Effect of Soil Gypsum Content on the Physical Properties of Soil

Abstract

The behavior of gypsum soil varies depending on its gypsum content. Low gypsum content have a positive effect on improving soil properties, if the soil has a high gypsum content it will lead to a deterioration in the physical, chemical and fertility properties. Gypsum affects physical soil properties , water movement and water functions because it is semi-soluble and thus affects plant growth and productivity.

Gypsum soils are generally of a fine texture, and there is a clear transfer of clay from the surface layers to the subsurface layers. For this reason the texture of the surface layer is often loam , while the subsurface layer has a clay loam texture. Most gypsum soils are poorly structure in their surface horizons, while the sub surface horizons are structure less , cohesive or in the form of individual grains.

Gypsum soils have a low ability to retain moisture at high pressures and high temperature conditions.An increase in the soil gypsum is accompanied by a decrease in the organic matter and clay percentage followed by a decrease in the percentage of available water. As the percentage of gypsum in the soil increases, the bulk density values increase up to 30% gypsum,as well as the value of the liquid , plasticity limits, and plasticity index value decrease .The values of saturated hydraulic conductivity depends on the nature of the gypsum crystals and their percentage in the soil. The rate of water column rise in an inverse relationship with the gypsum percentage.

Keywords:

Gypsum soil , Physical properties , moisture retention , Gypsum crystals

INTRODUSION

Gypsum Soil

are one of the natural soils that form large areas of the world and are exit in arid and semi-arid areas with low rainfall rates, as the amount of rainfall is not sufficient to dissolvthe gypsum ($CaSO_4.2H_2O$) from the soil.Gypsum soils in Iraq constitute a large area, approximately a quarter total area, and part of it is agriculturally exploited. It arearound in the edge of the Tigris and Euphrates rivers of Iraq , the alluvial plain, and the upper parts of the AL-Jazira, with its northern and southern parts represented by Sinjar, southeastern Tal Afar, and Qayyarah, as well as the lower AL-Jazira region and the western and southern desert regions.

It can be said that the presence of gypsum in quantities less than 14% in the soil positively affects the aggregate stability , and that increasing the percentage of gypsum above 25% negatively affects the suitability of agricultural soils.

The presence and spread of Gypsum Soil in Iraq, which are usually characterized by their low agricultural production, requires further research, study and investigation of all the physical properties and water functions of these soils for the purpose of improving their agricultural production and providing food for the growing population, as well as knowing the negative impact of gypsum and finding appropriate solutions for the purpose of improving The physical properties and hydrological functions of these soils.

Gypsum

is a soluble salt of hydrated calcium sulphate ($CaSO_4.2H_2O$). Its solubility is about (2.6 gm L^{-1}) of pure water at a temperature of 25 °C and under one atmosphere of pressure [1]. Its fine grains are white, sometimes gray or brown [2], and sometimes red, green, or colorless [3] .

[4] classified gypsum in Iraq into primary gypsum , It is represented by gypsum rocks that formed during geological times. Secondary gypsum is found in the soil and is formed from several sources, including the dissolution and deposition of gypsum rocks, the deposition of salts from agricultural irrigation water, or the evaporation of surface water containing gypsum.

The cralcium sulfate exists in one of the following forms:

 Hydrous calcium sulphate (gypsum) ($CaSO_4.2H_2O$).

 Hemihydrate ($CaSO_4$. $0.5H_2O$).

 Anhydrous calcium sulphate (anhydrite) ($CaSO_4$)

Definition of Gypsum soil

Gypsum soils are soils that contain more than (2%) gypsum, either in the form of gypsum or anhydrite in the surface horizon, and more than (14%) gypsum in the subsurface horizon [1] . According to the [5] gypsum soils were considered a separate family, as their gypsum content constitutes more than 35% of the total carbonate and gypsum, and this total increases40% of the weight of the soil. The percentage of 14% gypsum was considered a dividing line in the classification and could be used to differentiate between the gypsum and non-gypsum layers. This classification is no longer important for the depth, presence or thickness of the gypsum layer. According to the American classification [6] , gypsum soils are soils that contain a gypsum horizon or a gypsum rock horizon, the upper limit of which is located within the first meter of the soil surface. The gypsum horizon is a horizon that is not hardened or has weak hardness and is 15 cm thick or more, and contains at least 5% gypsum in excess of the content of the horizon or layers that follow it, and the product of thickness (cm) multiplied by the gypsum percentage is equal to or more than 150.

