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The Sodium Role on Soil Penetration, Its Impact in North Kabul, Afghanistan

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Abstract: ***The permeability is a very important phenomenon, for the slow penetration in soil trend to decrease of amount of water debt at water wells and other underground sources such as Karezes. Besides, it goes to large scale of groundwater table drow down, and consequently might be full destruction of Underground water sources. The Hypothesis of this research paper is – the assessment of Negative effect of Sodium (Na) at permeability process, for soil sodality which characterized as (SAR)tend to coagulation of soil's particles, and as result the soil permeability is decreased. The main goal of this paper is recognizing the mechanism of Ions function during water movement through soil purses and also combating with it impact on different aspect of social economical lives and soil contamination. As result of investigation founded that usage of gypsum ($CaCO_3$ $2H_2O$) among other conditioners most useful, harmless and also economic for solving above mentioned problem.***

Keywords: Permeability, Sodium Adsorption Ratio, Sodium Exchange Percent, Soil Conditioners, Soil Contamination

1. Introduction

The soil permeability is one of the most useful and important Hydraulics parameter which has direct effect on water intake and also movement in ground, because atmospheric precipitations couldn't go down .i.e. without any penetration run-off on earth surface. Therefore not only the underground water resources and general water balance tend toward Drought ,but it speeding up another harmful impact as called "Soil erosion and its outcome will be arise a lot of Environmental problems for society! Concerning to past study relating to topic some research paper had been written by different authors in abroad countries, such as Australian scholar (Mc Intyer, 1982), (Kazman, 1982) and others, but in my country Afghanistan especially in North depression of Kabul No body researched about,

In the beginning of water interring into soil the penetration speed very high, but by passing time the penetration speed gradually slowing down and finally reduced to a constant rate.

At start time velocity/speed –**z** will be calculated by Kostyakov Formula, 1932:

$$Z = Kt.\alpha \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

Where is, **K** and **α** - is the experiment parameters, it different for different soils.

One of defect of this formula is that, with long penetration duration time the penetration speed go toward Zero! Which in action not true. For this reason Kostiakove by improving formula suggest below formula:

$$I = dz\frac{dz}{dt} = \alpha.\ Kt\ \alpha^{-1} \qquad \ldots\ldots\ldots (2)$$

Where is, Z- flocculation penetration (m^3/cm), **t**−penetration opportunity **(**min**)**

K and **α** - is the experiment parameters, I – Ultimate penetration speed ($m^{3/}$m/min). As soil at the end penetration time shows stable rate, thus this formula more suitable for soil condition for irrigation purposes [SzabloocsI. 2016].

There is many methods for determination of soil penetration speed, such as "Blocked Furrows" "inflow- out flow "Bolderio, Nestrove methods and etc.

The high Sodium content in water or soil naturally tends to destruction of soil structure and its also caused soil vacuum and reduce the air and water amount into soil. The other most important parameter affecting soil penetration rate is (SAR)- Sodium Adsorption Ratio which calculated by formula (3):

$$\mathbf{SAR} = \frac{\mathbf{Na}}{\frac{\sqrt{Ca + Mg}}{2}} \qquad \ldots\ldots\ldots(3)$$

The concentration of Na^+, Ca^{++} & Mg^{++} ions - as **mg-eq**. The schematically illustration of Sodium Adsorption Ratio (SAR) shows in (fig 1):

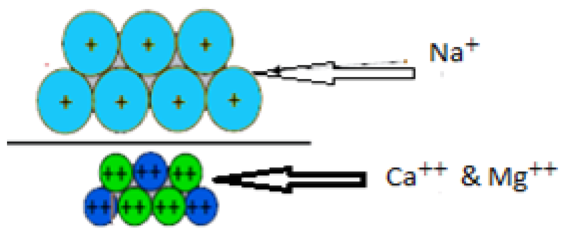

Figure 1: The schematically illustration of Sodium Adsorption Ratio (SAR).
[Plau Z, 1988].

