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PRACTICAL MANUAL ON FUNDAMENTAL OF SOIL SCIENCE

(ICAR 6th Dean Committee Recommendation)

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Practical Manual on Fundamental of Soil Science

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PREFACE

Soil is one of the natural resources supporting plant growth, productivity, ecosystem functioning, and human livelihoods. A clear understanding of soil properties and processes is important for students of agriculture, soil science and environmental science. The Practical Manual on Fundamentals of Soil Science provides a laboratory approach to understanding basic principles and practical applications of soil science.

This manual brings together nineteen selected exercises covering physical, chemical, mineralogical, and field aspects of soil. The practicals begin with collection and preparation of soil samples and determination of soil pH and electrical conductivity, followed by identification and study of rock types and soil minerals. Field-based exercises introduce students to soil profiles and soil colour, helping them relate laboratory observations to natural soil conditions.

The manual emphasizes important physical properties of soil, including bulk density, particle density, porosity, texture, structure, aggregate status, and moisture content. Different established methods, such as the core sampler, pycnometer, hydrometer, International Pipette, Yoder apparatus, gravimetric method, and Hilgard apparatus or Keen–Raczowski box, are included to develop familiarity with standard soil science techniques. The determination of available water capacity and saturated hydraulic conductivity provides insight into soil-water relationships and the movement and availability of water within soil.

Each exercise encourages careful observation, accurate measurement, scientific reasoning, and proper recording of results. The tabular format for dates, signatures, and remarks promotes documentation and laboratory discipline. This manual seeks to strengthen conceptual understanding through hands-on learning and equip students with fundamental skills required for soil characterization, interpretation, and sustainable soil management. It is hoped that this practical guide will serve as a highly useful academic resource for students, teachers, and practitioners engaged in the study and management of soil resources.

- Authors

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Exercise No. 1
Collection and Preparation of Soil Sample for Laboratory Analysis

Introduction

- **Soil Sampling:** A portion of entire soil mass taken from its natural occurrence for analysis of soil properties is known as soil sample and its collection from the field is known as soil sampling. The sample should represent the properties of entire soil mass.
- **Soil Testing:** The procedure used to determine the properties of soil with the help of different reagents and equipment are known as soil testing.
- **Composite Sample:** Soil samples are collected from various sites in the field, mixed thoroughly, and the resulting sample is called a composite sample.

Objectives of Soil Sampling

- To evaluate soil fertility status for making fertilizer recommendations.
- To predict the probable crop response to applied nutrients.
- To classify soils into different soil groups and fertility groups for preparing soil and soil-fertility maps.
- To identify the types and degree of soil-related problems such as salinity, alkalinity, and acidity and to suggest appropriate reclamation/amelioration measures.
- To determine the suitability of soil for growing crops and orchards.
- To study the soil genesis.

Materials Required: Spade, Bucket, 12-inch scale, Polythene sheet, Auger, Khurpi, Sieves (2 mm), screw-type auger for hard or dry soil, post hole auger for excessive wet area like rice field, tube auger/Spade/Khurpi for soft and moist soil

Sampling Depth: For cereals, vegetables and other seasonal crops: 0–15 cm (plough layer or furrow slice), For plantation crops or fruit trees: 0–90 cm (0–30, 30–60, 60–90 cm), For soil reclamation or saline/alkaline soils: 0–180 cm (0–30, 30–60, 60–90, 90–120, 120–150, 150–180 cm)

Procedure:

- Determine the soil unit, make a traverse over it and clean the upper surface
- If a spade or Khurpi is used, a “V" shaped cut may be first made up to plough layer (vertical depth of 15 cm)
- About 2 cm uniformly thick slice is taken out from one clean side
- From the field having standing crops in row, draw samples in between the rows
- When auger is used, place it in soil and turn round at the depth of 15 cm
- Mix the soil together and collect it in a bucket
- Reduce the bulk to about 500 g by quartering process
- For quartering, spread the entire soil mass, divide into four quarters, discard two opposite ones, and remix the remaining two.
- Repeat this process until about 500 g of soil is left.
- Then place the sample in a bag and label it.

General Considerations:

- Sample should represent the field.
- An area not exceeding 0.5 hectare is taken as one sampling unit.
- An area of about 2–3 metres along all the sides of the field should be left in large fields.
- Samples should be collected from areas differing in slope, colour, texture, crop growth, and management.
- Recently fertilized plots, bunds, channels, marshy spots and areas near trees, compost piles and buildings should be avoided.
- For micronutrient analysis, if an auger is used it should be made of stainless steel.
- Contact of samples with fertilizers, manures or ash should be avoided.
- Cotton, jute or plastic bags used in collection and storage of the sample should be clean.
- Use glass or porcelain jar for long-term storage.

Processing of Soil sample: Only 500g of soil will be sent to lab and the following processes will be performed there: Drying (at room temperature in shade), Grinding and Sieving (2 mm sieves but 0.2-0.5 mm sieves for specific analysis such as organic carbon).

