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Characteristics of natural clay deposits in Saudi Arabia and their potential for water conservations

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Abstract

Clay minerals in soils are the key component controlling water storage and movement in irrigated arid lands. Previous studies proved that application of high quality clay minerals even in low quantities to coarse textured desert soils improved dramatically water conservation and water use efficiency. The main objective of this research was to identify and characterize clay deposits and their desired characteristics for water conservation. Forty seven representative clay deposit samples were collected from different regions in Saudi Arabia. Samples were subjected to physical, chemical and mineralogical characterization. Results indicated that most of the selected sites are rich in natural clay deposits, some were found at the surface while others were exposed in the slopes of the mountainous areas. Data showed relatively high variations in the clay deposit characteristics from the different regions particularly in clay contents, salinity, alkalinity and the dominant clay minerals. Smectite clay minerals dominated the clay fraction of deposits collected from Khulays, Jeddah, Al-Hassa, and Al-Kharj areas beside attapulgite, Kaolinite and other minerals. Dhruma and Rawdat clays are dominated mostly by Kaolinite, illite and smectites. Clay deposit characteristics range as follows: clay content (20-96%), saturation percentage (29-184 %), field capacity (14-140 %), wilting point (6-64 %), available water content (8-77 %), ECe dS/m (0.66-47.0), pH (6.82-8.36), $CaCO_3$ (1-52.9 %) and CEC cmole/kg (10.3-77.2). It appears that samples with high clay contents have high available water and field capacity. Soluble B was relatively high in some samples collected from Al-Kharj which indicated relatively high levels. Available Fe was very high in all samples while other nutrients (K, Mn, Zn and Cu) are high to moderate. Total heavy metals (Cd,

Ni, Pb and Co) were low to moderate in most of the studied samples and relatively high in few samples particularly that collected from the western region.

Introduction

Saudi Arabia is geologically divided into four distinct and extensive terrains as described by Laurent (1993). These are the Proterozoic Arabian Shield, comprising metamorphosed volcano sedimentary successions intruded by granite and gabbros; Arabian platform dipping gently eastward; the Tertiary 'harrats' mainly overlying the Shield; and the narrow Red Sea coastal plain of Tertiary and Quaternary sedimentary rocks and coral reefs. According to Laurent (1993) favorable geologic conditions for the formation and accumulation of clay deposits are found in the following formations, Khuff, Marrat, Dhruma, Biyadh Sandstone, Wasia, Aruma, Hadrukh & Dam and some Paleogene-Neogene layers along the Red Sea. In most cases, the clay occurrences contain a predominant proportion of kaolinite. Exceptions are the distinctly marine deposits of the early Paleozoic (Jauf and Tauk formations) and the Tertiary littoral marine deposits of the east coast (Hadrukh and Dam formations) in which illite predominates. Certain lagoon or lacustrine environments generated deposits of attapulgite clay (Aruma and Dammam formations) or montmorillonitic clay (Tertiary formations of the Red Sea coast) Laurent (1993). Argiclays is essentially composed of argillaceous crystalline hydrous aluminum silicates containing Na, K, and Ca in which Mg and Fe may be substituted for Al. The most common commercial clay minerals are kaolinite, montmorillonite, illite and attapulgite. Natural clays such as clay stone or mudstone comprise several clay minerals with one or more impurities. The most common impurities are, free iron oxide minerals, amorphous silica and alumina, quartz grain, limestone, gypsum and other more soluble salts. These impurities affect largely clay characteristics and may affect adversely its use in specific applications. (Lee et. al 1983) reported that clay mineralogical composition of soils along the eastern coastal playa near Al Qatif is mostly smectite among layer silicate minerals in clay fraction. They added that palygorskite mineral is widely distributed in the eastern region soils. They believe that plygorskite originated from the underlying Mio-Pliocene limestone in the basin, and to be redistributed by alluvial and eolian processes. Thus, natural deposits may improve the above constraints and thus increase soil productivity, especially in the areas where these materials are avilable in abundence and cheap. There have been studies on the use of natural deposits to alleviate some of the soil constraints to its production (Sallam, 1995).

