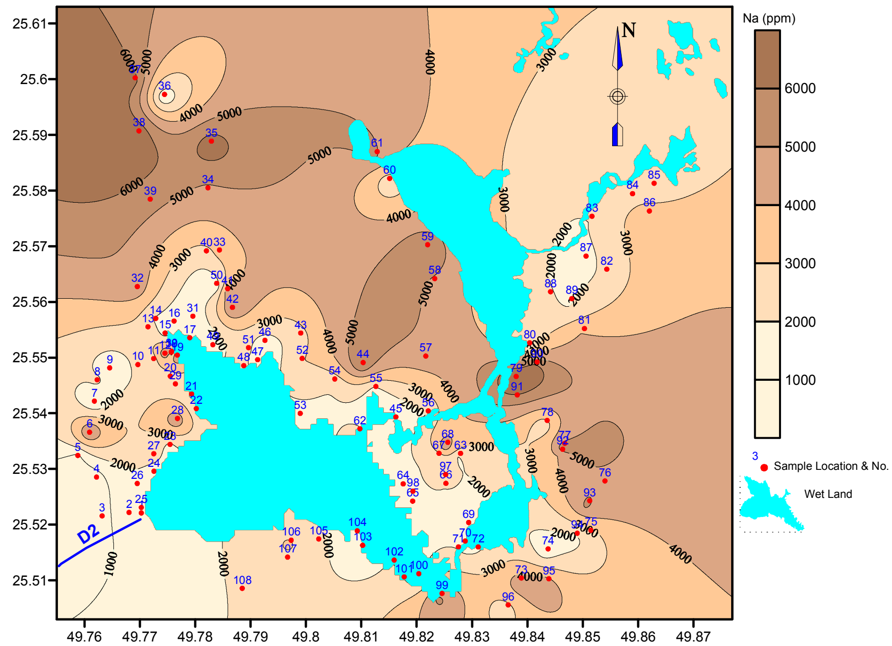
For the studied sabkha sediments, the total salinity ranges between 4,464 and 56,720 ppm, with mean value of 22,166.1 ppm. The increasing of soil and water salinity towards the east (Fig. 9a) is quite expected due to the effect of leaching process in the down-gradient direction. The lower gradient in salinity content towards the southwestern part can be attributed to the flushing effect of drain two canal (D-2) while the higher salinity content recorded for the zone located at the eastern side of the main lake of Al Asfar (Fig. 9a) and have the same trend of the lake extension (NW-SE). The higher salinity content is attributed to the influence of the intermittent charge and for the high evaporation rate. From the spatial distribution of salinity content of the sabkha soils, it is clear that salt content has a significant effect on the sabkha grade and has its effect on sabkha spectral signature in landsat-5 TM and SPOT imageries used in this study (Fig. 5).

The total salinity of surface water and pore water samples ranged from 7,624 to 81,840 ppm with mean value of 32,383.5 ppm (Fig. 9b). The relatively low values of total salinity are belonging to the surface water samples from the main lake of Al Asfar (Fig. 9b). The relatively low total salinity values are belonging to the surface water samples collected from the main lake of Al Asfar (where the irrigation drainage water of low salinity is discharged to the lake through drainage canal D2), while the high values are belonging to surface waters samples collected from isolated bonds around the main lake (where high evaporation and more salt is concentrated).This relatively low salinity values encourage to re-treat Al Asfar lake water and to reuse it in agricultural purposes, this will lead to minimize the sabkha extension, to mitigate its impact on the nearby farms of Al Hassa oasis and to mitigate aquifer recharge with high saline water and to optimize the water use of this surface water body in this arid environment. The increase of salinity of this lake is due to its closed nature, shallow depth of water, restricted condition and minor connection with continuous fresh water source.

