UNIVERSITEIT GENT

Faculty of Agriculture and Applied Biological Sciences

Soil Pollution and Soil Protection Project

(Physical Aspects)

By

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Introduction

The soil can be roughly defined as the top layer of the earth's crust. Soil is not a simple system. It is very complex and variable system with various kinds of components and various chemical, physical and biological processes take place in it.
Soil is considered as a slowly renewable resource. It takes several hundred years to develop one inch of soil from bed rock. Soil is important for most of agricultural works such as crop production and can be used to produce construction materials and to explore some minerals. Due to human activities and unexpected accidents most of soils in the world have been polluted.
For sustainable development, soil has to be managed in a sustainable manner. To manage the soil in proper manner, i.e. to eliminate polluted chemicals from soil, it is necessary to understand the chemical, physical and biological processes taking place in the soil under different situations. This will help policy makers to develop a good management plan for sustainable development and they can apply mitigation methods for already polluted soil.

1. Determination of Soil Moisture content

Soil moisture content can be determined in the field or in the laboratory.

Gravimetric / Thermo gravimetric method

Principle

It is based on the difference of wet weight and dry weight of soil. This method takes 24 hours to determine. The moisture content can be expressed in wet weight basis or in dry weight basis.

Procedure

An air dried soil sample was weighed and put in a moisture box and put in an oven for 24 hours at 105 0C. After the box was allowed to cool in a desiccator and mass of the dry soil was measured.

Readings and calculations

BOX NUMBER	43
Mass of Box	23.7g
Mass of box + wet soil	29.7g
Mass of box + dry soil	28.75g
Mass of Dry soil	5.65g
Mass of wet soil	6.0g
Mass of water	0.35g
Soil Moisture content (Dry weight basis)	6.93% w/w
Soil Moisture content (Wet weight basis)	5.83% w/w

Conclusion and discussion

The soil has a moisture content of 6.93%w/w in dry weight basis. This method takes long time to determine the water content in a soil and it is not suitable as the field method. Normally water content is expressed as a depth of water in soil science, but here it can be calculated as the volume of soil was not given.

Calcium Carbide method

Principle

CaC_2 reacts with water and produce acetylene gas. The volume of acetylene produced is proportional to the amount of water. If this reaction is carried out in a close container, the pressure developed due to the gas production is also proportional to the amount of water. So that moisture content can be expressed as a function of manometer pressure.

Procedure

5g of wet soil was put in to a steel pressure bottle together with two steel pieces and CaC_2 capsule. Then the bottle was closed to make it air tight. Then the bottle was shaken well till the CaC_2 capsule is broken. After the pressure of manometer become stable, the pressure was recorded. Then the moisture content responsible for this pressure was taken from the given table.

Readings and Calculation

Amount of soil used	5.0g
Read out pressure	0.5kPa
Soil moisture content on wet mass basis	9.8% (from the table 1.1)
Mass of water	0.49g
Soil moisture content on dry mass basis	10.865% w/w

Conclusion and discussion

The moisture content of this particular soil was 10.865% (w/w) on dry weight basis. This method is suitable for determination of soil moisture under field condition and it is quick method. But here, the total amount of water may not react with CaC_2, if the soil is very compacted and / or heavy.

2 Determination of Bulk density, Particle Density and total Pore Volume:

The bulk density is defined as the mass of dry soil (dried at 105 ^{0}C) per unit volume of soil in a natural and undisturbed condition.
The particle density is the ratio of total mass of solid particles to their volume.
The determination of bulk density, particle density and total pore volume is important in assessing its fertility, its vulnerability to different pollutants and in construction works.
They give information on the degree of compaction, infiltration capacity, and soil water holding capacity and some other important parameters in soil science. The normal particle density of Quarts is considered as 2.65g/cm^3. But the particle density of soil can be varying due to the basic minerals present in soil.