Afifi (1986) reported that the addition of Bentonite to sandy soil increased the retention and the availability of soil moisture as well as the increase of the cohesive forces among their particles. He concluded that the addition of Bentonite reduced the velocity of downward water movement and restricted the deep percolation and leaching out the nutrients. Das and Dakshinamurti (1973) showed that the infiltration rate and hydraulic conductivity of sandy loam soils treated with bentonite were reduced compared to untreated soils. They concluded that the horizontal infiltrations as well as the diffusivity were very much reduced in the treated soils. Therefore, the main objective of this research was to study the characteristics of natural clay sediments from different regions in order to evaluate their potential as natural amendments for irrigated sandy soils.

Materials and Methods

Forty seven representative clay deposit samples were collected from selected locations in the different regions in Saudi Arabia. The selection of the sites based on the previous geological studies e.g. Laurent (1993). Collected samples were prepared for mineralogical, physical and chemical analyses following the standard procedures. Particle size distribution was carried out using the international pipette method. Saturation water percentage (SP%) was determined gravimetrically. Soluble salts were measured electrometrically using EC meter in the saturation paste extract while pH was measure in the same extract using pH meter. Calcium carbonate content was determined according to Allison and Moodie (1965). Organic matter content was determined Spectophotometrically according to Sims and Haby (1971). Representative sub-samples were extracted by DTPA (Di Tetra Penta Amine Acetic Acid) according to Lindsay & Norvell (1978) for available micronutrients determinations. Extractable Fe, Mn, Zn and Cu were measured using atomic absorption spectrometry (AAS) according to Barker and Suthr (1982). Available phosphorus was determined by the modified $NaHCO_3$ method using ascorbic acid as a reducing agent, (Olsen and Sommers, 1982). Total elemental analysis was carried out after sample digestion using hydrofluoric acid in a closed vessel as described by Jackson (1974). Total Fe, Cu, Mn, Co, Cd, Zn, Ni, Pb were measured in the acid extracts using AAS. Total K was measured using flame photometer while total P was measured in the same extract spectrophotometrically. Clay fraction (< 2 um) was separated according to (Jackson, 1974). Subsamples of clay fraction were Mg or K saturated using 1M $MgCl_2$ or 1M KCl, respectively, then slides were prepared as oriented mounts. X-ray diffractograms were obtained using Cu-Kα radiation at 40kV and 25mA. K-saturated samples were scanned after air drying and following heat treatment at 550 ^{o}C for 2 h. Mg-saturated samples were scanned following air drying and ethylene glycol solvation. Identification of clay minerals and accessory minerals was carried out according to (Dixon & Weed, 1989). Free iron and manganese oxides (Fe_d & Mn_d) were extracted using sodium citrate bicarbonate- dithionate method (CBD) according to (Mehra and Jackson, 1960). Amorphous silica and alumina (Si_{am} & Al_{am}) were dissolved in boiled NaOH (1N) for 2.5 minutes according to Alexiades & Jackson (1966) then Al and Si in the extracts were measured by AAS. following the procedure described by Dale and Norman (1982).

Results and Discussion

Dhruma-Marrat sites samples Nos. (1-7) are characterized by the presence of deep and massive clayey layers having different colors. Al-Kharj and Harad sites sample Nos. 8-17 located on eastern platform and consist of isolated hills where clay and sand exposed on gentle slopes beneath the limestone. These layers contain massive compacted clays in some sites while other sites contain friable clayey layers in the form of fractured mud stone having different colors. Jeddah –Khulays sites (Nos. 19-33) contain widespread thick clay layers with different colors, some are compacted and the others are friable. Clay layers in most of the studied locations are exposed intermittently on gentle slopes beneath the stony layers on the surface. Al-Rawdat sediments (Nos. 34, 40, 44 and 47) are found in the nearly level surfaces in the depressions and contain thick deposits carried out from the surrounding hills and mountains. It has cracked surface particularly during the dried periods.