The (SAR) amount directly controlled the soil salinity, Sodacity and many properties of soil as well as Penetration rate. By increasing Sodium amount in soil the soil particles spreading/scattering and the small porousness closed. This event of gathering and scathing soil particles could be easily understood from illustrations as follows (Fig 2. Fig 3):

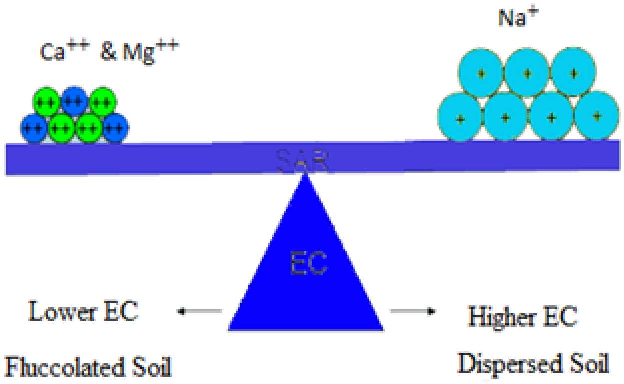

Figure 2: Illustration shows equilibrium between **Na**$^{+}$ *and (*$\mathbf{Ca^{++}}$**&** $\mathbf{Mg^{++}}$*) ions.*
[Plau. Z, 1988]

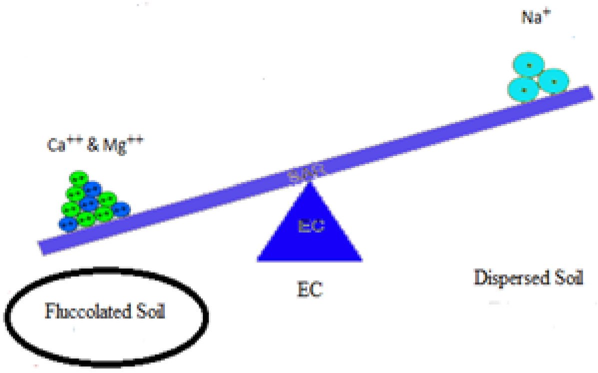

Figure 3: Soil particles will flocculated in case of Ca and Mg Ions amount are Increased relative to the concentration of Na^{+} ions, thus (SAR) is decreased

By increasing of Sodium ions the soil particle scattering and as result the (SAR) value is increased which come to reducing of soil penetration out (fig 4).

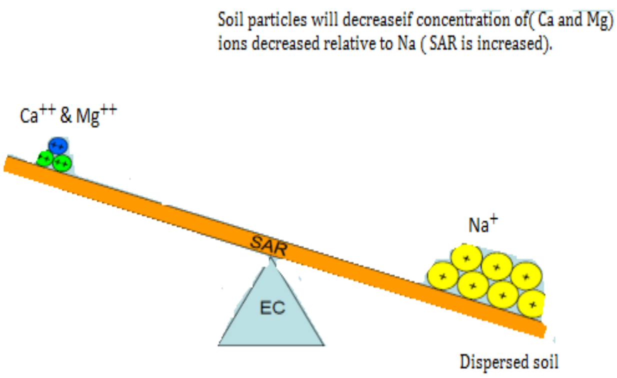

Figure 4: Relation between increasing Na ions with (SAR)
[Plau . Z, 1988]

2. The Study Area

Afghanistan is a mountainous and dry region located in the arid sub-tropics in south-Asia. It has an arid and semi-arid continental climate with cold winters and hot summers. The study area Coordinate: (34^{o}, 30' N – 34^{o}, 40' N and 69^{o}, 10'E- 69^{o}, 20'E) and located in northern Kabul, Afghanistan. The elevation of region varies between 1800 to 1950 m. The climate is hot at summer and cold during winter. The mean annual temperature of about 22^{0} C and mean precipitation of about 400mm/year.

Figure 5 (a): A look from study area in North Kabul Depression
[Photo: Author- 2020]

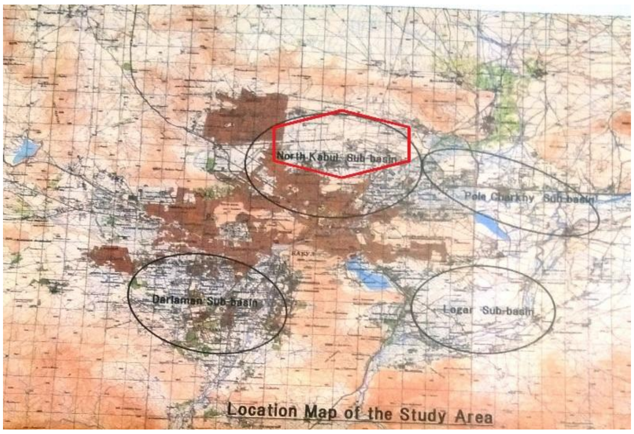

Figure 5 (b): Location Map of the study area
[JICA, 2009]