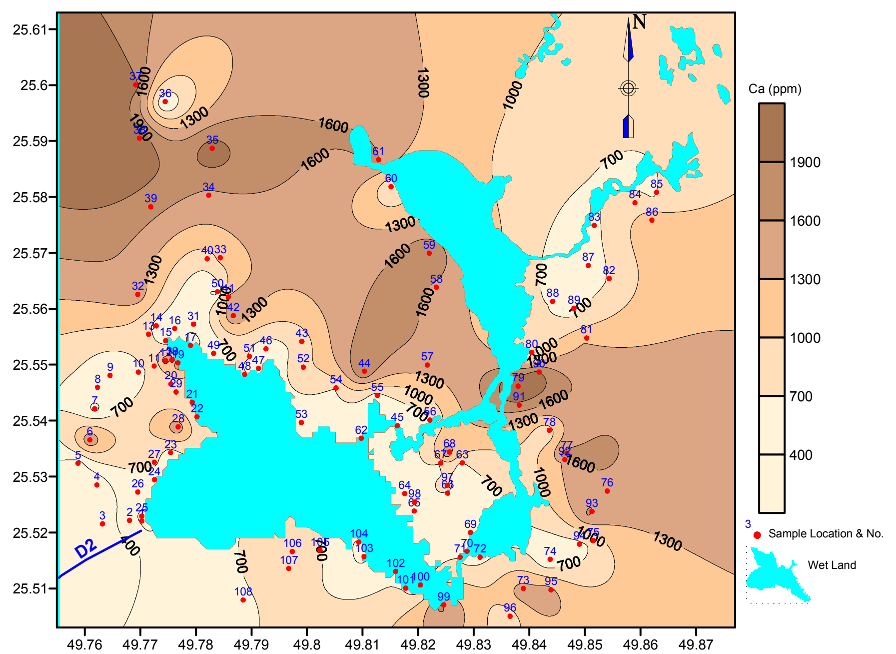
The soil water salinity at the margins of Al Asfar Lake ranges from less than 10,000 ppm (for example salinity of samples Nos. Als1, Als5 and Als7) to about 80,000 ppm (see for example salinity of samples Nos. Als 6, Als11 and Als19), (Fig. 9b). The salt content of soil water for the collected samples depends on the distance from the main water body of Al Asfar lake, i.e., the nearest to the lake, the less of salt content. The soil water under this sabkha is more saline than the normal sea water. It is worthy to mention that the contour pattern of the constructed spatial distribution maps for the major cations of soil samples (Fig. 10a) are similar to that of TDS shown in Fig. 9a. The same feature is also noticed for the major cations of water samples (Fig. 9b, Fig. 10b). However, in case of anions the contour pattern for chloride and sulphate have the similar pattern of TDS while for both Bicarbonate and Nitrate have a different pattern (Fig. 11a, b). The bicarbonate in this sabkha is thought to be derived partly from the outcrops of Neogene carbonate ridges originated under marine conditions. It is worthy to mention that the bicarbonate ions distribution either in soil or in water (Fig. 11a, b) is in a good match with carbonate content distribution of soil sabkha samples shown in (Fig. 7a).

The major hydrodynamic process operating in this inland sabkha is upward migration of the brines by capillary movement precipitating salts. The presence of salts at the surface due to the rate of evaporation at the sabkha surface at these sites exceeds than the total input of water to the sabkha, so that high concentration of TDS in the water are reached (Handford, 1981). The variation in the salinity is relatively influenced by the following factors; evaporation, the lithologic characteristics of the soils, as well as transportation, solubility of salts and the rate of discharge of the surface water from the agricultural drains to Al Asfar Lake.

The rate of evaporation in the inland sabkhas is supposedly higher than that in the coastal ones due to the more arid conditions. Consequently, the ground-water table plays a substantial role in the development of inland sabkhas, which are usually less developed than coastal sabkha flats and are predominantly tectonically and/or topographically controlled (El-Naggar, 1988). The sediments of these sabkhas consist predominantly of gypsum (desert roses), quartz and calcite, with halite always existing at the crust (Kinsman, 1969).The crustal part is the product of a combination of geological processes like desiccation, weathering and, above all, cementation of the salts precipitated through evaporation of highly saline groundwater. Khedr (1989) terms such a growth or development of sabkhas through this latter process as sabkhaization.