Moisture characteristics: Table 2 showed that saturation water percentages (SP%) were greatly variable and range from 29-184% with an average of 80.8% and STD of 36.45. High SP was corresponding with high clay content in most of the studied samples. Also, Al-Hassa sediment samples (Nos 35-37) as well as many samples from Khulays (Nos 23, 24, 29) Al-Kharj (Nos 8-10), Dhruma (Nos3, 8) and Sider (No.48) show high SP values. Data also indicated that field capacity (FC) and wilting point (WP) values of all the studied samples have relatively high values particularly those with high clay content. On the other hand available water contents (FC – WP) are high and reaches about 77% which was quite high. Addition of sediments having high saturation percentage and other moisture characteristics to sandy soil will improve soil water holding capacity and eliminate deep percolation of irrigation water and hence improve water conservation in such soils, Al-Omran et.al 2003.

Physical and chemical properties: Table1& 2 indicated also that the studied sediment have clay content ranges from (18.0-96.0 %) with the mean of 54.8% clay and stander deviation (STD) of 20.01. All the studied samples are clayey texture, with some exceptions. Most of the studied samples have high clay content and others have very high clay content up to 96% particularly those collected from eastern region (Nos. 35-36). Sand contents range from 0-73% with the mean value of 25.1% where the maximum content was found in one sediment sample from volcanic sediments at Al-Madinah (N0. 42). Cation exchange capacity values (CEC) was quite high in most of the studied samples and range from 8.4 to 77.2 cmole kg^{-1} with the mean of 31.7 cmole kg^{-1} and standard deviation of 18.44. High CEC values correspond to the high clay content in most of the studied samples. High CEC values and clay content are considered one of the favorable characteristics that reflect the positive sign for increasing water storage capacity of the sediment sample. $CaCO_3$ contents range from 1.0 to 56.0 g kg^{-1} with the mean values of 13.3% and STD of 14.82. Low carbonates were found mostly in the samples collected from Dhruma, Jeddah-Khulays areas and in some locations of Al-Kharj, while Al-Rawdat and the other two samples from eastern region (Nos. 45and46) have relatively high $CaCO_3$ contents. High carbonate contents in the natural sediments may be considered one of the constraints for their use as soil amendments in arid lands mostly because of their unfavorable physicochemical properties toward nutrient precipitation in the soil. Salinity levels in the studied sediments (Table 2) are quite variable and range from 0.66-52.2 dSm^{-1} with the mean value of 18.5 dSm^{-1}. Al-Rawdat sediments and most of the samples collected from western region indicated also a relatively low salt content. High salt contents in the sediment samples are one of the major constraints for sediment applications to sandy soils due to their possible effects on the increase of soluble salts in the soil. On the other hand methods of sediment applications and the appropriate soil and water management practices can control the undesired effects of the applied sediments and salts to sandy soil (Al-Omran et. Al 2004). Values of sediment's pH range from 6.82 to 8.36 with an average of 7.7. Such pH range correspond to most the arid soils. Data of water soluble B in the saturation past extract are region have relatively low salt contents due to leaching effects caused by deep percolation of rain water (Sheta et al., 2003)). Some sediment samples from the eastern variable and range from 0.74 – 11.79 mg B/l with mean of 4.6 mg/l. The highest values were found in some samples of Al-Kharj (Nos 13-17) while most of the studied samples. particularly Dhrurma sediments were quite low in soluble B. Such high B values may not be that critical from the toxicity viewpoint taking into account the quantity of applied sediments and the methods of sediments application. Data in (Table, 2) indicated the studied sediments have relatively high contents of total Fe particularly in the sediment samples from Al-Madinah (Nos. 41 and 42) where the sediments formed from the basaltic lava of the Harrates dominated the area. Total Fe ranges from 6.2-132.5 gkg^{-1} with the mean value at 57.8 gkg^{-1} and STD at 29.63. The lowest content was found in the clayey samples collected from Al-Hassa. Total K_2O and P_2O_5 are quite variable and ranges from 0.10-23.2 and 0.01-16.9 gkg^{-1} respectively. Dhruma, Al-Kharj and Khulays samples have relatively high contents of total K while samples collected from Al-Madinah and many samples from Khulays and Al-Kharj have relatively high contents of total P_2O_5. Total contents of heavy metals i.e. Cd, Pb, Ni, Co, Zn, Mn and Cu in all the studied sediments are highly variable (Table 2). Most of the collected samples have low contents of total heavy metals and are below the maximum allowable limits (MAL) for heavy metals in soils used in different countries (Kabata-Pendias, 1995). Total Cd ranges from 1.5-5.53 $mgkg^{-1}$ with the mean at 2.45 $mgkg^{-1}$ and (STD 1.06). 0nly three samples from Al-Hassa and Sudair have values above MAL at 5 $mgkg^{-1.}$ Total Co was far below (M.A.L.) in all the collected samples. Total Ni was mostly below M.A.L. value (100 $mgkg^{-1}$) except one sample from Khulays (No.34) and one sample from Al-Samman (No. 44). Total Ni ranges from 2.30-130 $mgkg^{-1}$ with the mean value at 49.6 $mgkg^{-1}$ and STD at 24.63. Total Pb content was low (< 35 $mgkg^{-1}$) in all the collected samples from Dhuroma, Khulays and Al-Kharj while few samples from Al-Hassa, Harrat Al-Madenah and Haiel have relatively high total Pb > 100 $mgkg^{-1}$. Samples (Nos 43 and 44) have very high total Pb content. The high content in sample No.43 could be due to Pb pollution caused by the heavy traffic on Kharj-Riyadh high way where the sample was taken. Total Zn content was low (< 100 $mgkg^{-1}$) in most of the collected samples and show high (about 300 mgkg-1) to very high (> 400 $mgkg^{-1}$) contents in the samples collected from Al-Hassa, Harrat Al-Madenah and Haiel.