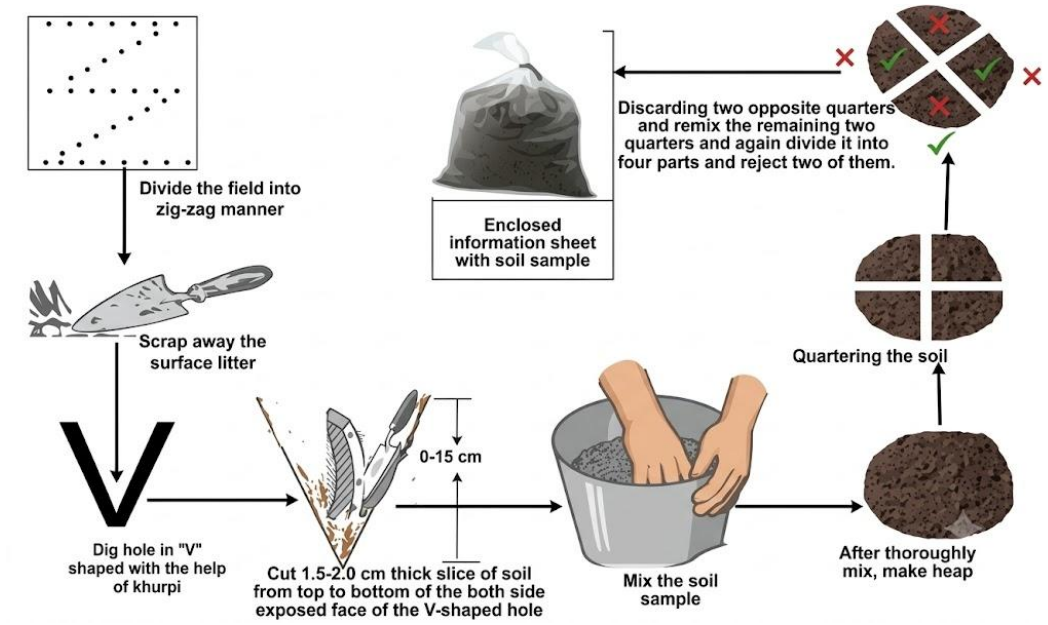


Figure 1: Schematic view of soil sampling procedure

Data Sheet

Sr. No.	Particulars	Details
1.	**Sample No.**	
2.	**Geocoordinate Data**	Latitude: Longitude:
3.	**Name of Farmer**	
4.	**Address**	
5.	**Fertilizer Used**	
6.	**Biofertilizer Used**	☐ Yes ☐ No
7.	**Soil Health Card Available**	☐ Yes ☐ No

Exercise No. 2
Determination of Soil pH with the Help of a pH Meter

Introduction:

pH is a measure of hydrogen ion activity of the soil–water system. It indicates whether the soil is acidic, neutral or alkaline in reaction. The nutrient availability is governed by soil reaction. For many nutrients, availability is greatest in the near-neutral range and decreases under strongly acidic or alkaline conditions. Thus, pH value gives an idea about the availability of nutrients to plants. It is measured and expressed in pH units. The word pH has originated from the French word 'pouvoir hydrogène' which means power of hydrogen ions. pH scale was given by S. P. L. Sørensen (1909) with a scale ranging from 0 to 14

Mathematically $pH = -\log_{10}(aH^+)$

where aH^+ is the activity of hydrogen ions

The pH scale for an aqueous system extends from 0 to 14. In pure water at 25 °C, the concentration of ions, i.e. (H+) = (OH-) = 10–7 moles/liter and therefore pH = 7.0. So, pure water is neutral in reaction.

"pH is defined as the negative logarithm of the hydrogen ion activity".

It is expressed as $pH = -\log_{10}(aH^+)$

Principle:

pH meter measures the active acidity. Before measuring the pH of the soil, the instrument has to be calibrated with standard buffer solution of known pH. Since, the pH is also affected by the temperature; hence, the pH meter should be adjusted to the temperature of the solution by temperature correction knob. This method is based on the measurement of electrical potential developed by an electrode, whose potential depends on the concentration of the H+ ion in solution. When glass electrode is placed in soil or water solution, an electrical potential is established across the membrane which is proportional to the difference in H+ ion activity between dilute HCl solution and soil or water solution. The potential of glass electrode half-cell is the electromotive force of galvanic cell which is measured with a voltmeter. The voltage developed by the combination of a glass electrode and reference electrode which is measured with an instrument called pH meter.

Glass Electrode:

- The sensing electrode is a thin glass bulb filled with an internal electrolyte of high buffering capacity (commonly an internal electrolyte/reference solution).
- It allows only a very small current to pass and develops a potential dependent on H^+ concentration.

Reference Calomel Electrode:

- Consists of mercury (Hg) in contact with potassium chloride (KCl) saturated with mercurous chloride ($Hg_2 Cl_2$).
- Provides a stable reference potential against which the glass electrode potential is measured**.**