Na^{+}



Ca^{++}

Fig. 10a: Continued

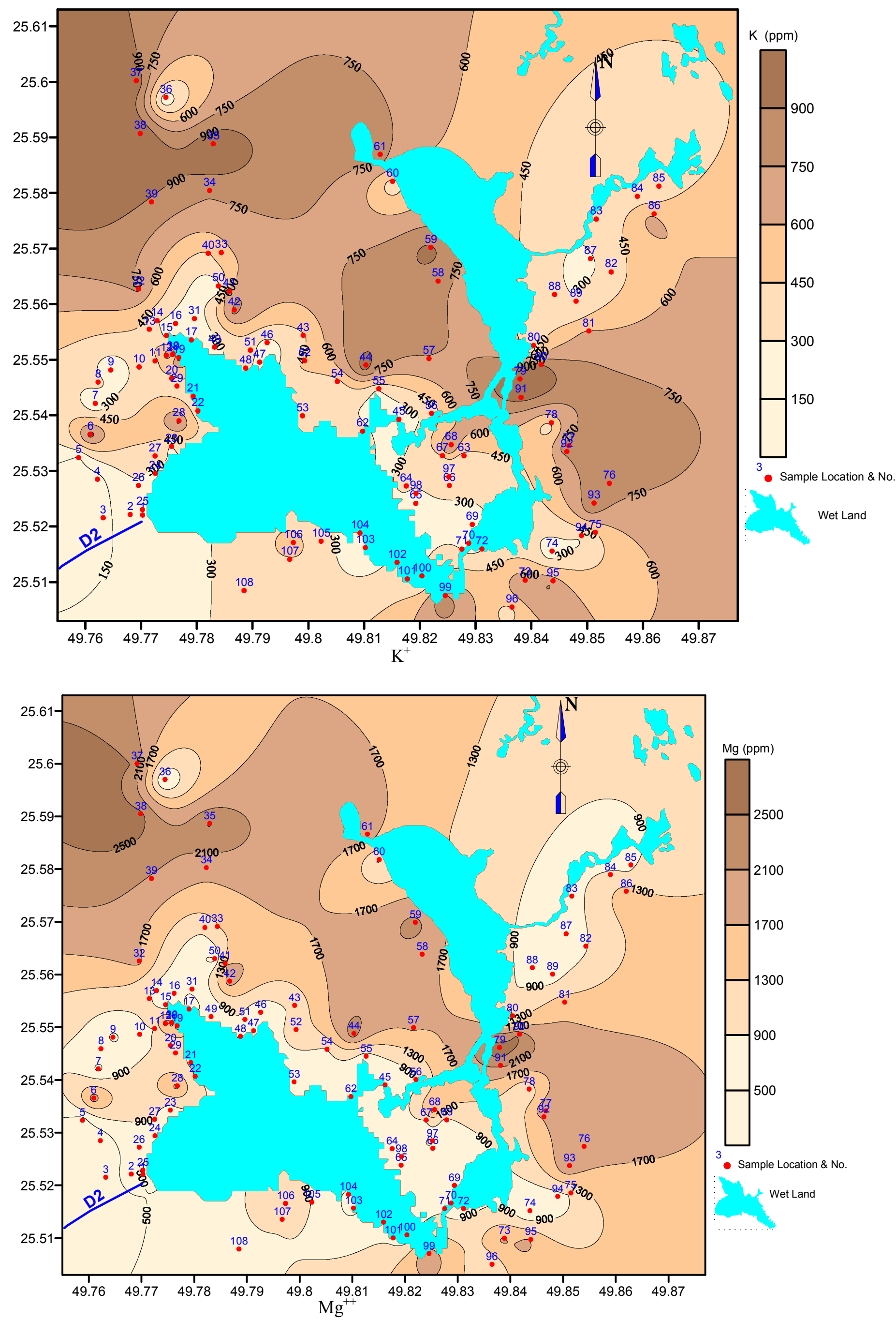