Available Nutrient Status: Data in Table 2 indicated the ranges, means and standard deviation values of some nutrient status of the collected samples. It indicated that available P range from 0.01-21.4 $mgkg^{-1}$ with the mean value at 3.11 $mgkg^{-1}$ and STD at 3.15 $mgkg^{-1}$. Most of the studied sediments have low contents and few samples have high to very high contents of available P. Available Fe show very high values in most of the studied samples particularly in Al-Rawdat, Harrat Al-Madinah and Khulays samples. It ranges from 0.70-280.0 $mgkg^{-1}$ with the mean value at 25.6 $mgkg^{-1}$ which considered very high for Fe level (Sultanpour,). High available Fe could be expected in the sediments formed from igneous rocks rich in Fe–silicates particularly those formed in Jeddah and Khulays areas. Weathering processes for ferro-magnesium minerals under the exciting and pre-exciting climatic conditions were responsible for the formation of Fe-rich clay deposits and the accessory minerals mainly iron oxides. Weathering products and other Fe-bearing minerals are considered the main sources for available Fe and other micronutrients in the sediments as well as for the retention of nutrient cations in readily available form. Zn levels ranges from 0.25-35.80 $mgkg^{-1}$ with the mean value at 3.56 $mgkg^{-1}$. High available Zn was recorded in sediment samples collected from many locations at Al-Kharj, Al-Harrat, Sudair, Al-Rawdat and Al-Hassa. A very high content of available Mn was also recorded in Al-Summan sample (No.44), Al-Rawdate (No.34), Hail (No.40) and Harrat Al-Madinah samples. Available Mn ranges from 0.14 to 53.8 $mgkg^{-1}$ and the mean was 6.01 which considered also very high according to Soultanpour,). It seems from these data that most of the collected sediment samples contain relatively high contents of the available micronutrients Fe, Mn and Zn. Such high levels of micronutrients in many of the studied samples will improve the content of these nutrients when applied to micronutrient deficient sandy soils.

Mineralogical characteristics: Free Fe and Mn oxides were determined in selected sediment samples (Nos1-36). Free Fe oxides data ranges from 2.13-61.62 g kg^{-1} with the mean of 24.09 g kg^{-1}. Drhuma and Khulays samples high the highest contents while Al-Hassa and some samples from Jeddah area have relatively low amounts. On the other hand free Mn oxides show relatively low quantities ranges from 0.008-3.59 g kg^{-1} with quite similar trend except that high quantities were observed in Khulays and Jeddah areas which could reflect the mineralogical composition of the dominant igneous and metamorphic rocks from which these deposits was formed.