[7] indicated, the term “Gypseous” is more appropriate to describe soils in which the gypsum content is more than (50%), and the term “Gypsiferous” is used for soils with a content of less than (50%). [8] Gypsum soils contain a gypsum horizon whose thickness is more than (15) cm and whose depth is less than (1) m if the gypsum content is more than (25%) or when the product of the percentage of gypsum multiplied by the thickness of the horizon equals (150) cm or more.

[9] divided gypsum soils into three groups:

1. Soil with a content of less than (10%) gypsum, which is suitable for all crops.

2. Soil with a gypsum content between (10-50%) and is suitable for a specific number of crops.

3. Soils with a soil content higher than (50%) are not suitable for irrigated agriculture.

Distributions of Gypsum soil in the World

Gypsum soils are widespread in arid and semi-arid regions of the world when the source material is rocks or gypsum deposits and the small amount of rainfall is insufficient to wash and dissolve the gypsum from the soil bed [10]. Despite the difficulty of determining the lands affected by gypsum, available reports and studies indicate that the area of gypsum lands in the world is approximately 85 million hectares [1] , most of which are located in southwestern Siberia, northern and central Iraq, southeastern Somalia, eastern Spain, and Algeria. In southern and central Australia, Iran, Georgia and the Caucasus region.

Distribution of Gypsum soils in Iraq

In Iraq, the area of gypsum soil is approximately (12.5) million hectares, representing (28.6%) of the total soil area of Iraq [11] . [12] indicated the presence of large areas of gypsum land in northern and central Iraq, where it is found Gypsum at a depth of (15-30) cm.

[13]explained that the shallow soil formed on a gypsum layer forms large areas of dry plains in northern Iraq, and includes agricultural areas and areas of agricultural projects in Al-Jazira, Al-Hawija, Al-Tharthar, and Kirkuk. It was also found that the soils of the northern plains in Iraq contain more than 25% gypsum is not a good media for plant growth.

Calcium carbonate and its relationship to the gypsum content of the soil

[14] The content of calcium carbonate decreases with increasing gypsum content in the soil, as it ranged between 143 and 256 gm kg^{-1} within gypsum content between 540 and 59 gm kg^{-1}, respectively. The X-ray results also confirm that the calcite decreases with increasing gypsum content, and this may be due towhat [15] mentioned, the occurrence of the gypsification process during the soil formation processes led to an increase in the percentage of gypsum in the gypsum horizons at the expense of other soil components such as calcium carbonate and clay, as the gypsum dissolved in the upper horizons due to rain water or irrigation water and its washing. down ;It leads to a concentration of the amount of calcium carbonate in the washed horizons over the time . [16] also stated that the presence of gypsum reduce the solubility of lime through the common ion effect, but the presence of lime also reduces the solubility of gypsum for the same reason.[17] found that the use of electron microprobe techniques revealed that lime can be deposited on gypsum surfaces, forming a layer covering it. This process may occur under certain field conditions, such as the slow washing process, which leads to the dissolution of gypsum in small quantities. Also, not all of the gypsum in the soil is ready for dissolution.

Gypsum soil texture

There was a clear increase in the percentage of both clay and silt in the subsurface layer compared to their percentage in the surface layer at the Tal Afar and Qayyarah locations, while similar percentages appeared for both clay and silt in the surface and subsurface layers at the Sinjar location [18] , this was indicated by [13] , who explained that the gypsum soils in northern Iraq are generally of a fine texture, and that there is a clear transfer of clay from the surface layers to the subsurface layers. For this reason, the texture of the surface layer is often loam

, while the texture of the subsurface layer is clay loam .