Geology of Region

The study area located in North Kabul depression historically belongs to Lacustrine Quaternary modern deposition .i.e. long before at tertiary period it was a lake ,then as result of Endogenic and geotectonic process and also climatic change, water body evaporated and gradually the old lake filled with mentioned above depositions. From Lithological view the area composed of Loam, fine sand, clay and sandy-clay with different thickness layers. The whole region occupied about 35 km, but myself due to limited possibility and lack of laboratory equipment for necessary analyzing only studied a small region about 18 km^{2}. The Lacustrine deposition located directly over the alluvial sediment with a medium thickness about 25m. The ground water depth different from (30 to 60m).The water debt also changed from (0.4 to 3)lit/sec. The hardness of water well from (0.8 up to13, 8) mg-eq. The recharge of water-bearing horizon obtained from atmospherics precipitations and also from lower lacustrine layers deposition. Due to arid climate and Drought in region, most of water body because of Capillarity phenomenon evaporated and the salt which bringing from depths as a result of evaporation process remained on surface which made the soil salty. The Schematic look admin.map, Electro conductivity (EC) value and Soil Horizons' of study area shows in (Fig 6 and 7).

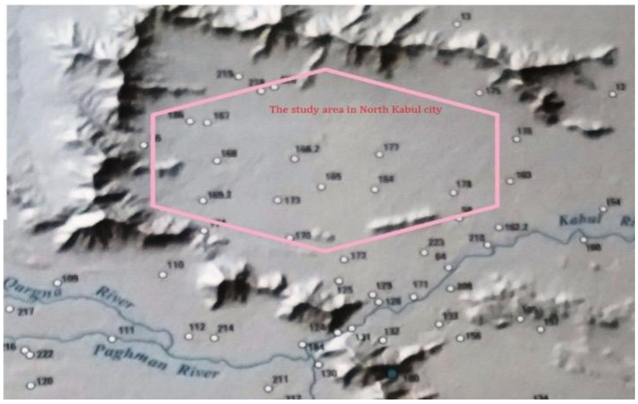

Figure 6 (a): The study area geographical Satellite map [USGS, 2011]

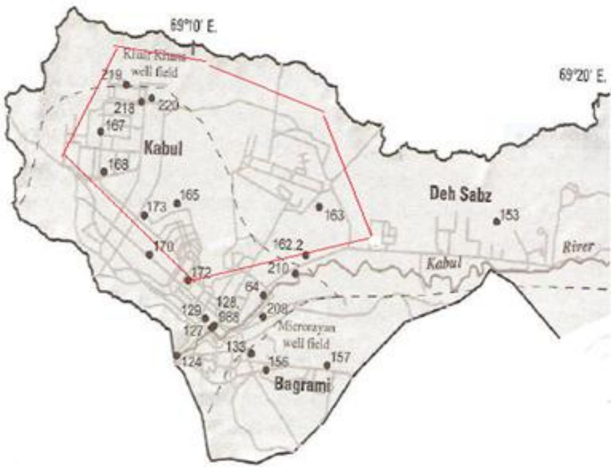

Figure 6 (b): The administrative location of study area [USGS, Kabul office, 1984]

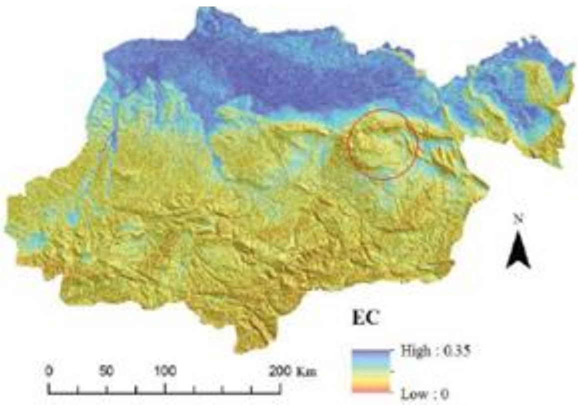

Figure 7: The electrical conductivity (EC) predicted map for the study area
[Foa, 2014]

3. Methodology

For assessment of role of Sodium on reduction of Soil permeability in the study area, used basically two methods:

1) Library methods: reading and studying pervious research papers of different Authors relating to topic about 20 books, articles, national and international journals and cases study. such as (KarimH. 2012), (Satar J, 2011), (Ward D, 1996), (Barzergar A,1999) etc.
2) Site investigation by Author: which include taking soil samples for Sieve analysis of soil about 20 samples. Applying site experiments by using Bolderyio and Nestrov methods for determination of soil penetration in 10 points. Due to Author economic limitation and also lack of modern laboratory equipment's in our university had satisfied to carrying mentioned limit experiments.