Clay fraction separated from selected sediment samples was characterized using selective chemical techniques for amorphous Si & Al and free Fe & Mn determination. Surface area and CEC was also measured in selected samples and presented in Table 3. Data indicated that CEC values were quite high particularly in most of the high clay samples. It ranges from 32.05 – 93.8 cmole/kg. Data also indicated that most of the studied clays have high surface area it ranges from 66.3-371.4 m2/gm which is very high and reflect the high reactivity of the clay fraction in relation to water retention and ion exchange if it was added to low surface area's sandy soil. The highest values were found in the clay fraction separated from Dhruma samples (Nos 7 and 8) while the lowest was found in clay fraction of Harrat (No.42). Data of amorphous Si and Al in the clay fraction are quite variable between the locations. It appears that most of Dhruma clays contain very relatively high Al_{am} than Si_{am} compared with clays from other regions.

Semi-quantitative mineralogical composition of clay fraction separated from sediment samples were calculated from the obtained X-ray diffractograms of the studied sediments and figured out in (Table 4). Clay fraction was dominated by smectite or kaolinite and or palygorskite minerals. Sediment samples from Dhruma and Al-Kharj are dominated by either smectite or kaolinite with no palygorskite exists except few samples. It was noticed that most of the obtained variation was related to the location in the mining area from which the sample was taken. For example at Dhruma site one sample was dominated by smectite (sample No.5 collected from the grayish layer in the mining area) while the other samples in the site were dominated by kaolinite (Nos 3 and 4 in the same mining site). Data also indicated the dominance of smectit clays in most of the collected samples from Khulays and Jeddah area (i.e. samples No. 19, 22, 23, 27). Samples No 35 and 36 were dominated mainly by smectite clays followed by illite and vermiculte. Clay fraction separated from Harrat Al-Madinah was dominated by smectite followed by kaolinite and chlorite while Sudir and Al-Hassa clays were dominated by palygorskite followed by smectite and interstratified minerals. The dominance of smectite type clays in the sediment samples is considered a positive indication for increasing water holding capacity of sediment as well as increasing nutrient retention against leaching and losses in sandy soils.

Smectite minerals have relatively high CEC, high specific surface area and other desired characteristics for water retention and water conservation in irrigated sandy soils.

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Table 1: location, sample description and some characteristics of thecollected sediment samples.

No.	Location	Color, dry	EC, dS/m	B,ppm	$CaCO_3$, %	Clay, %	Description
1	Marrat Road	2.5YR5/4	10.7	1.31	3.0	78	Thick, friable, flocculated clay
2	Marrat Road	7.5YR6/4	7.15	2.59	3.0	60	Thick uncompacted layer
3	Marrat Road	7.5YR5/4	10.26	7.57	3.0	74	Thick layer, compacted
4	Marrat Road	7.5YR5/4	25.1	4.67	22.0	48	Noncompacted clayey layer
5	Marrat Road	10YR7/2	6.2	0.76	4.0	84	Olive layer between the red layers
6	Marrat Road	7.5YR6/4	7.13	0.93	3.0	84	Fine clay, grind
7	Marrat Road	7.5YR6/4	8.47	0.93	3.0	48	Layer of thick mud clay
8	Al-Kharj	2.5Y7/4	47.6	6.87	3.0	68	Mottled mud clayey layers
9	Al-Kharj	10YR7/4	28.2	2.85	3.0	66	Blocky, compacted clay layer
10	Al-Kharj	5YR7/4	8.83	1.02	5.0	66	Colored friable clayey layer
11	Al-Kharj	5YR7/3	11.28	1.46	1.0	60	Clayey, friable layer
12	Al-Kharj	5YR5/6	7.0	2.55	2.0	56	Granulated, compacted layer
13	Al-Kharj	2.5Y7/8	21.0	11.79	10.0	44	Mud stones with cemented
14	Al-Kharj	10YR7/6	10.62	11.4	42.0	36	Clay layer, friable, not compacted
15	Al-Kharj	10YR7/6	12.52	11.4	35.0	48	Clay layers, thin gypsum layers
16	Al-Kharj	10YR6/3	34.0	11.79	4.0	48	Thick clayey layers, compacted
17	Al-Kharj	2.5Y7/8	15.3	10.45	39.0	48	Layers, compacted clays, friable