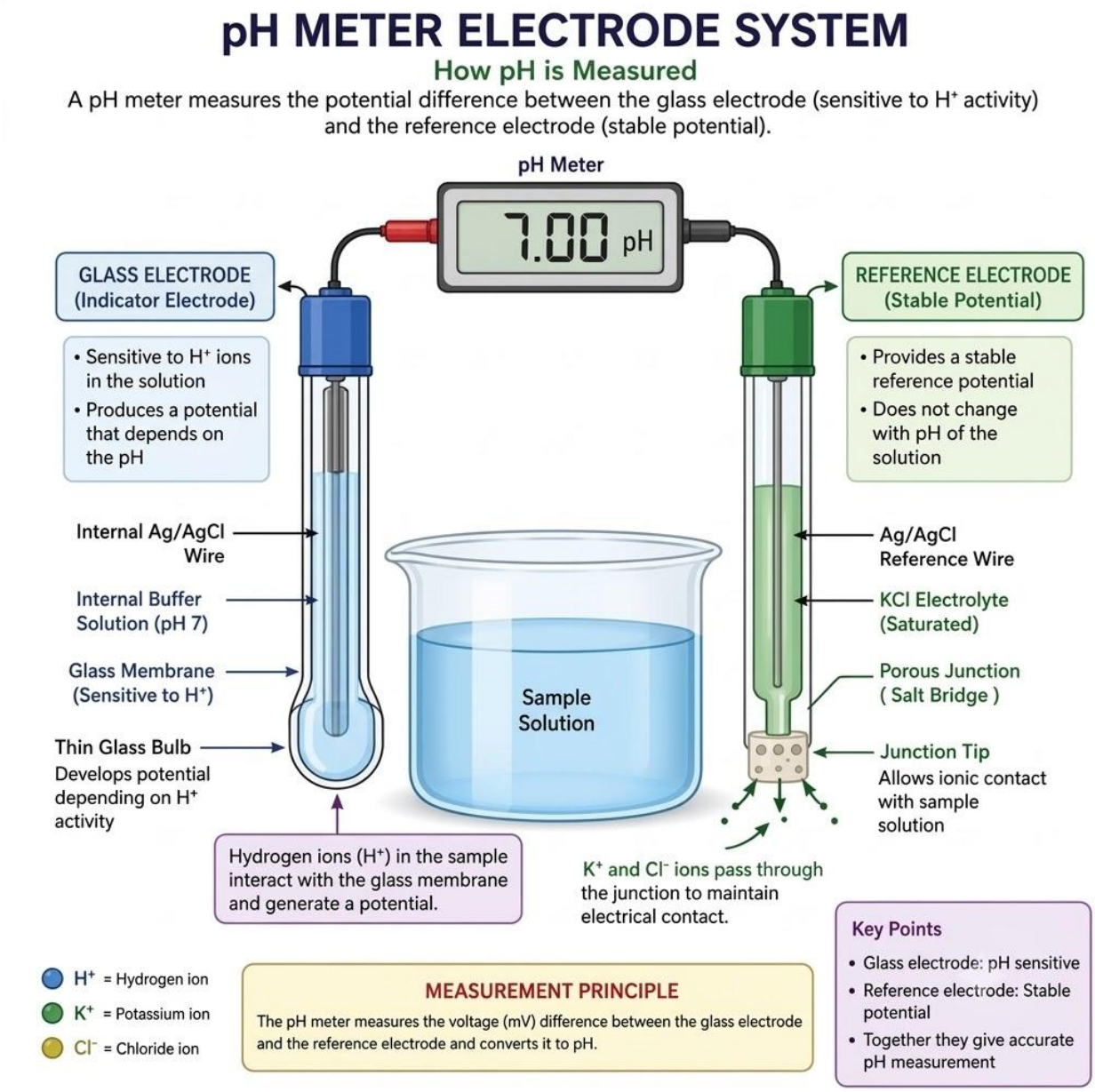


Figure 2: Representation of the two electrodes used in a pH meter

Equipment and Apparatus:

pH meter, Analytical balance, Beaker, Measuring cylinder, Glass rod and Spatula etc.

Reagents:

i. Buffer solution of pH 4.0 – Dissolve one commercially available buffer tablet pH 4.0 in freshly prepared distilled water and make the volume to 100 mL.
ii. **Buffer solution pH 7.0 –**As per buffer solution of pH 4.0
iii. **Buffer solution pH 9.2 –** As per buffer solution of pH 7.0

Calibration of the Instrument

- Before use, the pH meter must be calibrated with standard buffer solutions of known pH values (commonly pH 4.0, 7.0, and 9.2).
- Since pH readings are influenced by temperature, the instrument should be adjusted to the solution's temperature using the temperature correction knob.

Procedure:

- Take 10 g of soil sample in 100 ml beaker.
- Add 25 mL of distilled water and stir the suspension with a glass rod intermittently for about 30 minutes.
- Switch on the pH meter and set the temperature compensation knob at buffer solution temperature and allow the pH meter to warm up for 30 minutes.
- After the warm-up period, calibrate the pH meter using at least two buffer solutions of different pH values.
- First, measure the temperature of the solution and adjust the temperature knob.
- Second, dip the electrode in pH 4.0 buffer solution, check for actual pH at measured temperature and adjust with the buffer knob. Then, dip the electrode in the pH 9.2 buffer solution and adjust it with the sensitivity knob.
- Repeat until pH meter gives correct reading of both buffer solutions.
- Again, stir just before immersing the electrodes and place the electrode in the suspension and take the reading after 30 seconds.
- Remove the electrode from suspension and rinse thoroughly with distilled water and carefully remove excess water with a tissue paper.

Precautions:

- pH meter should always be warmed up for about half an hour.
- The electrodes must be washed with distilled water and dried gently with the help of filter or tissue paper before each measurement.
- The electrode of pH meter should always remain dipped or immersed in distilled water.
- Adjust the temperature knob of pH meter at room temperature for correct pH determination.
- Buffer solution should be prepared accurately and stored well in glass container. It is desirable to prepare fresh buffer solution after a few days.
- Before measuring the pH of the soil, instrument should be calibrated with appropriate standard buffer solutions (e.g., pH 4.0 and 7.0, or pH 7.0 and 9.2, as appropriate).
- Before removing electrodes, instrument should always be switched to standby position.
- For soil samples very high in organic matter, use a 1:2 or 1:5 (Soil:Water) ratio.

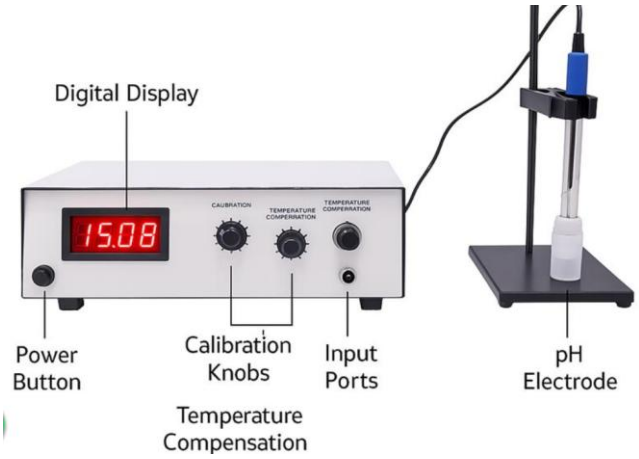


Figure 3: pH meter used in laboratory

Result: The sample of the soil sample is _____

Interpretation:

pH (1:2.5)	Nature of the soil
< 6.5	Acidic soil
6.5 - 8.0	Soil is fit for all crops grown in the region and need no treatment
8.0 - 8.4	Soils are moderately alkaline and need small amounts of amendments or even organic manures like green manuring andFYM
> 8.4	Gypsum requirement of soil sample should be determined and applied according to the requirement of the soil on the hectarebasis

Denomination	pH range	Interpretation	Tick the right
Ultra acidic	< 3.5	Require liming	
Extremely acidic	3.5–4.4	Require liming	
Very strongly acidic	4.5–5.0	Require liming	
Strongly acidic	5.1–5.5	Require liming	
Moderately acidic	5.6–6.0	Require liming	
Slightly acidic	6.1–6.5	Require liming	
Neutral	6.6–7.3	No amendment	
Slightly alkaline	7.4–7.8	Require Gypsum	
Moderately alkaline	7.9–8.4	Require Gypsum	
Strongly alkaline	8.5–9.0	Require Gypsum	
Very strongly alkaline	> 9.0	Require Gypsum	

Exercise No. 3
Determination of Electrical Conductivity in Soil with Help of Conductivity meter

Introduction:

All soils contain varying amounts of soluble salts in the form of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), sulphate (SO_4^{2-}), chloride (Cl^-), nitrate (NO_3^-), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+) and potassium (K^+). Excessive accumulation of these soluble salts in the soil results in harmful effects on seed germination, plant growth and intake of water by plants. It is therefore, essential that the amount of these soluble salts in soil is determined so as to appraise the salinity problem of soils.