How measured soil penetration by Bolderio Method: In this method used 2 water numerical cylinder, a ruller, stop watch (timer), glasses tube as shown in fig 8.

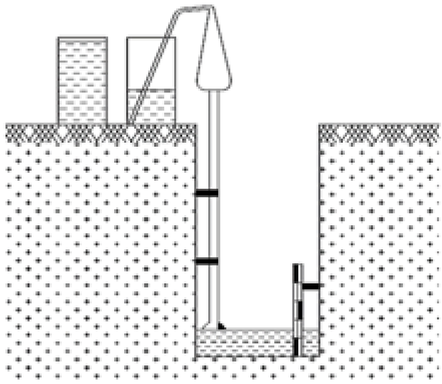

Figure 8: Bolderio schematic equipment for soil Penetration rate
[drawing: by Author, 2020]

$$k = \frac{Q}{F*J} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where is, **K**- filtration index, **Q**- consuming Water amount (lit/sec), **F**- surface square (cm^2). **J**- pressure gradient

Nestrove Method: According to this method2 steel ring with 50cm outer diameter and 25cm interior diameter put in the bottom of pit(Radios=100cm),then from2 numeric cylinder running water to pit. During penetration the table depth must be kept about 10cm up from bottom of pit. The filtration process continued until stabilization of water table at pit. By measuring consuming water from cylinder byNestrove Formula easily can calculated the Filtration index(**K**).

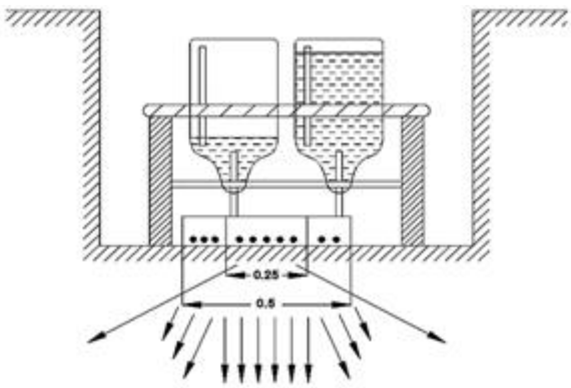

Figure 9: Nestrove schematic illustration for penetration soil rate.
[Drawing: by Author, 2020]

According to this method, uses 2 Numerical Water cylinder with 2 steel rings for limiting penetration through bottom pit to subsoil horizons, by consumption of water could calculate the rate of penetration by Bandiman Formula:

$$k = \frac{Q*Z}{F(Hk+h+z)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

J- pressure gradient. By applying Bandiman Formula for better result we shall have: Where is, Hk- Capillary pressure, h- soil layer thickness (cm), Z- water adsorption depth from bottom of pit(cm).

Table 1: Relation between Capillary pressure and earth materials

Rock Nomenclature	HK, m
Heavy sandy clay	1
Light sandy clay	0.80
Sand with less clay (heavy)	0.60
Sand with less clay (light)	0.40
Fine sand	0.30
Fine sand(pyre)	0.20
Sand (medium)	0.10
Coarse Sand	0.05

Table 2: The Moisture relation with soil's depth

Samples No	Samples depth , m	Water Content %	
		Natural	After experiment
1	0.05	0.19	0.28
2	0.5	0.20	0.24
3	1.0	0.21	0.23
4	1.5	0.21	0.23
5	2.0	0.20	0.22
6	2.5	0.20	0.21
7	3.0	0.19	0.20
8	3.5	0.19	0.19
9	4.0	0.18	0.18

To finding the mechanism of acting Sodium Na ions on soil penetration phenomenon was taking samples from study area about 20 samples due to limitation of Lab. equipment and expensive cost of chemical analysis. Where, counted mg-eq. and %-eq. of Na, Ca and Mg ions amounts, in order to calculate the Sodium Adsorption Ratio (SAR) and also Exchangeable Sodium Percent (ESP). Afterward, the result was compared with Data which found by different researcher relating to similar case studies and then made conclusion and particularly recommendation for mitigation its hazard on soil contamination at region.