Table 1. continued

No.	Location	Color, dry	EC, dS/m	B,ppm	$CaCO_3$, %	Clay, %	Description
18	Al-Kharj	10YR7/2	15.3	3.79	4.0	20	Compacted, disconnected clay
19	Jeddah	10YR8/1	22.8	5.59	16.0	32	Cemented, disconnected friable
20	Jeddah	5YR5/4	22.9	3.44	1.0	48	Thick sticky clayey layer
21	Jeddah	2.5YR4/6	38.9	4.29	7.0	84	Very thick sticky clayey layer
22	Jeddah	5YR7/3	6.47	3.13	4.0	28	Layers of compacted white clay
23	Khulays	2.5YR5/6	19.4	6.62	13.0	44	Thick compacted red clays
24	Khulays	10YR5/8	7.6	5.25	5.0	52	Thin layer, gully erosion
25	Khulays	5Y8/2	22.7	5.96	3.0	56	Clods of mud, friable, fine
26	Khulays	5Y8/2	21.0	7.28	14.0	24	Clods of mud, friable, fine
27	Khulays	5YR5/6	22.0	4.92	3.0	60	Clayey clods, red, compacted
28	Khulays	2.5Y7/8	52.2	6.87	3.0	28	Clayey clods, red, compacted
29	Khulays	10YR8/1	31.0	3.59	3.0	60	Clayey clods, compacted , mottled
30	Khulays	2.5Y7/2	40.8	5.18	5.0	60	Clayey clods, red, compacted
31	Khulays	5Y7/3	12.38	3.74	5.0	68	Fine clods in cracks
32	Khulays	5YR4/6	5.48	1.56	5.0	32	Very fine clayey clods, sticky
33	Khulays	5YR5/4	12.06	1.05	3.0	48	Very fine clayey clods, v. sticky
34	Rawdat	10YR7/3	3.35	0.74	42.0	59	Cracked flat surface, sticky clay
35	Al-Hassa	5Y7/2	12.09	3.31	3.0	96	Compacted clayey thick layers
36	Al-Hassa	5Y7/2	6.44	1.31	5.0	96	Compacted v. sticky clayey layers
37	Al-Hassa	5Y7/2	13.5	3.01	2.0	86	Compacted sticky clayey layers

Table 1. continued

No.	Location	Color, dry	EC, dS/m	B,ppm	$CaCO_3$, %	Clay, %	Description
38	Al-Hassa	5Y7/2	47.0	2.02	19.0	51	Compacted clayey thick layers
39	Al-Hassa	5Y 8/2	22.5	2.08	28.0	27	Compacted clayey thick layers
40	Hail, Hilali	10YR7/4	19.0	-	10.4	65	Fraible thick clayey layers
41	Harrat, 1	10YR7/4	2.35	-	9.3	61	Thick clayey layers, very sticky
42	Harrat 2	2.5Y6/2	1.9	-	4.9	18	Thick clayey layers, very sticky
43	R-Kharj	2.5Y 7/6	19.5	-	29.6	57	Thick clayey layers, very sticky
44	Al-Summan	10YR 7/3	0.66	-	34.4	81	Cracked flat surface, sticky clay
45	Al-Hassa	10YR 8/2	35.0	-	56.0	20	Compacted, clayey layers
46	Al-Hassa	10YR 8/2	19.5	-	52.9	46	Compacted, friable clay
47	Sudir	2.5Y 7/6	27.0	-	21.1	53	Compacted, mottled, sticky clay

Table (2): Means, maximum, minimum and standard deviation (STD) values of sediment characteristics for all the collected sediments.

Characteristic	**Mean**	**Minimum**	**Maximum**	**STD**
Moisture characteristics (30 sample)				
Saturation %	80.77	29.0	184	36.54
Field Capacity %	58.6	14.0	140	27.55
Welting point%	25.67	6.0	64	13.87
Available water %	32.93	8.0	77	158.1
Some physical and chemical characteristics (47 sample)				
Clay %	54.8	18.0	96.0	20.01
Silt %	20.6	2.00	56.0	12.04
$CaCO_3$ %	12.7	1.00	56.0	14.82
ECe dS m^{-1}		0.66	52.2	
CEC Cmole kg^{-1}	31.7	8.39	77.2	18.44
Total elemental and heavy metal contents (47 sample)				
Fe_2O_3 (g kg^{-1})	57.8	6.20	132.5	29.6
K_2O (g kg^{-1})	4.72	0.10	23.2	4.98
P_2O_5 (g kg^{-1})	2.12	0.01	16.9	2.67
Cd (mg kg^{-1})	2.54	1.50	5.53	1.06
Pb (mg kg^{-1})	47.04	14.0	455.0	71.74
Ni (mg kg^{-1})	49.56	2.3	130.0	24.63
Co (mg kg^{-1})	17.62	2.0	36.0	10.13
Zn (mg kg^{-1})	155.3	11.0	1421.0	272.0
Mn (mg kg^{-1})	393.3	14.0	3859.0	659.6
Available nutrient levels (47 sample)				
P_2O_5 (mg kg^{-1})	3.11	0.01	21.4	3.15
Zn (mg kg^{-1})	3.56	0.25	35.8	6.06
Mn (mg kg^{-1})	6.01	0.14	53.8	10.69
Fe (mg kg^{-1})	25.6	0.70	280.0	45.7