Determination of bulk density and total pore volume of an undisturbed soil sample

Procedure 01 (Bulk density)

An undisturbed soil sample (in a ring) was taken and wet weight of it was measured. Then a sub sample was taken to determine the soil moisture content and it was put in a moisture box and put in an oven at 105 ^{0}C until constant weight is reached. The inner diameter and the height of the ring also were measured.

Procedure 02 (Bulk density)

An undisturbed soil core was taken and the mass of it was measured. After that it was put in an oven at 105C for 24 hr period. After the achieving of constant weight, the weight of the ring with soil was taken and the inner diameter and height of the ring was measured.

Procedure 03 (Particle density)

A clean and closed pycnometer (with the stopper) was taken and the weight was measured by using an analytical balance. Then about 2 gram of soil was put in to it and the weight was measured again. Then 2/3 of the pycnometer was filled with distilled deionized water and it was put in a vacuum dedicator for 20 minutes in order to remove all the air entrapped within soil particles. After that it was completely filled with deionized distilled water and the weight of was measured by using an analytical balance. The temperature of water was also measured. Finally all the content in pycnometer was removed completely and it was filled with deionized distilled water and weight was measured using an analytical balance.

Readings and Calculations for sub sampling method

Box number	42
Mass of Box	23.72g
Mass of box + wet soil	37.92g
Mass of box + dry soil	36.84g
Mass of Dry soil	13.12g
Mass of wet soil	14.2g
Mass of water	1.08g
Soil Moisture content (Dry weight basis)	8.18% w/w
Soil Moisture content (Wet weight basis)	

Ring number	203
Mass ring + wet soil	240.73g
Mass ring	94.01g
Mass wet soil	146.72g
Soil moisture content %w/w (wet mass basis)	12.96%
Mass water Mw	16.83g
Mass dry soil	129.89g
Inner diameter of ring	4.99cm
Height of ring	5.10cm
Volume of ring	$96.89cm^3$
Bulk density	$1.34g/cm^3$
Volumetric moisture content	17.37%
Particle density (standard value)	2.65
Total Pore Volume (TPV) %	49%

Readings and Calculations for second method

Ring number	285
Mass ring + wet soil	234.89g
Mass ring + dry soil	216.08g
Mass ring	93.79g
Mass dry soil	122.29g
Mass water	18.81g
Soil moisture content	15.38%
Inner diameter of ring	4.95cm
Height of ring	5.02cm
Volume of ring	$96.61cm^3$
Bulk density	$1.27g/cm^3$
Volumetric moisture content	19.53%
Particle density (from experiment)	2.57
Total Pore Volume (TPV) %	51.0%

Readings and Calculations for Particle density

Pycnometer number	17
Mass of Pycnometer Ma	49.6941g
Mass of Pycnometer + soil Ms	52.0502g
Mass of Pycnometer + soil + water Msw	150.7826g
Mass of Pycnometer water Mw	149.3406g
Temperature of water	20^0C
Density of water at 20 0C	0.99823g/cm^3
Particle density = $\rho w.Ms - Ma/(Ms - Ma) - (Msw - mw)$	2.58g/cm^3

Conclusion and discussion

The bulk density of the soil sample measured by sub sample method was 1.27g/cm^3 and total pore space at that bulk density was 51.0%. This soil has good pore space and it is suitable for crop cultivation. On the other hand, this high pore space will support to store a large amount of pollutants in the soil.

The bulk density of the soil where undisturbed soil core sample method was used was 1.27g/cm^3. This soil is fairly bulky and is not compacted as the previous soil. The soil sample might be come a recently ploughed agricultural field or from undisturbed forest soil. It has more than 50% of total pore space and this condition is very good for agricultural purposes. But it can create some leaching problems also.

The particle density of the used soil was 2.57g/cm^3. The value of particle density is lower than that of quarts. This is because the soil is made up of minerals which have different particle densities. The organic material in the soil is also causes low particle density.