Principle:

Electrical conductivity (EC) is a measurement of soluble salts in the soil water system. Ions, like metals, allow the electric current to pass through them. Hence, electrical conductivity of soil water system increases with increasing content of soluble salts in the soil. Thus, the measurements of EC give the concentration of soluble salts in the soil at any particular temperature. Solution containing salts offer some resistance to the passage of electric current depending upon the concentration and type of salts (ions) present. Higher the salt content, lower the resistance to the flow of electric current. This resistance (R) is defined be Ohm's law as the ratio of electrical potential in volts (E) and strength of current in ampere (l).

$$E/I = \frac{\text{Volts}}{\text{Current}} \text{ R in ohm}$$

Electrical conductivity is the reciprocal of resistance and is defined as the reciprocal of the resistance of a conductor (1 cm long and 1-2 cm in cross sectional area). It is expressed in mhos or millimhos/cm or dS m-1.

$$G = 1/R$$

where G is conductance (S)

Figure 4: Conductivity meter used in laboratory

Material required:

Conductivity meter, Analytical balance, Beaker, Measuring cylinder, Glass rod and Spatula etc.

Reagent:

0.01 N potassium chloride solution (KCl): Dry a small quantity of AR grade potassium chloride at 60˚C for 2 hours in a hot-air oven. Weigh 0.7456 g of it and dissolve in freshly prepared distilled water and make to one litre. This solution gives an electrical conductivity of 1.41 dS m-1 at 25 ˚C.

Procedure:

- Start the EC meter, Adjust the temperature knob of conductivity meter at 25 ℃
- Check the instrument with 0.01N KCl solution (conductivity 1.41 dS m^{-1} at 25 ℃)
- Immerse the electrode in soil-water suspension and note the reading
- The clear supernatant of 1:2.5 soil–water suspension prepared for pH measurement can be used for estimation of electrical conductivity.
- Calibrate the conductivity meter using 0.01N KCl solution prepared & determine the cell constant.
- Determine conductivity of the supernatant liquid
- Take 10 gm of soil sample in a 100 mL beaker.
- Add 25 mL of distilled water and stir the suspension with a glass rod intermittently for about 30 minutes.
- Allow to stand until clear supernatant liquid is obtained.
- Determine the conductivity of the supernatant liquid with the help of conductivity meter.
- The electrical conductivity of saturation extract (EC) is also determined for salinity ratings

Precautions:

- Conductivity meter always be warmed up for 30 minutes before taking the reading.
- Soil water suspension should be allowed to settle for sufficient time to obtain clear supernatant solution.
- The electrodes of the conductivity cell should be completely dipped in the supernatant solution.
- After each reading, wash the cell with distilled water and dry it with the filter paper or tissue paper and dip the cell in distilled water while not in use.
- Readings are usually taken and reported at a standard temperature of 25ºC.
- Check accuracy of the EC meter using a 0.01 N Potassium chloride solution, which should give reading of 1.41 dS m^{-1} at 25ºC.
- Reading is recorded in millimhos per centimetre (mmhos/cm) or deciSiemens per meter (dS m-1). Both units are equal, that is 1 dS m^{-1} = 1 mmhos cm^{-1}.

$$\text{Cell Constant (K)} \frac{\text{Actual conductivity of 0.01N KCl solution}}{\text{Observed conductivity of 0.01N KCl solution}}$$

Reading of the EC meter (C) = ... dS m^{-1}

Electrical Conductivity = K × C = ……. dS m^{-1}

Reading:

The EC meter reading of soil is ……

EC at 1:2.5 soil:water suspension (dS m^{-1}) suspension (dS m^{-1})	**Salt concentration (%)**	**Suitability**
< 0.8	0.05	Fit for most crops
0.8 - 1.6	0.05 - 0.15	Critical for sensitive crops
1.6 - 2.5	0.15 - 0.20	Critical for tolerant crops
> 2.5	0.20 - 0.25	Injurious for all crops
> 16		Only few tolerant crops yield satisfactory

EC Rating

Soil	**EC (mS/cm)**	**Total salt content (%)**	**Crop reaction**
Salt-free	0–2	<0.15	Salinity effect negligible, except for sensitive crops
Slightly saline	4–8	0.15–0.35	Yield of many crops restricted
Moderately saline	8–15	0.35–0.65	Only tolerant crops yield satisfactorily
Highly saline	>15	>0.65	Only very tolerant crops yield satisfactorily

Interpretation:

Soil Salinity

S. No.	**EC (dS/m)**	**Remark**	**Tick the correct**
1	< 1	Normal soil for crops	
2	1 – 2	Critical for germination	
3	2 – 4	Critical for crop growth	
4	>4	Injurious for crops	

Exercise No. 4
Study of Igneous, Sedimentary and Metamorphic rocks

Rocks: Rocks are the materials that form the essential part of the Earth's solid crust. "Rocks are hard mass of mineral matter comprising one or more rock forming minerals". Rocks are formed from the molten material known as magma.

The study of rocks is called Petrology (in Greek, petra means rock, logos means science). Petrography deals with the description of rocks; Petrogenesis is the study of the origin of rocks.