Table 3: Amorphous Si and Al, Free Fe and Mn oxides, surface area and cation exchange capacity (CEC) of clays separated from sediment samples.

No.	CEC Cmole kg-1	Surface Area m2 gm-1	Alam	Siam	Fed	Mnd ppm
			g/kg			
3	34.75	-	0.73	1.18	7.90	24.0
4	52.72	-	2.15	1.49	19.30	58.6
7	73.91	318.9	2.82	0.83	15.52	60.8
8	93.80	371.4	3.96	1.01	11.07	39.1
9	34.38	150.0	0.08	0.86	3.68	16.7
10	78.24	-	2.84	0.87	24.99	155.8
12	44.03	-	0.45	0.76	1.19	5.66
13	71.28	327.9	1.32	1.12	5.62	24.2
14	84.06	-	4.06	1.53	8.54	21.0
16	78.73	-	1.75	1.72	16.24	87.5
17	48.89	240.3	0.45	1.51	14.88	47.1
18	88.98	-	0.27	0.85	4.37	376.2
19	62.33	252.1	0.42	2.13	11.11	987.2
20	33.48	95.4	0.47	1.04	9.47	42.8
21	39.25	149.3	0.68	0.61	29.21	73.6
24	61.95	-	0.31	0.42	13.55	335.7
25	80.2	341.1	0.24	0.96	7.57	41.4
26	80.89	-	0.34	1.41	3.38	14.0
27	56.04	128.4	0.98	1.34	25.99	131.4
28	-	273.8	-	-	-	-
29	55.55	201.2	0.30	1.75	1.15	5.85
30	74.76	206.3	0.34	0.96	5.92	47.2
31	76.43	190.8	0.26	0.95	4.77	4.8
32	54.38	-	0.38	0.64	18.82	151.3
33	65.43	-	0.73	1.00	20.14	187.1
34	45.58	149.9	1.00	2.88	9.61	164.8
35	56.87	224.8	-	-	-	-
36	61.65	254.4	-	-	-	-
37	-	110.4	-	-	-	-
38	32.05	207.5	-	-	-	-
39	-	118.7	-	-	-	-
40	46.68	198.2	-	-	-	-
41	56.54	149.6	0.80	1.92	9.71	156.64
42	-	66.3	-	-	-	-
43	-	109.1	-	-	-	-
44	46.85	288.5	0.53	1.41	10.17	67.59

Al_{am}: amorphous alumina, Si_{am} amorphous silica, Fe_d free Fe oxides, Mn_d Free Mn oxides.

Table 4: Semi quantitative analysis of X-ray diffractograms obtained for clay fraction separated from sediment samples.

No.	Smectite	Kaolinit	Palygorskite	Interstratified	illite	quartz	Others
3	++	++++	-	++	+	+	-
4	++	++++	-	+	+	+	-
5	++++	+	-	+	+	+	-
6	++++	++	+	-	+	+	-
8	+++	+++	-	+	+	+	-
10	++++	+++	-	+	+	+	Fl. +
15	+++	++++	-	-	+	+	-
17	+++	+	+	+	-	+	-
19	+++	+	+	-	+	++	Cal.+
21	+++	++++	-	-	+	+	-
22	++++	+	-	-	+	+	Fl+
23	++++	++	+	-	+	-	Fl+
27	++++	+++	-	+	+	+	Cal+
34	+	++++	+	+	+	+	Vr+
35	++++	+	+	-	+	+	Vr+
36	++++	+	+	-	++	+	Vr. T
37	++	+	++	T	+	++	Vr.T
38	++	+	++	++	+	T	Vr.+
40	+	+	T	+++	+	+	Vr.+
41	+++	++	T	-	+	+	Ch++
42	+++	++	T	-	+	+	Ch+
43	++	+++	-	-	+	-	Vr+
44	+	+++	++	-	-	T	Ch.+
45	++	T	+++	++	-	-	Vr+
46	++	T	++++	++	+	+	Vr+
47	++	-	++++	++	-	+	Vr+