Figure 10: Author sampling in study area
[Photo: Jamshid, Author's son, 2018]

The result of chemical analysis for determination of Exchangeable Sodium percent (ESP) shows in Tab 3a.

Table 3 (a): Relation between **ESP** and Soil Permeability at wells in study area

Samples No well	EC (micro-mohas/cm)	Ca (mg/lit)	Na (mg/lit)	Ca/Na ESP,%	Remarks
1	1503	336	80	4.2	middle
2	1486	48	96	0.5	low
3	1044	98	250	0.3	low
4	1725	126	370	0.07	Soil permeability too low
5	1314	116	150	0.8	low
6	-	324	492	0.65	low
7	-	90.3	112	0.8	low
8	-	327	336	1.18	middle
9	-	24	79	0.3	low
10	-	360	667	0.5	low

As digits at tab 3 shows sample N0 4 (ChamanBabrak in Center of depression)as salt soil has too much low ESP value about (0.07) and therefore too low soil permeability.

4. Result and Discussion

Actually the soil particles at soil surfaces than underlyer surface soil particles much sensitive concerning to effect of water quality and exchangeable Sodium Ion (Esp),because soil surface particles under pressure/force of rain strike lose it connection structures and displaced, and the permeability speed increased by duration time. That is mean, how much the (ESP) ration is higher the ultimate soil penetration is directly decreased. Adding Gypsum help the reducing the (ESP) and as result the penetration velocity is increased. Generally, assumed that the effect of **Ca**$^{++}$and **Mg**$^{++}$ Ions are the equal on permeability process and also water movement in soil, but due to penetration phenomenon it might be different!? The assessment shows that the effect of **Mg**$^{++}$ Higher than **Ca**$^{++}$ at soil stability and rain control speed. Moreover, the difference between Calcium and Magnesium effects on soil penetration speed higher than permeability in soil interior structure and layers Finally, at the end of this research come out, that: The higher value reduction of soil penetration occurred, while the amount of Exchangeable sodium portion (ESP) tend to Zero(0) and the also the Electric Conductivity (Ecw< 0.5 ds/m)!As result of study founded:

- The water penetration problems soil goes to reducing water well debt and also the catastrophic draw downing water Table, which finally caused destruction of Underground Water-Table resources.
- The water slow penetration into soil, caused salinity.
- The penetration speed is a function of time, i.e. by passing time the penetration speed is slowing down.
- The penetration speed is different from one point to another! Max. in Wazir-abad about 40cm/day ,while it reduce to 15cm/day in ChamanBabrak region.
- The "penetration speed time" not constant .i.e. it changed from start point in ditch toward the ditch end.

Recommendation for avoiding soil penetration reduction problems:

- Containing the usage of Agriculture chemical fertilizers in soil,

- Persuading Farmers to use "Animal fertilizer" instead of chemical fertilizers.
- Avoiding and also containing of heavy traffic on soil surface.
- Owing (up and down) soil layer and applying under layer breakage Machine.
- Usage of "Soil Conditioners" specially the "Gypsum".

Relative permeability index

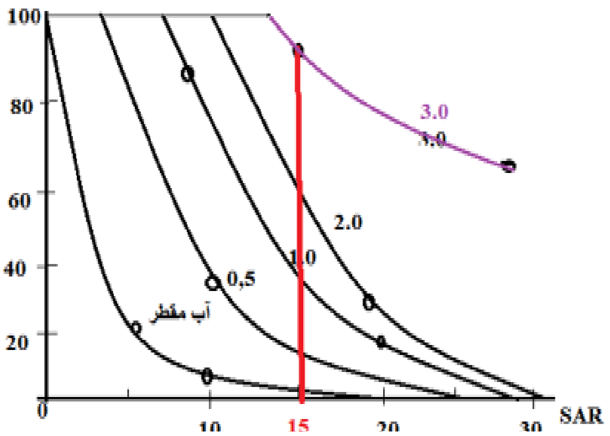

Figure 12: Relation between (SAR) and soil Permeability for different salt concentration.
[Sheinberg et.al, 1982]

As clearly could see at diagram with increasing (SAR) to 15 the permeability Index equal 40%, and for further increasing SAR, the Permeability index decreases. Another important parameter which effected on soil permeability is called Exchangeable Sodium proportional (ESP) or Ca/ Na ions ratio. By increasing (ESP) percent(%), the soil permeability decreased ,because the clay particle largely swelled (closes the porous between). when the ESP close to (15-20)% ,as many experiments shows the Soil permeability rate rapidly reduced(Referred to (Tab 3.) In this research work by comparing and analyzing chemical data from different point in study area found, that the permeability from 26.7 in Char-Qala(dist#4) decreased to (0.2 %) in ChamanBabrak (dist#11) (Refer to Tab 3b).