3. Determination of Saturated Hydraulic Conductivity Ks on Undisturbed Samples

Introduction

The hydraulic conductivity of a soil is inversely proportional to the resistance the fluid experiences when traveling through a porous medium. It is a function of the pore size and soil matrix. This property is important for irrigation and drainage, design of channels, landfills, contaminant transport to name a few in understanding the movement of water in saturated soil.

There are several methods to calculate Ks. Among them, Mariotte-bottle Permeameter method and volumetric – flask method is commonly used. In this practical exercise, volumetric – flask method was used.

The flow of water through a porous medium (hydraulic conductivity) Ks can be described by *Darcy's law* as follows.

$$Ks = (V/A*t) \times l/\Delta H$$

V = volume of water passing soil in time t (m^3)
A = cross sectional area of the soil sample (m^2)
Δ H = hydraulic head difference (m)
Ks = Hydraulic conductivity of the soil (ms^{-1})
L = length of the soil sample (m)
t = time (s)

Ks at 20 C are the standard permeability and is given by:

$$Ks\ (20C) = Ks \times (\eta t/\eta 20C)$$

η = dynamic viscosity of water ($kg/m/s^2$)
t = temperature

Procedure

A soil core sample was taken and wrapped in a nylon cloth at its bottom. A filter paper was placed on top of the soil sample and an empty ring was fixed on top of the ring with soil, by using an insulating tape in order to seal the two cores. A 1 liter flask was filled with water and the tubing closed with a rubber stopper. Tubing was inserted for the flow of water. The flask assembly is clamped on the holder in an inverted position so that the tubing is just above the surface of soil.

The clamp was opened and water was allowed to flow in to the core slowly. At the break through point, where the water starts to percolate out through the soil into a burette, the volume of water flow per unit time was measured. This was done till the constant volume per unit time was achieved.

Results and calculations

Internal diameter of the soil core	4.95 cm
Height of the soil column	5.08 cm
Height of the water	3.64 cm
Temperature of water	19 ^{0}C
Viscosity 19^{0}C	0.0010050 Pa.s
Viscosity 20^{0}C	0.0010299 Pa.s

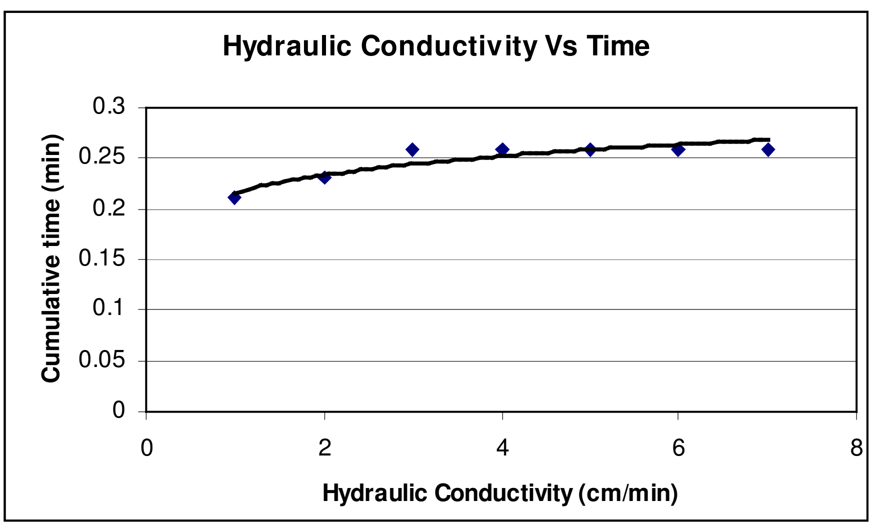
Constant Head Permeability Measurements.