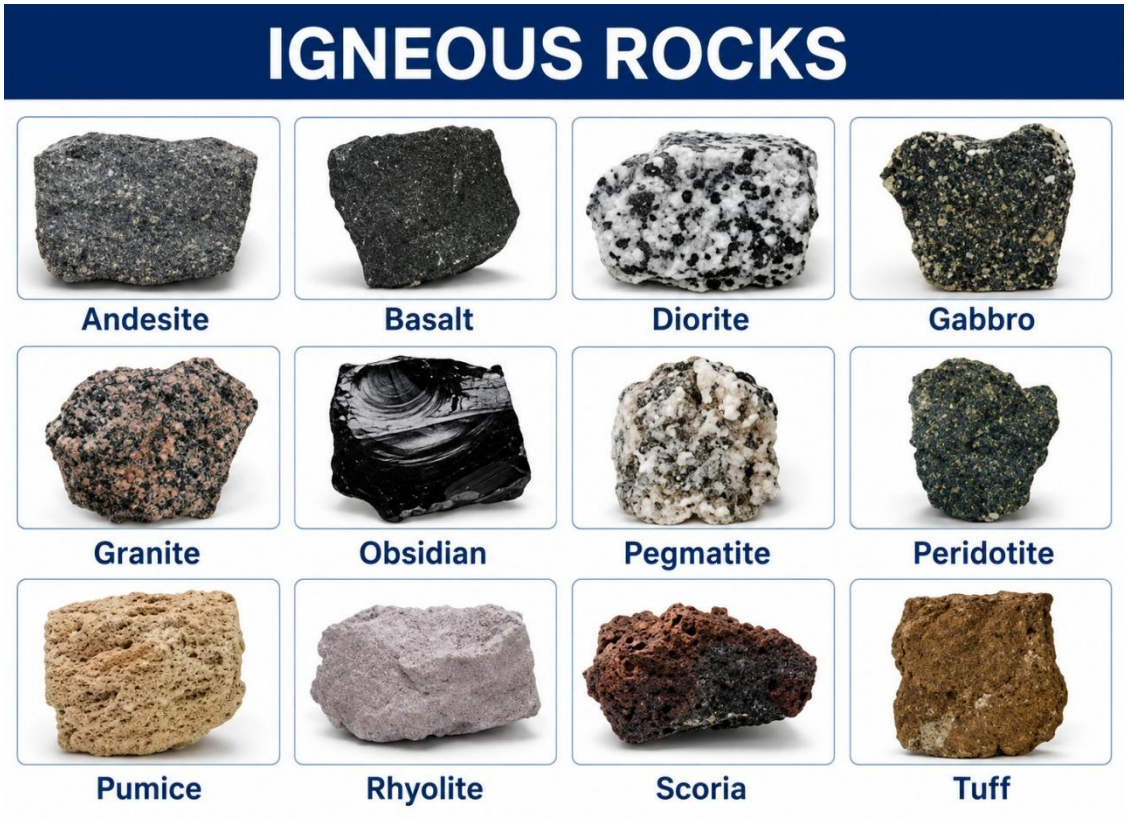
Types of Rocks:

A. Igneous or primary rocks or massive rocks or crystalline rocks:

These rocks are formed from the cooling and consolidation of molten magma within or on the surface of earth. These are first formed in the Earth's crust due to the solidification of molten magma (granite, basalt, gabbro, diabase).

a. Based on the mode of origin, they are further classified as extrusive and intrusive rocks

Extrusive rocks or Volcanic Rocks or Glossy Rocks: Magma that has cooled and solidified on the earth's surface is what gives rise to these rocks. Lava is the term used to describe the flow of magma onto the earth's surface example-basalt	**Intrusive Rocks or Plutonic Rocks:** These rocks are coarse grained and produced due to solidification of magma below the surface of the earth. Plutonic/Intrusive rocks solidify at greater depth and Hypabyssal rocks solidifies at shallow depth from the surface. (Granite, syenite, diorite, Gabbro *etc.*). Rocks formed in vertical cracks are called dykes and in horizontal cracks are called sills.



b. Based on the silica content igneous rocks are also classified as-

- **Acidic rocks**: >65% SiO_2 (Granite, Rhyolite)
- **Intermediate:** 56 to 65% SiO_2
- **Basic rocks** – 40 to 55% (Gabbro, Basalt)

B. Sedimentary or secondary rocks:

These rocks are formed from the transportation, deposition, compaction, and cementation of primary rocks. These rocks are produced by the consolidation of sediments deposited at the earth's surface by wind or water. Many are created through chemical reactions as precipitates from aqueous solutions or are deposited in layers (chemical sedimentary rocks). Sediments may contain various size particles cemented together by substances like SiO_2, Fe_2O_3 or lime.

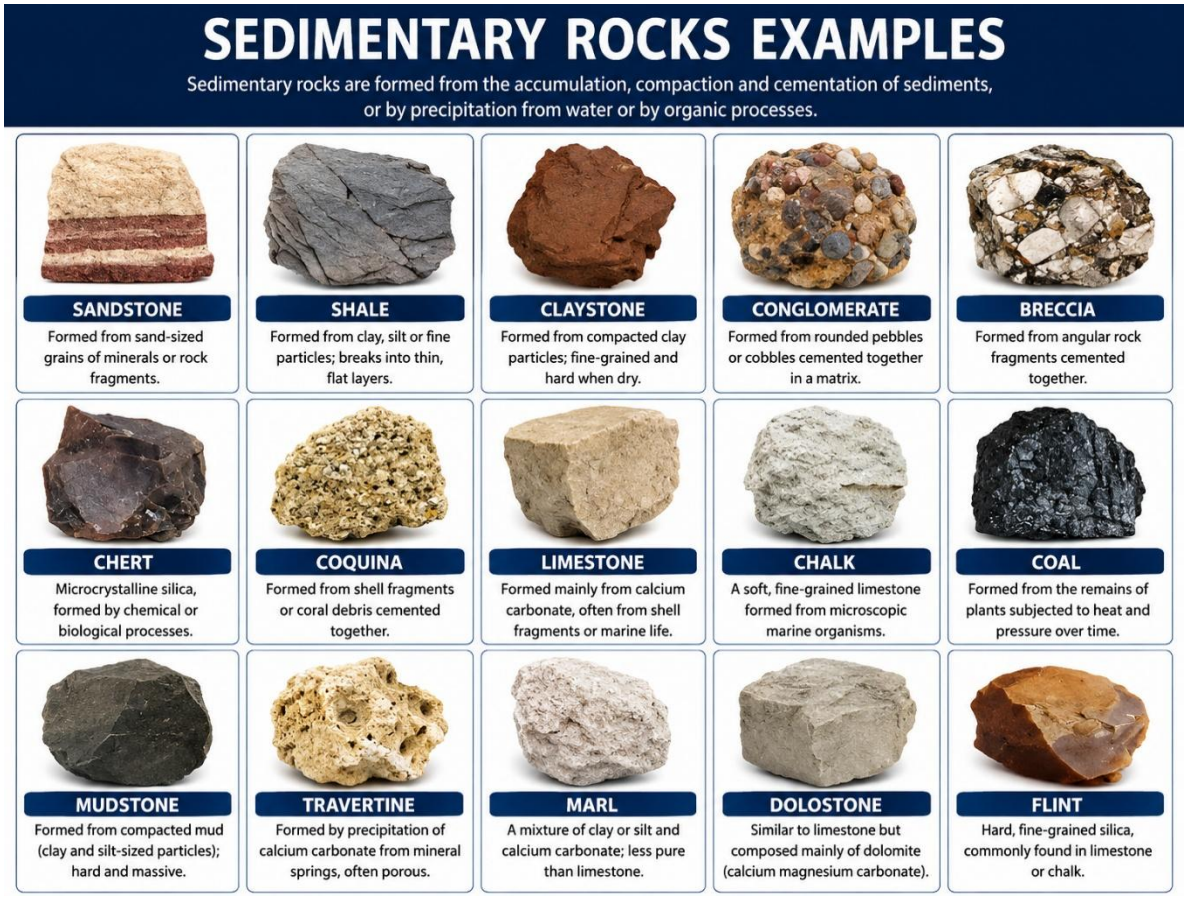
1. Based on the origin, the sedimentary rocks are classified as-