Structure ofGypsum Soils

The structure of the soil expresses the arrangement and organization of its particles in the form of aggregates and with the help of various binding agents. This organization determines the geometric properties of the interstitial pores through which both soil air and water are transported and held [19]. [20]referred the difficulty in identifying the structure of these soils, which are often platy , massive, or prismaticand indicated that most gypsum soils are weak in their ability to aggregate, due to the weak cohesive forces between their particles and the lack of exchange capacity for positive ions. [21] mentioned that gypsum soil are poorly structure in their surface horizons, while the non-surface horizons are structure less , cohesion or in the form of individual grains. In general, gypsum horizons are cohesion when dry and brittle when wet. While [22] stated that the presence of gypsum in quantities less than 14% in the soil positively affects the stability of the aggregates, and that increasing the percentage of gypsum above 25% negatively affects the suitability of agricultural soils.

Estimating the Moisture Content of Gypsum Soil

Drying gypsum soil at a temperature higher than 70 °C leads to high estimates of the moisture content of the soil compared to its actual moisture content. The sudden change in moisture loss is due to the loss of crystalline water in the gypsum. Therefore, estimating the moisture content of gypsum soil is based on drying the soil was kept at a temperature 65°C for 48 hours instead of 105°C to avoid the interference of crystalline water in calculating the moisture content of the soil [23] .

Soil Moisture Description Curves

[18] the moisture content values for all soil samples from which the gypsum was removed are higher than the moisture content values for the soil samples without the gypsum removed at different moisture retention ,the reason for this may be due to the decrease in the soil's ability to retain moisture with the increase in the gypsum content of the soil when moisture tensions increase . The high percentage of clay content of the soil led to an increase in the moisture content at different moisture retention , especially after removing the gypsum from it, as the positive effect of fine particles (clay and silt) appeared.The results also showed that the moisture content (θv) at saturation with gypsum soil at the Sinjar location is higher than the moisture content values from the gypsum-free soil samples at the Tal Afar and Qayyarah location for the same two layers. The reason for this may be due to the soil samples at the Sinjar location containing a high percentage of gypsum, as it reached (452.1 and 430.7) $g\ kg^{-1}$ for the surface and subsurface layers respectively compared to the

another samples, the shape and size of the gypsum particles change from crystalline to powder form, which increases the surface area and thus increases the total porosity, as the diameters of the pores are smaller and therefore their number is larger, which led to an increase in the soil's ability to retain moisture upon saturation, and this was indicated [24] .

The relationship between the gypsum content of the soil and the available water for the plant (the difference in volumetric moisture between 33 and 1500 kPa) is significantly inverse (R^2 = -0.824, where the highest and lowest values of available water reached 0.154 and 0.122 $cm^{-3}.cm^{-3}$ in the soil with gypsum content of 115 and 508 $g.kg^{-1}$, respectively,this attributed to the decrease in clay content and organic matter due to the increase in the percentage of gypsum in the soil [18] .

Particle density

The results showed a clear increase in the particle density values in the surface and subsurface layers of the Sinjar soil from which the gypsum was removed compared to the soil samples from which the gypsum was not removed. The reason for this may be due to dissolving the gypsum from the soil, which leads to keeping a number of clay minerals with a high particle density in their value.[18] . In the Al-Dour area [15] found that the particle density value of the non-gypsum surface horizons from the soil sample ranged between 2.64 -2.95 Mgm m^{-3}, while the value decreased to 2.39 - 2.5 Mgm m^{-3} in the gypsum horizons, and he suggested a negative correlation. Significantly r = -0.93 between the gypsum content and the particle density of the study soil. This relationship is represented by the linear equation