Measurement	**Volumetric flask**	
1	cm^3 water	
	Time in min	3
	cm^3 /min	15
2	cm^3 water	
	Time in min	21.15
	cm^3 /min	18
3	cm^3 water	
	Time in min	1
	cm^3 /min	13
4	cm^3 water	
	Time in min	1
	cm^3 /min	13
5	cm^3 water	
	Time in min	1
	cm^3 /min	13
6	cm^3 water	
	Time in min	1
	cm^3 /min	13
7	cm^3 water	
	Time in min	1
	cm^3 /min	13

	Volumetric Flask	
V	**6×10^{-6} (m^3)**	13 cm^3
Time t	**60s**	1 min
l	**5.08×10^{-2} m**	5.12cm
Δ H	**8.72×10^{-2} m**	0.1009m
A	**1.924×10^{-3} m**	19.24 cm^2
Ks(19 ^{0}C)	**4.283×10^{-5} m/s**	0.0036 cm/min
Ks(20^{0}C)	**4.383×10^{-5} m/s**	0.0037 cm/min

Hydraulic Conductivity Vs Time

Cumulative time (min)	Hydraulic Conductivity (cm/min)
1	0.211
2	0.230
3	0.259
4	0.259
5	0.259
6	0.259
7	0.259



4. Vertical Infiltration: Infiltration Rate and Cumulative Infiltration

Introduction

The infiltration rate of a soil is important for plants, irrigation, surface run off and soil erosion. This is very important to know the movement of pollutants in the soil and hence it is important to determine the potential of ground water contamination in a polluted area. There are 2 main important parameters in infiltration process as the infiltration rate (I) and cumulative infiltration (i). The rate of infiltration is determined by several factors. These include porosity, soil texture, and soil structure and depend on the soil biological factors.

There are several methods to estimate soil infiltration rate. Among them the most common methods used are the single Ring infiltrometer, Double Ring infiltrometer and The Mariotte Siphons. In this experiment the double ring infiltrometer was used.

Cumulative infiltration can be represented by *Kostiakovs* equation as follows:

$$i = a.\ t^{b}$$

t	=	infiltration time (s)
a, b	=	empirical constants which are function of soil characteristics

Infiltration rate is given by:

$$I = di/dt = a.\ b\ .\ t^{\,b-1}$$

Parameters a and b can be solved by transferring the *Kostiakov* equation into a linear equation of form y = A + Bx and performing linear regression.

Procedure

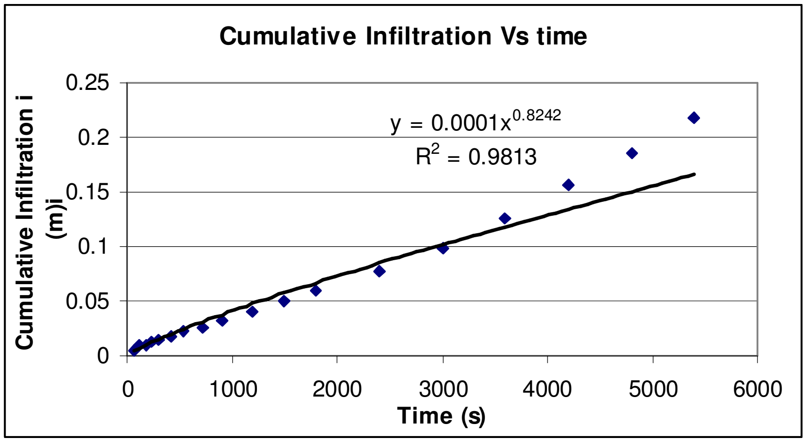
A large (Diameter of 45 – 50 cm) and a small (Diameter of 20cm) steel cylinders were hammered concentrically in to the soil up to the depth of about 15cm and leveled. The each ring was filled with water to equal height of about 15 to 20 cm above the ground level. Measuring gauge (Ruler) was installed in it for the measurements of water depth. The falling depth of water in the inner cylinder was measured at particular time intervals. During the process the same height of water was maintained in both rings. The data were recorded in a data sheet. This procedure was followed till the constant flow rate was reached.