i. Residual–Laterite
ii. Transported

- Deposited as solids in suspension–Sandstone, Shale
- Deposited by chemical precipitation–Limestone, Ironstone
- Deposited through agency of organic matter–Peat, Phosphatic deposits

2. Based on the grain size, sedimentary rocks are classified as-

- Rocks with boulder pebbles sized minerals (Rudaceous) – Conglomerate
- Rocks with sand size particles (Arenaceous)–Sandstone
- Rocks with silt size particles (silt rocks)–Siltstone
- Rocks with clay size particles (Argillaceous)–Shale

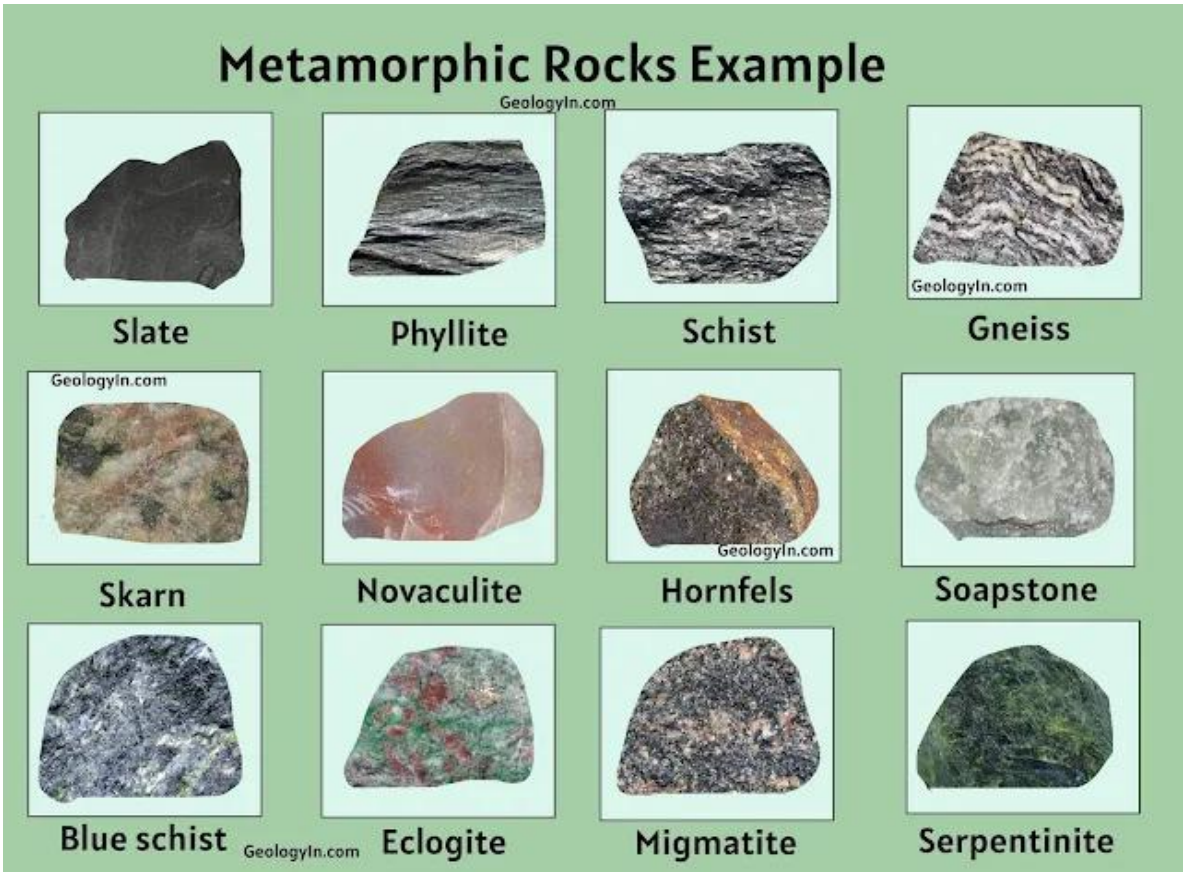


C. Metamorphic Rocks

These rocks are formed from the alteration of existing primary and secondary rocks. These are made of sedimentary and igneous rocks that have been subjected to heat, pressure, chemically active liquids, and gases. Mineral content, texture, or both may change. Changes caused by water are called hydrometamorphism, the changes caused by heat are called thermometamorphism and changes caused by pressure are called dynamometamorphism

a. Pre-existing rock - Metamorphic rocks

- Sandstone-Quartzite
- Limestone-Marble
- Granite-Gneiss
- Dolerite–Hornblende
- Shale-Slate



Rocks in the Earth's crust up to 5 km

- **Igneous rock-18%** (Granite-15% and Basalt-3%)
- **Sedimentary rocks–74%** (Shales-52%, Sandstone-15%, Limestone and Dolomite-7%)