$$Y = 2.61 - 0.003X$$

Y particle density Mgm m^{-3}

X soil gypsum content gm kg^{-1}

The Effect of Gypsum on Bulk density

A study by [25] on soil samples with different gypsum percentages (including natural and prepared samples (6, 13.76 , 27.52 , 34.4 , 48.16 , 68.8 and 86)%gypsum , to know the effect of the gypsum percentage on the bulk density values, as the average bulk density values increased (significantly at a probability level of 0.05)with the increase in thegypsum percentage in the 1,2,3,4 samples , as the bulk density values reached 1.42, 1.46, 1.49, and 1.51 $Mgmm^{-3}$ respectively, Then the bulk density decreased with an increase in the gypsum percentage for the rest of the samples , which gave the lowest bulk density value of 1.38, 1.41, and 1.37 Mg m^{-3}, respectively, and the decrease was significant at the 0.05 probability level. The reason for the increase in the bulk density values at gypsum levels 1, 2, 3, 4 is perhaps due to the presence of fine gypsum crystals that take up space in the pores, which increases the bulk density values. As for the decrease in the bulk density values with the increase in the percentage of gypsum in the soil samples 5, 6, 7 to a decrease in the percentage of clay, and he explained that this inflection point for the bulk density is about 300 gm kg^{-1} gypsum.

This was reinforced by the results of [18] in his study of gypsum soil location in Nineveh Governorate, where he showed that the soil of the Sinjar location for the surface and subsurface layers, where the percentage of gypsum reached (452.1 - 430.7) gm kg^{-1}, with bulk density values of (1.33 - 1.31) M g m^{-3}, respectively, is low compared to the soil of the Qayyarah location for the surface and subsurface layers, with a gypsum percentage of (140-106) gm kg^{-1}, with a bulk density of (1.42-1.56) Mg m^{-3}.

Main Weight Diameter:

[18] In his study of three gypsum location in Nineveh Governorate, it was found that the average M.W.D of soil samples for both the surface and subsurface layers at the Sinjar location and in the soil sample for the subsurface layer at the Qayyarah location amounted to (0.64, 0.48, and0.52) mm, respectively . The increase in the values of the M.W.D may be due to the increase in the percentage of gypsum, that reached (452.1, 430.7, and 126) gm kg^{-1} respectively, which led to an increase in gypsum crystals that are the size of medium and fine sand particles .

Undissolved gypsum crystals within the stable soil aggregates led to an increase in the values of stability standards, then increase in the stability of the soil aggregates. The lowest value of the M.W.D appeared in the surface soil sample at the Tal Afar location , reaching (0.21) mm. The reason for this may be due to the low percentage of clay and gypsum (140 and 139.3) gm kg^{-1} respectively.

The Liquid , plastic limits and plasticity Index

[25] The clay content in the studied soil samples has a clear effect on both the liquid and plastic limits and plasticity Index , then the evidence of plasticity due to the small size of its particles and the high surface area. It has colloidal properties that make it highly capable of retaining moisture and holding water, and because of the low percentage of clay in the soil samples with different gypsum percentage (including natural ones and others prepared from gypsum) (6 - 13.76 - 27.52 - 34.4 - 48.16 - 68.8 and 86)%. The plasticity index decreased within increased in gypsum percentage (11.45, 11.19, 11.06 , 10.71 , 10.00 , 8.31, and 5.41) % respectively.

[18] explained that the lowest values for both the liquid and plastic limits and the plasticity index for soil samples at the Sinjar location were (25.11 - 18.08 - 7.03)% for the surface layer and (23.65 - 17.15 - 6.5)% for the subsurface layer, respectively, compared to the other values,for the Tal Afar and Qayyarah location, the reason for this may be due

to the high percentage of gypsum in this location , which reached (452.1 and 430.7) gm kg^{-1} for the surface and subsurface layers. The results also showed high values of the liquid , plastic limits and plasticity index for the soil samples of the subsurface layer of the Qayyarah location (32.06 , 24.6 and 7.46)%, especially when the gypsum was removed in the laboratory, as the values reached (35.11 - 28.21 and 6.9)% respectively. The reason for this may be due to the clay content of this layer was high reaching (372.6) gm kg^{-1}.

Saturated Hydraulic Conductivity of soil

The linear relationship between the flux and the hydraulic gradient of the soil represents the saturated hydraulic

conductivity coefficient . The value of the hydraulic conductivity of the Sinjar location was 0.2 - 0.25 cm hr^{-1}, compared to the location of Al-Dur and Al-Shirqat (2.5 and 8.28) cm hr^{-1} respectively , The reason for this due to the role of small crystals of gypsum, which it led to smaller soil pores, which was reflected in the values of hydraulic conductivity .while the medium and large gypsum crystals of the Al-Dur and Al-Shirqat location, respectively, led to a clear increase in the values of hydraulic

conductivity. Increase the gypsum percentage in the second depth than the first depth, led to an increase of up to two times the hydraulic conductivity, while the increase in the percentage of clay and silt at the first depth has a role in reducing the hydraulic conductivity values [23] .