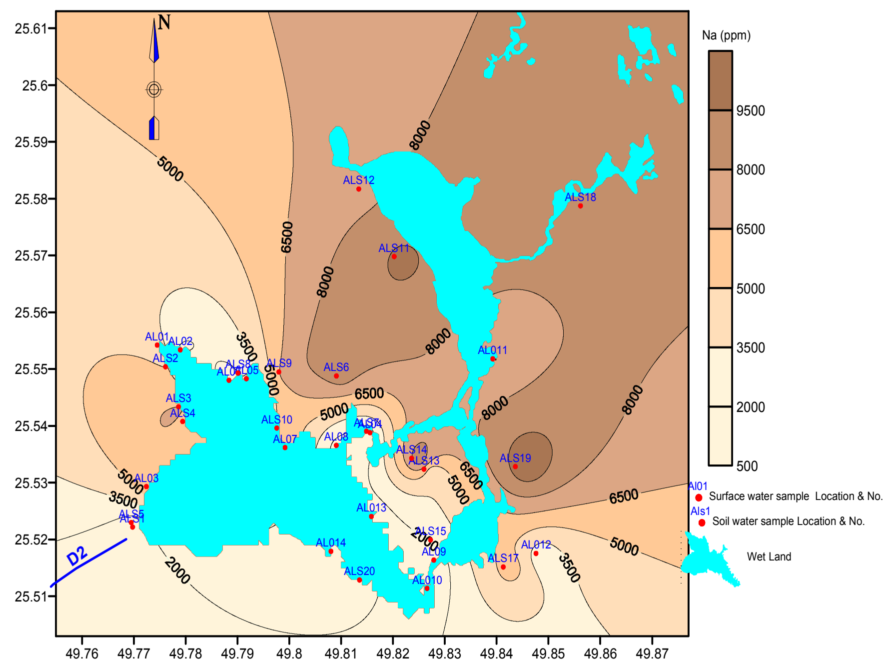
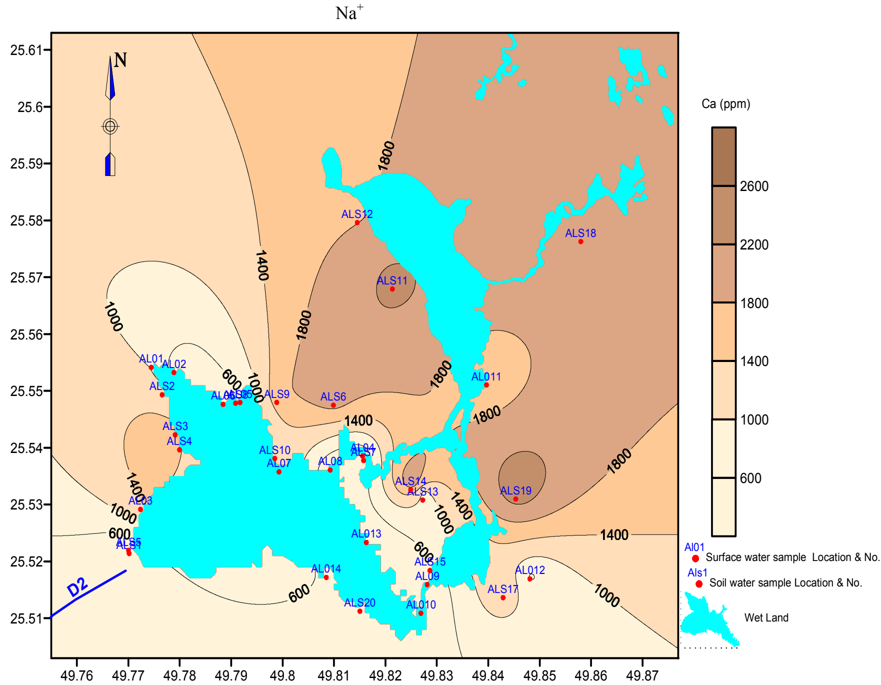