Entire Earth's Crust

- Igneous rocks–95%
- Sedimentary rocks- 5%

Brief Description of Important Rocks

	Grain size	Essential minerals	Most common accessory Minerals	Average Specific Gravity	Remarks
Igneous rocks					
Granite	Plutonic, Holo crystalline	Predominant quartz, 20-35% orthoclase	Hornblende mica, magneti te	2.64	Visible to naked eyes,Light colored, White or reddish
Syenite	- do -	Predominance Quartz 100% plus of orthoclase, nephelineand albite	Hornblende biotite, magnetite	2.08	- do -
Grano, Diorite	- do -	Intermediate quartz plagioclase exceedsorthoclase		2.07	Medium colored reddish
Diorite	- do -	Intermediate quartz absent plagioclase	- do -	2.85	Darker
Gabbro	- do-	Labradorite augite + olivine	Hornblende, Ilmenite	3.00	Visible, Blackish
Dolerite	Hypabyssal ophitic, Texture	- do -	- do -	3.00	-do–
Basalt	Volcanicmi crocrystallin ewith glassy Mass	- do -	- do -	3.00	- do -

Rocks	Mineral composition	Colour and structure
Sedimentary rocks		
Sandstone	Mainly quartz with same contents, such As calcium carbonate, iron Oxides and clays	Light to red, usually granular in structure
Shale	Clay minerals, quartz and some organic Matter	Light to dark thinly laminatedstructure
Limestone	With some iron oxides, clay, phosphate, and organic materials in addition to calcite or calcite and dolomite.	Usually, light grey to Yellow Usually Fine-grained and compact
Metamorphic rocks		
Gneiss	Formed from granite, mineral compositionlike that of granite	Alternating light and dark colours. Banded and foliatedstructure
Schist	Formed from basalt or shales. Mineral composition much As That of original rock	Much as original rock, foliatedstructure
Quartzite	Formed from sandstone and of same composition	Light to brown. Compact and uniform texture, Foliated structure
Slate	Formed from shale and of same composition	Grey to black, compact, and uniform texture, foliated structure
Marble	Formed from limestone	Compact, fine to coarse texture, non-foliated structure, light red, green, and black

Exercise No. 5
Study of Silicate and Non silicate Soil Minerals

Minerals

Minerals are naturally occurring solids with a definite chemical composition and crystal structure. "Solid substances composed of atoms having an orderly and regular arrangement" Different elements that are present in liquid lava freely arrange according to attractive forces and geometric form when it solidifies. The primary building blocks for the formation of many minerals are silica tetrahedra (SiO_2). Orthosilicates, inosilicates, cyclosilicates, phyllosilicates, and tectosilicates are several silicate minerals. There are also minerals that are not silicates. These include various oxides, carbonates, sulphates, and phosphates, among others.

- Minerals that are original components of rocks are called primary minerals. (Feldspar, Quartz, Amphiboles, Pyroxenes, Carbonates, Mica, apatites, etc.).
- Minerals that are formed from changes in primary minerals and rocks are called secondary minerals (Gypsum, Clay minerals).
- Those minerals that are chief constituents of rocks are called as essential minerals (Feldspars, Pyroxenes, Micas etc.)
- Those which are present in small quantities, whose presence or absence will not alter the properties of rocks are called accessory minerals (Tourmaline, magnetite *etc.*).

Of the >2,000 known minerals, only few occur in abundance in the Earth's crust

Minerals (arranged in the order oftheir crystallization)	**Important constituents**	**% Distribution**
A. PRIMARY MINERALS		
a. Ferromagnesium minerals		
i. Ortho-inosilicates		16.8
Olivine	Fe, Mg	
Pyroxenes	Ca, Na, Fe, Mg	
Amphiboles	Ca, Na, Fe, Mg, Al, OH	
ii. phyllosilicates		3.6
Biotite	K, Fe, Mg, Al, OH	
Muscovite	K, Al, OH	
b. Non-Ferromagnesium		
Tectosilicates		
Feldspars		61.0
Anorthite	Ca, Al	
Albite	Na, Al	
Orthoclase	K, Al	
Quartz		
B. SECONDARY CLAY MINERALS		
Minerals	Na, K, Ca	11.6
Others	Mg, Fe, Al, OH	6.0

- No single mineral can be considered the most crucial in all soils; common primary soil minerals include feldspars, quartz, micas, pyroxenes, and amphiboles. The amphibole group includes minerals such as tremolite, actinolite, and hornblende; olivine belongs to the nesosilicate group can be used to represent the amphibole group of minerals, which are frequently found in acidic rocks.
- Pyroxenes generally weather more rapidly than amphiboles because of their structure and lower resistance to weathering.
- Goethite and hematite, which are found as coatings on the surface of soil particles, are what contribute to red, yellow, or brown soil colours.
- Apatite (rock phosphate (apatite) is the an important source of phosphorus

Physical Properties of Minerals

- Streak – related to the mineral's powdered form's colour. A coloured line results from rubbing an unidentified mineral against an unglazed porcelain streak plate. For example, talc has a white streak, magnetite a black streak, and hematite a reddish-brown to red streak.
- **Fracture and cleavage** describe how a mineral breaks. Fracture is the nature of the surface produced as a result of its breakage
- **Cleavage –** Cleavage planes are well-defined planes along which some minerals break.
- **Hardness -** This demonstrates a mineral's scratch-resistance. The Mohs scale is used to categorise the hardness of a specific mineral. Try to scratch the unidentified mineral with various objects like a steel file, a coin, a steel nail, and a fingernail (which has a hardness of roughly 2.5)
- **Lustre –** the way a mineral reflects light; it may be metallic, vitreous, pearly, etc.
- **Crystal form –** Homogeneous atoms are grouped regularly to form a crystal structure. A crystal is a geometric solid because it has a polyhedral form. It has a particular set of faces, corners, and edges that are consistent with how the atoms are packed geometrically. There are 6 basic crystal forms.

i. Magnetism – Is the mineral magnetic? This may be tested by using a compass. This quality distinguishes magnetite.
ii. Effervescence – Some minerals bubble when they are exposed to acids; for example, calcite effervesces in dilute HCl.