[26] chose a location in the College of Agriculture, Tikrit University, with a depth of one meter, where it is clear that the value of saturated hydraulic conductivity increases with the increase in the percentage of gypsum in the depths of the soil.

Depth / cm	Gypsum gm Kg^{-1}	Saturated hydraulic conductivity cm hr^{-1}
0 – 30	65	1.5
30 - 60	130	3.13
60 – 90	240	3.13

This was parallel to the results of [18] and he attributed the reason to the arrangement in the gypsum crystals, thus increasing the size of the pores and the cross-sectional area that conducts water.

Rise of the Capillary water

In an experiment Samir [14] measure the capillary rise of water in glass columns with a diameter of 1.2 cm and a length of 70 cm within a water tension of 1 cm, the capillary rise through two stages, the first increases approximately with the increase of the gypsum content up to the time period between 20-30 hours, (for example) a time of one hour, the capillary water rise reached 9.5 cm at a gypsum level of 59 gm kg^{-1} and 14.6 cm at a gypsum content of 540 g kg^{-1}. The reason for this may be due to the affinity of gypsum to water and its increased ability to wet [27] . The second begins after this period, where the rate of water rise begins to decrease as the gypsum content increases, and continues to decrease with time until the final time of 200 hours is reached. At the final time of 200 hours, the highest capillary water rise in the experiment was for the soil sample with a gypsum content of 59 gm kg^{-1}, reached 62 cm, and at a gypsum content of 540 gm kg^{-1}, the capillary water rise reached 49.3 cm used the river water treatment .

Pore Radius

found that the decrease of the effective pore radius, accompanies greater capillary rise, as the correlation coefficient between them (calculated from Eq.)

$$h = \frac{2\gamma \cos(\sigma)}{\rho g r}$$

with highly negative significant (- 0.99) for treating river water. The increase in gypsum content is accompanied by a decrease in the average effective pore radius until the gypsum content reaches 300 gm kg^{-1}, which is the critical point. Then the average effective pore radius increases, which could be the reason for the variation the properties studied at this point: The highest value for the radius reached 1360 microns for a gypsum content of 59 gm kg^{-1}, and the lowest value was 846 microns for a gypsum content of 508 gm kg^{-1} [14] .

Soil Shrinkage values

In a study conducted by [25] on soil samples with different gypsum contents (6, 13.76, 27.52, 34.4, 48.16, 68.8 and 86)%, where the increase in gypsum was accompanied by a significant decrease in soil shrinkage values (4.4 , 3.13 , 2.6 , 2.26 , 2.06 , 2.6 , 1.6)% . The low values of the shrinkage limit in the soil samples are due to the dominant mineral in the gypsum soils, palygoriskite which has no ability to expand and swelling . As well as its weak ability to hold water, as confirmed by [28] . In addition, the increase in the gypsum content is accompanied by a decrease in the clay percentage that has cohesion and adhesion property.

Sorptivity Rate:

While increasing the gypsum content did not lead to a clear effect on the sorptivity rate values. There was a fluctuation in the sorptivity rate with increasing gypsum content. As the correlation coefficient between them was

0.32, the value of sorptivity for water was between 0.241 and 0.313 cm $min^{1/2}$, at a gypsum content of (186 - 300) gm kg^{-1} respectively [14] .

Conclusion:

Gypsum soils constitute a large area of Iraq, approximately a quarter total area , which requires attention to these soils and the expansion of studying their properties, including physical properties, and orientation towards managing and improving those properties, such as increasing the ability of these soils to retain moisture, water conductivity, water capillary rise, and sorptivity rate, in addition to reducing the negative impact of high values of bulk density and surface soil hardness, then improves plant growth and increases its productivity.

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