Fig. 10a: Distribution maps of the major cations concentration for the soil of Al Asfar area, Al Hassa, KSA

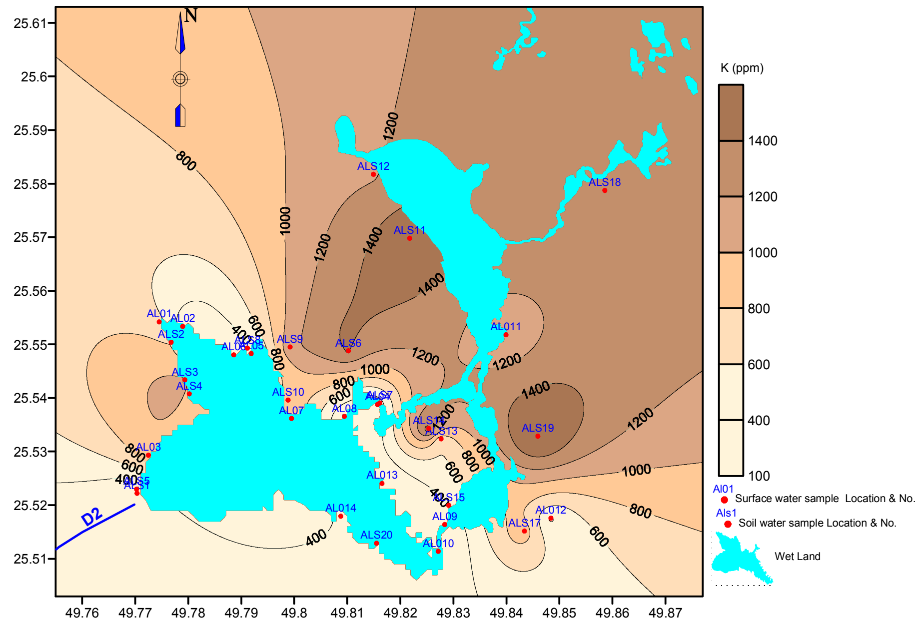


Na^{+}

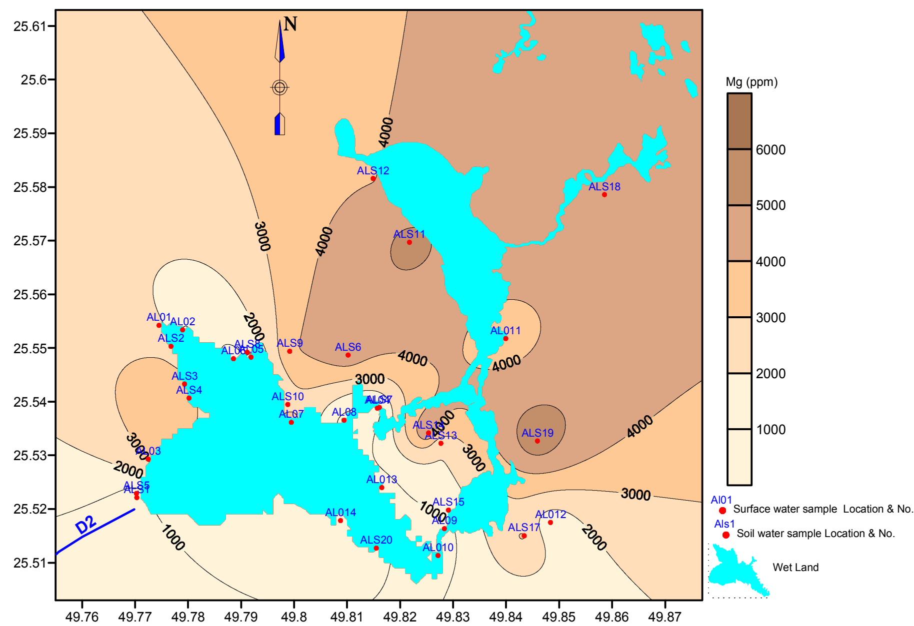


Ca^{++}

Fig. 10b: Continued