Results and Calculations

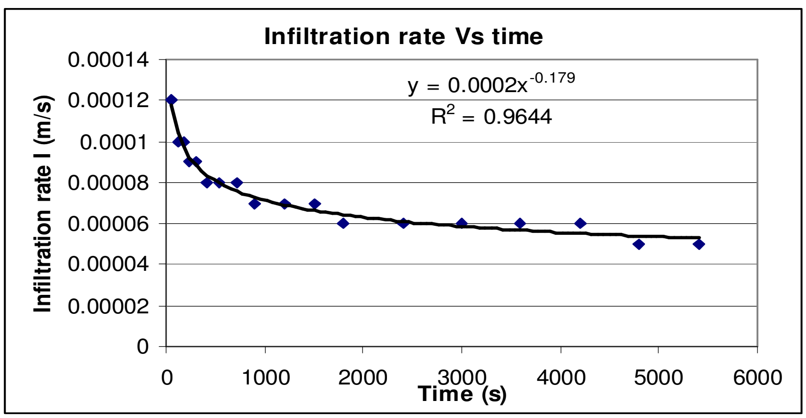
The results are presented as follows:

Time (t)		**Depth water level (cm)**			**Cumulative intake (i)**		**Infiltration rate (I)**
min	sec	End (Δt)	Beginning (Δt)	Head decline	cm	m	m/s
			3	0.5			
1	60	3.5	3.5	0.4	0.5	0.005	0.00012
2	120	3.9	3.9	0.1	0.9	0.009	0.0001
3	180	4	4	0.3	1	0.01	0.0001
4	240	4.3	4.3	0.2	1.3	0.013	0.00009
5	300	4.5	4.5	0.3	1.5	0.015	0.00009
7	420	4.8	4.8	0.4	1.8	0.018	0.00008
9	540	5.2	5.2	0.4	2.2	0.022	0.00008
12	720	5.6	5.6	0.6	2.6	0.026	0.00008
15	900	6.2	6.2	0.8	3.2	0.032	0.00007
20	1200	7	7	1	4	0.04	0.00007
25	1500	8	8	1	5	0.05	0.00007
30	1800	9	0.2	1.8	6	0.06	0.00006
40	2400	2	2	2	7.8	0.078	0.00006
50	3000	4	5	2.8	9.8	0.098	0.00006
60	3600	7.8	1	3	12.6	0.126	0.00006
70	4200	4	4	3	15.6	0.156	0.00006
80	4800	7	0.5	3.2	18.6	0.186	0.00005
90	5400	3.7	3.4	3.4	21.8	0.218	0.00005
Cumulative infiltration i (m) at t=4hrs							
	i=at^b				a	0.0001	
	y = 0.0003t^0.8211				b	0.8242	
Infiltration rate I (m/s) at t=4hrs							
	I=abt^(b-1)				ab	0.0002	
	y = 0.0002t^-0.179				b-1	-0.179	