++++ Dominant, +++ High, ++ medium, + low, T. traces, Fd. Feldspar, Vr. Vermiculite, Ch. Chlorite, Cal. Calcite.

خواص رواسب الطين الطبيعية بالمملكة العربية السعودية ودورها في ترشيد المياه في الترب الرملية المروية

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الملخص تتحكم معادن الطين في التربة في حفظ الرطوبة وحركة الماء في تـرب المناطق الجافة المروية. أوضحت دراسات عديدة أن إضافة معادن الطين ذات الجودة العالية وبتركيزات منخفضة إلي الترب الرملية الصحراوية قد أدت إلي تحسين كبير في كفاءة استخدام المياه وترشيدها. يهدف البحث إلي التعرف علي أماكن وجود رواسب الطين الطبيعية في بعض المناطق بالمملكة العربية السعودية وتحديد أهم خواصها الفيزيائية والكيميائية والمعدنية ذات العلاقة بتحسين خواص الترب الصحراوية الرملية وترشيد مياه الري بها. ولقد تم جمع عينة من مواقع مختلفة من مناطق المملكة وإعدادها للتحليلات المعملية المختلفة. أوضحت الدراسة أن معظم المواقع المختارة بها كميات كبيرة من رواسب الطين الطبقية والتي تتكشف في المنحدرات الجبلية. أوضحت النتائج وجود اختلافات كبيرة في خواص هذه الرواسب من المناطق المختلفة خاصة في نسبة ونوع الطين، تركيز الأملاح الذائبة، القلوية، ونسبة الجير ومحتواها من العناصر الغذائية الميسرة. تسود معادن السمكتيت مكون الطين في رواسب المنطقة الغربية (خليص، جدة) ورواسب بعض المناطق الأخري (القطيف والخرج) بجانب معادن أخري أهمها الكاؤلينيت في الأولي والأتابولجيت في الثانية بينما تسود معادن الكاؤلينيت يليها الاليت والسمكتيت في رواسب ضرما وروضات المنطقة الوسطي. وجد أن الرواسب تتفاوت في محتواها من أكاسيد الحديد والمنجنيز الحرة وكذلك المواد غير المتبلورة للسيليكا والألومينا. تراوحت عينات الرواسب في خواصها المختلفة حيث تراوح محتوي الطين (بين – %)، درجة التشبع بالماء (بين – %)، السعة الحقلية (بين – %)، نقطة الزبول (بين – %)، الماء الميسر (بين – %)، تلركيز الأملاح (بين –)، (بين –)، (بين – %)، السعة التبادلية الكاتيونية (بين –). توضح النتائج أن العينات المرتفعة في محتواها من الطين تمتلك قيم عالية لكل من الماء الميسر والسعة الحقلية. كان مستوي الحديد الميسر مرتفعا جدا في كل العينات بينما كان مستوي عناصر مرتفع الي متوسط في معظم العينات. أوضحت نتائج التحليل الكلي أن مستوي عناصر

كان منخفضا الي متوسطا عدا بعض عينات رواسب الروضات التي كان بها تركيز مرتفـــع مـــن وبصفة عامة كانت رواسب المنطقة الغربية أعلي في محتواها من العناصر الثقيلة.

يستنتج من هذه الدراسة أن رواسب الطين الطبيعية الغنية بمعادن السمكتيت والمرتفعة في محتوى مـــن الطـــين والسعة التبادلية الكاتيونية ومستوى العناصر الغذائية الميسرة والماء الميسر تكون ذات قدرة عاليـــة في تحـــسين خواص الترب الرملية وترشيد المياه بها.