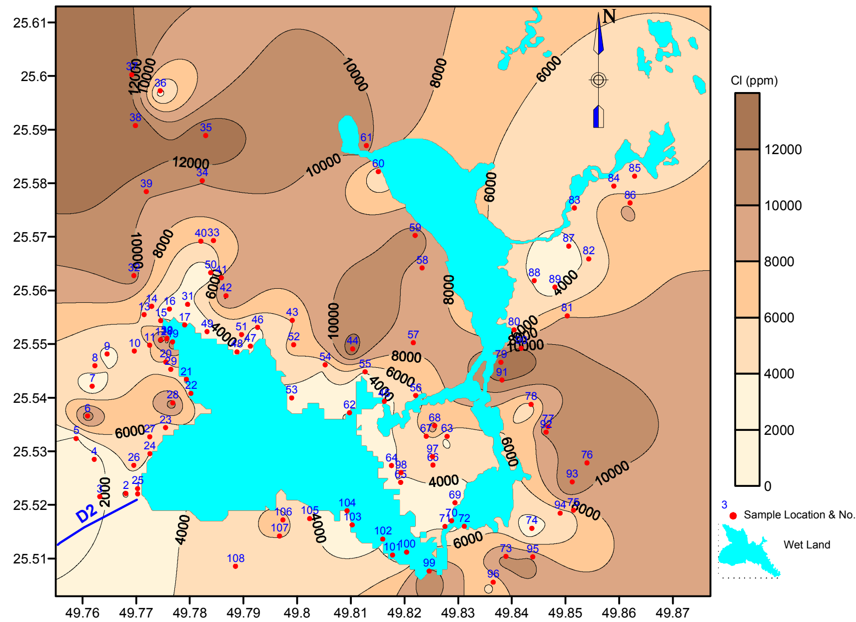


K⁺

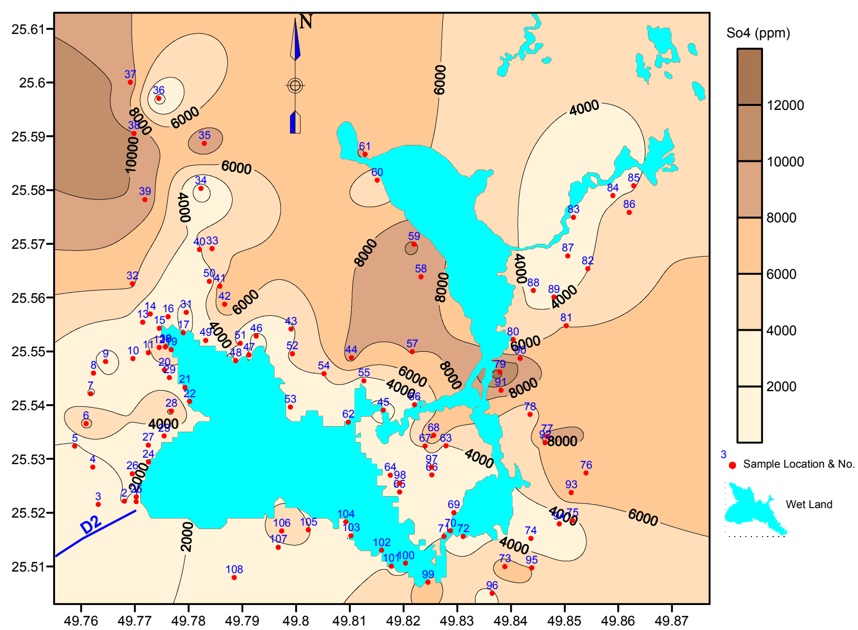


Mg⁺⁺

Fig. 10b: Distribution maps of the major cations concentration for the surface water and soil water of Al Asfar area, Al Hassa, KSA