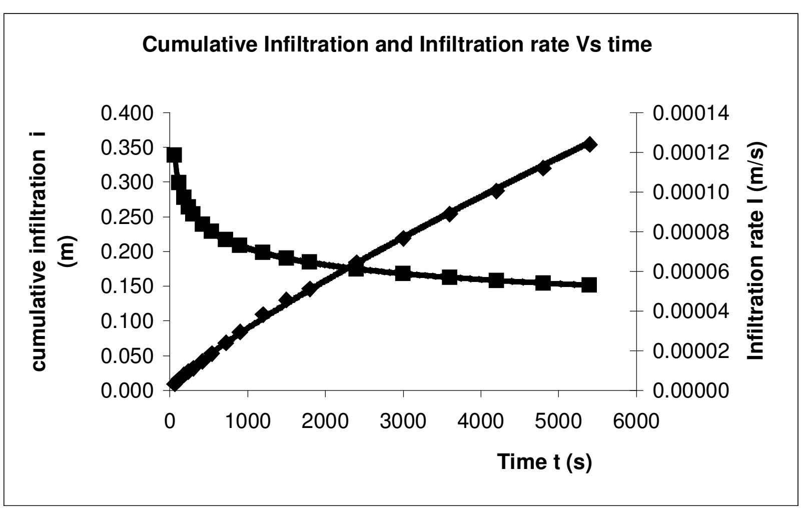
Cumulative Infiltration Vs time



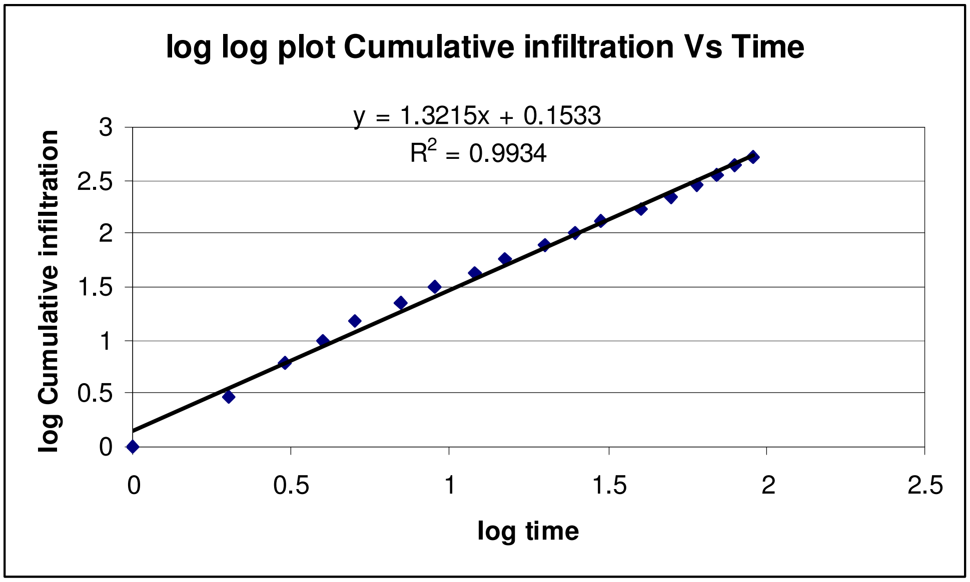
Infiltration rate Vs time



Cumulative Infiltration and Infiltration rate Vs time



Calculation of slope of log - log cumulative infiltration vs. time



5. Determination of the Salt content of the soil

The soil is a good source of different kinds of salts. But the excess amount of soil is not a good character of soil, as it can make toxicity effects as well as it can determine the water availability of soil by changing the osmotic potential of the soil. The salt content of a soil can be roughly estimated by measuring its electrical conductivity (EC). It depends on the nature or origin of salts. Osmotic pressure of the soil can also be calculated from the EC.
To measure the electrical conductivity many methods are available.
In this particle exercise, EC of a saturated soil extract (ECe) and extract of the diluted suspension (with soil water ratio of 1/5; $EC_{1/5}$) was measured.
ECe is recommended as a general method for appraising soil salinity in relation to plant growth. $EC_{1/5}$ method is used when limited amount of soil is available. And there is a relation between $EC_{1/5}$ and ECe. Soil salinity is expressed in terms of the conductivity of the saturation extract in Ms cm^{-1}.