Table 3 (b): Relation between reducing permeability and (ESP) at Pits

$\frac{Ca}{Na}$ (**ESP) %** Exchangeable Sodium percent	$\frac{85.2}{14.72}$ Pet 1	$\frac{324}{492}$ Pet 2	$\frac{1120}{1854}$ Pet 3	$\frac{55.2}{292}$ Pet 4
Relative Permeability%	26.7	12.5	11.5	**0,2**

Moreover, as the research by different people at world wide range shows, there is a close relation between Soil salinity, Alkalinity, and (SAR) existed. In other words the Sodium adsorption ratio and Alkalinity could be effected each other, and may be written by formula as follow:

$$SAR=\frac{ESP}{100-ESP} \quad \ldots\ldots\ldots\ldots\ldots (6)$$

Besides, the ration between SoilElectro conductivity and (SAR) also has its effect on soil permeability which shows in below diagram (fig. 13):

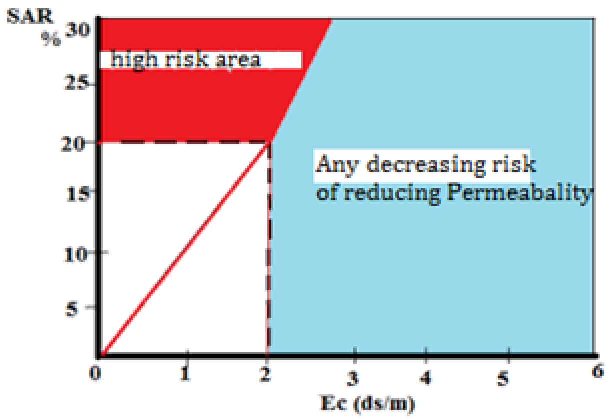

Figure 13: Relation between EC and SAR.
[Schwab G, 1996]

As clear could see from above diagram, in area with higher value of Electro conductivity **EC**>2 ds/m (deci –mohas) there is any risk of permeability problem (blue color area), but in area where the EC< 2 ds/mohas and in case of (SAR)>20% -the risk of soil reduction permeability is very High!(Red color area). The other important factor ,which control the soil permeability rate is Time, it mean that at the beginning of entering of water in to soil (Initial rate) , the penetration speed very high, but by passing time it the end(Basic rate) slowing down even close to Zero[Schwab G,1996]. (fig 14).

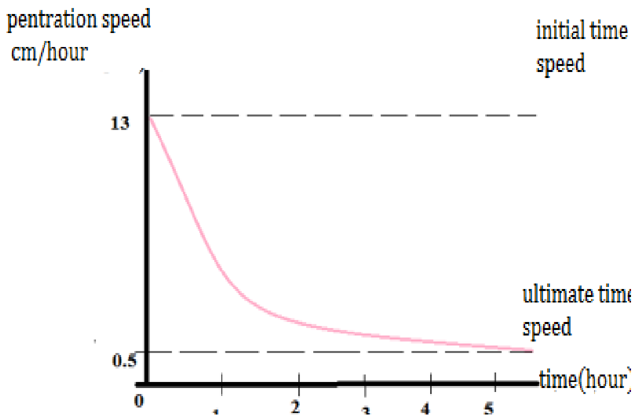

Figure 14: The diagram shows permeability change due to time (t)
[Oster M, Singer J, 1996]

5. Conclusion

Generally, Water concluding Calcium and Magnesium Ions increases soil penetration process. While existing of Sodium and Potassium Ions usually causes gathering (sticking) soil's particle.

Moreover, many chemical components such as Bicarbonate (HCO_3) and Carbonates (CO_3**)** also bring changes to water Quality. Due to arid climate and Drought in region, most of water body because of Capillarity phenomenon evaporated and the salt which bringing from depths as a result of evaporation process remained on surface which made the soil salty. Therefore, the amount of salt has the maximum value which caused the reducing of soil penetration and also permeability. Finally, it goes to soil pollution which arrows many social economically problems not only for habitats.

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