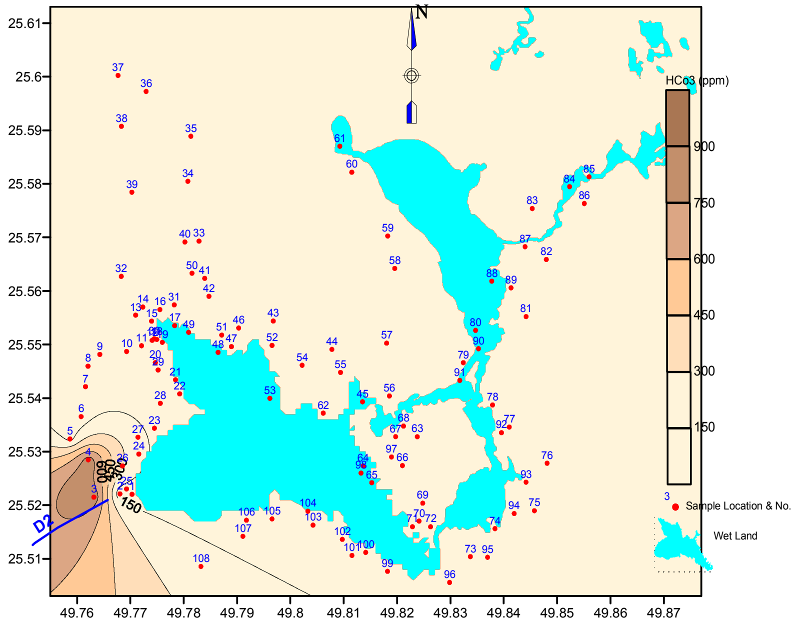


Cl^-

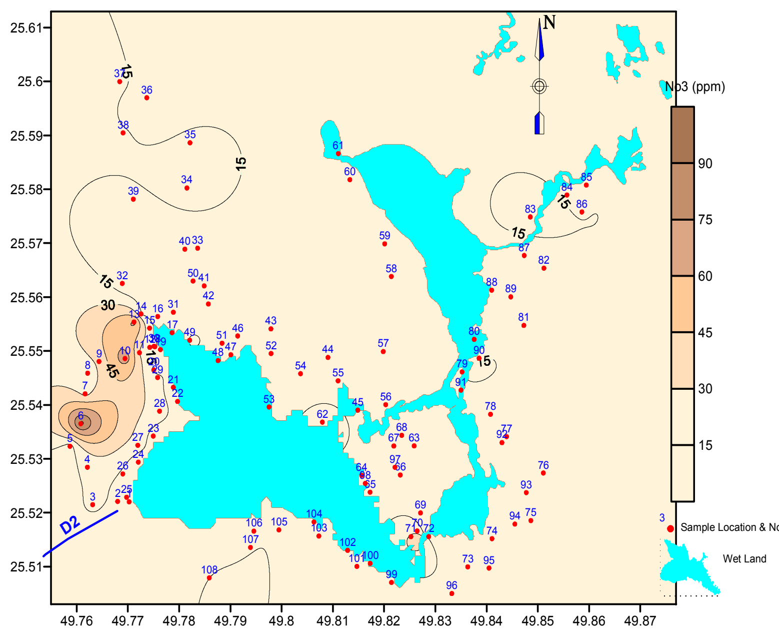


SO_4^-

Fig. 11a: Continued

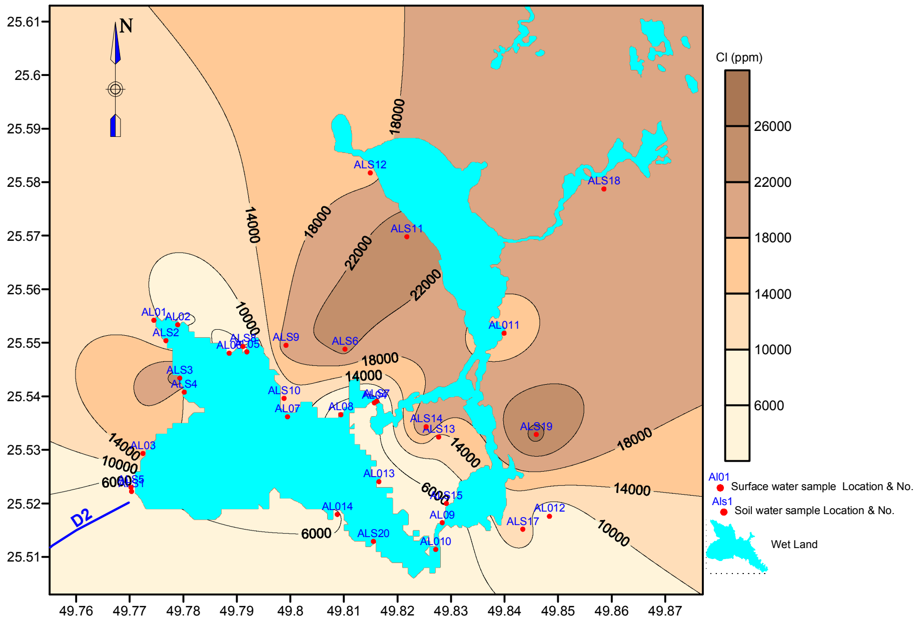


HCO_3^-

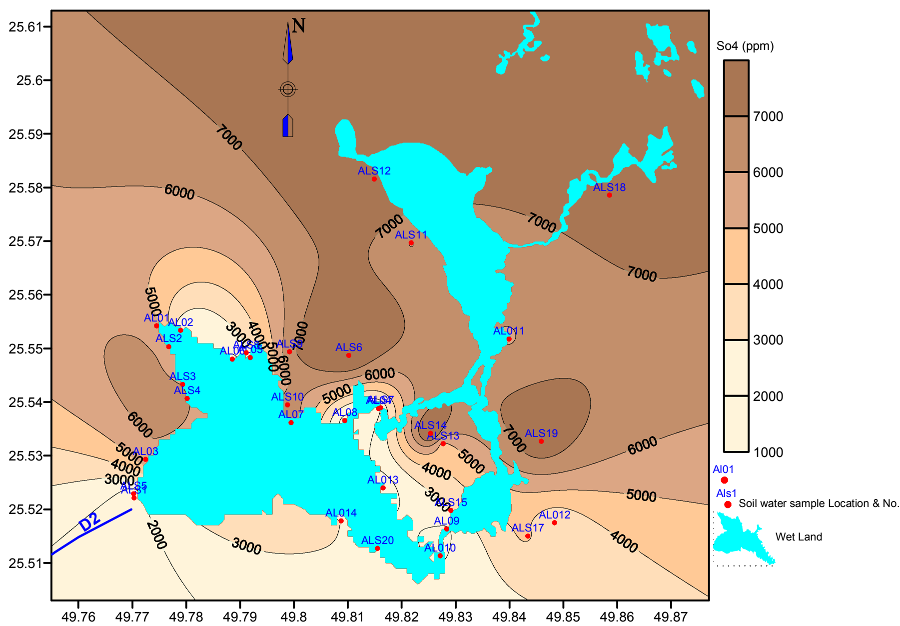


NO_3^-

Fig. 11a: Distribution maps of the major anions concentration for the soil of Al Asfar area, Al Hassa, KSA