Principle

The salt content of a soil solution is nearly proportional to its electrical conductivity and the osmotic pressure. The relationship between osmotic pressure and EC can be represented by;

$$\pi(atm) = 0.36xEC(mS / cm)$$

$$\pi(Pa) = 3.6 \times 10^4 \text{ EC (mS/cm)}$$

The relation between EC and concentration can be given by;

$$\text{EC (mS/cm)} \approx 0.01 \text{moldm}^{-3}$$

The measured EC can be converted in mg of ash of the solution.

$$\text{\% salt in the extract} = 0.06 \text{ [mScm}^{-1}\text{] \%}$$

Sometimes the salt content in the soil is expressed as a percentage of the dry mass of the soil. This value can be deducted by directly from the above mentioned ash of a solution by calculating it on the basis of the amount of extracted water.

$$\text{\% salt as dry mass percentage} = \frac{0.6 \text{ EC (mS/cm)} \times \theta_{m(sat)}}{1000}$$

$\theta_{m(sat)}$ is the moisture content at saturation (on dry mass basis)

The relation between $EC_{1/5}$ and ECe can be expressed by;

$$ECe = \frac{EC_{1/5} \times 500}{\theta_{m(sat)}}$$

Procedure

Determination of ECe value

250g of air dry soil was weighted in a plastic box. Distil water was added to the soil sample gradually by using a pipette till saturation is obtained. While water was added, the soil was stirred well. The amount of water added was recorded. Then the saturated soil was brought into a Buchner funnel with a moist filter paper. It was connected to a special filter flask and whole aperture was connected to a vacuum pump.

The extract was collected in a test tube and ECe was determined with the conductivity cell and the temperature of the sample also measured.

Determination of ECe value by means of an $EC_{1/5}$ extract

20 g of air dry soil was measured and brought it in an Erlenmeyer flask of 250ml. then 100 ml of water was added and it was closed by using a rubber stopper. The whole mixture was agitated in a mechanical shaker for 15 minutes and allowed it to settle for one hour. Then again it was agitated for 5 minutes and filtrate was obtained.

The EC value of the extract was determined on about 50ml filtrate by means of a conductivity cell.

Readings and Calculations

Quantity of water added to 250g of air dry soil	79.3ml
Moisture content (θ_m) of air dry soil	1%
Moisture content at saturation $\theta_{m(sat)}$ %	33.05%
Temperature of the extract	19^0C
Cel constant	
Electrical conductivity ECe (mS/cm)	0.507
Osmotic pressure π of the saturation extract (atm)	0.1825
Salt concentration of the saturation extract %	0.01%
Electrical conductivity at field capacity (mS/cm)	1.008
Osmotic pressure π at field capacity (atm)	0.33288
Electrical conductivity of the 1/5 extract $EC_{1/5}$ (mS/cm)	0.293
ECe calculated from the $EC_{1/5}$ (mS/cm)	4.432

Discussion

Comparison of determined Ece value and calculated Ece value

The determined ECe value based on the saturated soil extract and the calculated ECe value based on the 1/5 saturated extract is different. The ECe based on saturated extraction should give a higher value. Because the amount of water that extract salt is limited and the salts are coming from relatively high mass of soil (250g).

But in the ECe value determined based on 1/5 extraction method should give lower value of EC. This is because the volume of extraction is comparatively higher than the saturation extract. And the amount of soil used is also small. Therefore less amount of salt will be available in the extract. So that it would lead to low ECe value.

But in this exercise, the obtained value of 1/5 extract was somewhat higher. It may be due to an instrumental error and due to personal errors.

Toxicity of Salt Concentration

The particular soil that used to determine the salt concentration has 0.01% of salts at its saturation condition. When the soil moisture level decreases, the concentrations of salts increase making some potential toxicity effects for the plants and soil organisms. When the soil moisture level decreases, it increases the osmotic potential of the soil leading to decrease in soil water availability. This condition would cause physiological drought ness for the plants, and subsequently it will cause some toxic effects to plants depending on the plant species.

At higher salt concentrations, a layer of salt deposit can be seen on the surface of the soil. Apart from that, it can change the availability of some other elements. Some elements can be available at higher amounts and availability while some elements can be lower.

Apart from plants, it may adversely affect the soil micro organisms and macro organisms. This condition can alter some important soil biological processes, such as mineralization.