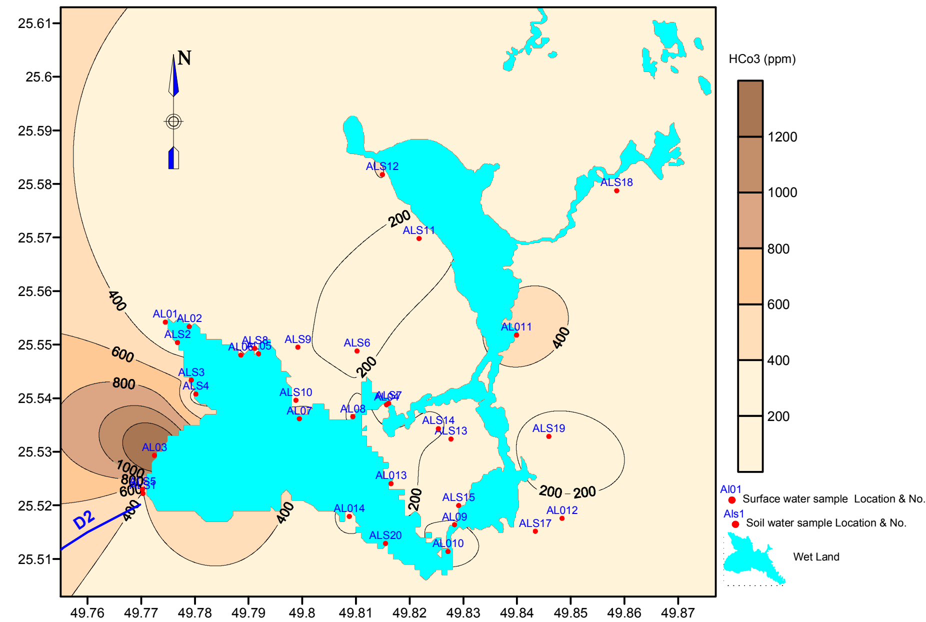


Cl^-

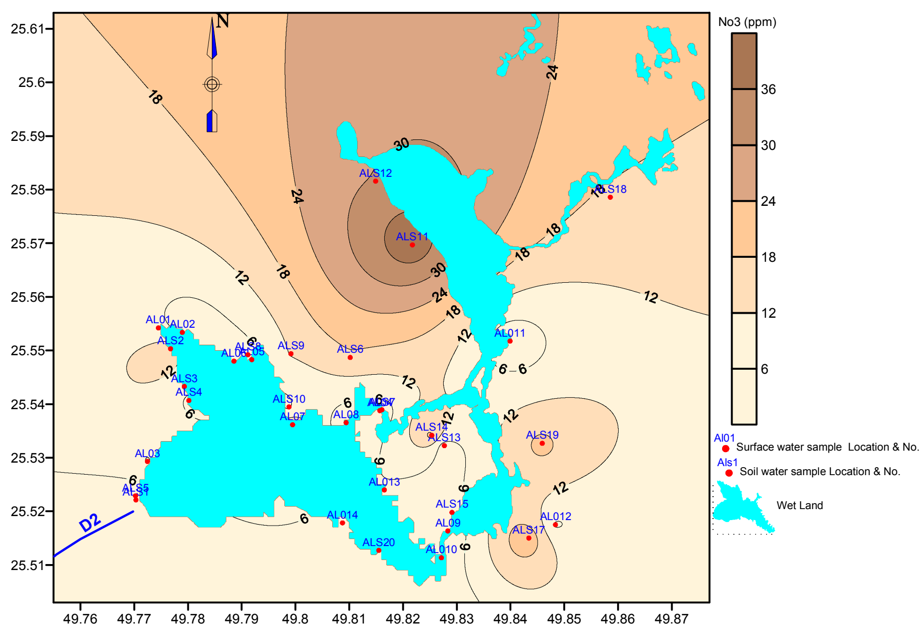


SO_4^-

Fig. 11b: Continued



HCO_3^-



NO_3^-

Fig. 11b: Distribution maps of the major anions concentration for the surface water and soil water of Al Asfar area, Al Hassa, KSA

Further, these results shed light on the maturity status of the inland Sabkha of Al Asfar. Thus the observed higher TDS in both soil and water confirms the slightly developed to developed nature of sabkha as per the classification of Bahafzallah *et al*. (1993).

CONCLUSIONS

The processed landsat-5 TM and SPOT imageries indicated there is a general increment in both sabkha and wet land areas extent with the passage of time at Al Asfar Lake area. The study indicates that the area receives sediments from more than one source. These sources include, aeolian sand in addition to sediment from transported through drainage system in the area. These new data will be extremely important for any future development of Al Asfar area. Different sabkha grades are recognized. These different sabkha grades have various degrees of salt content as it is indicated from the TDS spatial distribution at Al Asfar area. This study revealed that the surface water of Al Asfar lake is characterized by a relatively low salinity and then re-treating and reusing of this water in agricultural purposes will lead to minimize the sabkha extension, to mitigate its impact on the nearby farms of Al Hassa oasis, to mitigate aquifer recharge with high saline water and to optimize the water use of this available surface water body in this arid environment. Chemical results are very important to be taken in consideration by Saudi Aramco, as the different sabkha grades have their various corrosion levels that may impact the pipelines crossing this sabkha area. Sabkha dynamics information and chemical results gained from this study may be used to optimize pipelines maintenance and future cost effective pipelines route planning. The evaporation condition prevailing in the present study and the absence of continuous recharge from the main drainage (D2) led to the concentration of highly saline lagoon water. The major hydrodynamic process is possibly the upward migration subsurface of brines from groundwater by capillary action due to evaporation, precipitating salt on the surface.

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