Clay Minerals

Due to weathering processes, clay minerals in soils are formed from primary minerals. These 0.002 mm-sized clay minerals are thought to be the soil's most reactive component. Clay minerals regulate crucial soil characteristics, including nutrient and water retention capacity. These minerals are layered silicates consisting of silica tetrahedron and an aluminum-octahedron. 1 silicon tetrahedron +1 aluminium octahedron:

- 1:1 clay mineral (Kaolinite)
- **2:1 non-expanding clay mineral**–Black mica (Biotite), White mica(Muscovite), Weathered mica (illite)
- **2:1 expanding clay mineral**-Partially expanding (Vermiculite), Fullyexpanding

(Montmorillonite)

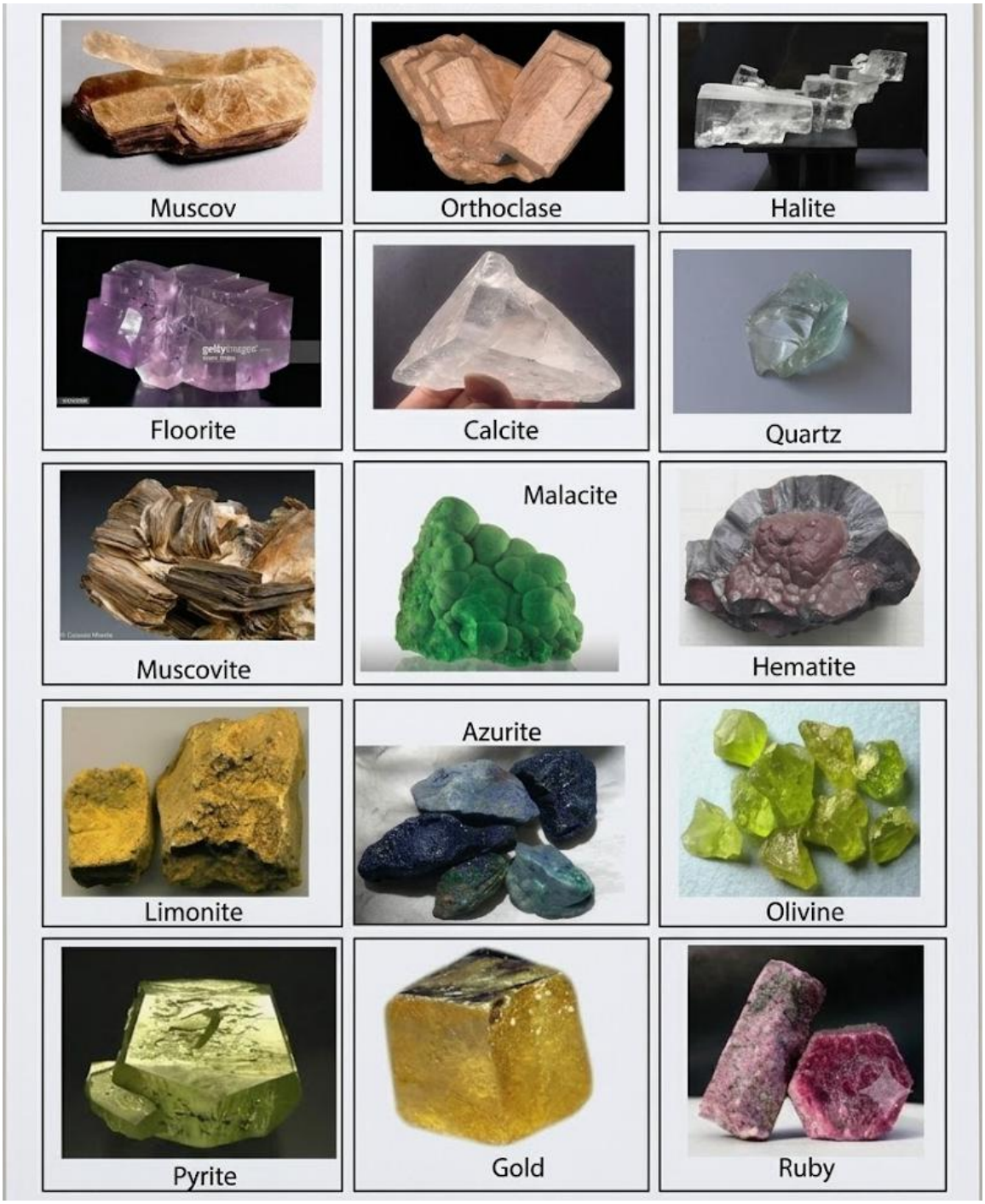
- 2:1:1 clay mineral–(Chlorite)

Mohs scale of Hardness

Mineral	Relative hardness
Talc	1 (Softest)
Gypsum	2
Calcite	3
Fluorite	4
Apatite	5
Feldspar	6
Quartz	7
Topaz	8
Corundum	9
Diamond	10 (Hardest)

Mineral	Colour	Hardness	Other characteristics
Amphiboles	Green, blue,brown, black	3–6	Needle-like crystals, cleavages forming120°angle
Apatite	Yellowish	5	Hexagonal in cross-section
Biotite mica	Black	5.5	Cleavage into thin sheets
Calcite	White to pale	3	Effervesces in HCl
Chlorite	Light green	2.0–2.5	Cleave into small flakes
Dolomite	Whitetopale	3.5–4.0	Powdered minerals effervescence inacid
Epidote	Green	6–7	Glassy luster
Garnet	Reddish brown	7	Glassy luster
Gypsum	Whitetopale	2	Rhombus-shaped crystals
Halite	Colourless	2.5	Salty taste, cubes
Hematite	Red or dark grey	5.5–6.5	Red brown streaks
Magnetite	Black	6	Strongly magnetic
Muscovite	Whitetopale	2.0–2.5	Excellent cleavage into sheets
Olivine	Olive green	6.5–7.0	Glassy luster
Plagioclase feldspar	White or grey	6	Fine striations on cleavage surfaces
Potassium feldspar	White, pink	6	No striation, cleavage at 90 °
Pyrite	Yellow/golden	6.0–6.5	Metallic luster, black streak
Pyroxene	Green or pink	5–7	Silky luster
Quartz	Colorless	7	Glassy luster, conchoidal fracture
Tourmaline	Blackish red, green	7.0–7.5	Elongated crystals, triangular Conchoidal fracture

Identification of some of the Minerals



Exercise No. 6
Study of Soil Profile in the Field

The vertical section of soil showing its horizons is called a soil profile, and the individual layers are called soil horizons.

Soil Horizons

There are Six master horizons: O, A, E, B, C and R. In a hypothetical mineral soil profile, O, A, B, C, and R master horizons as well as all potential sub-horizons will be present.

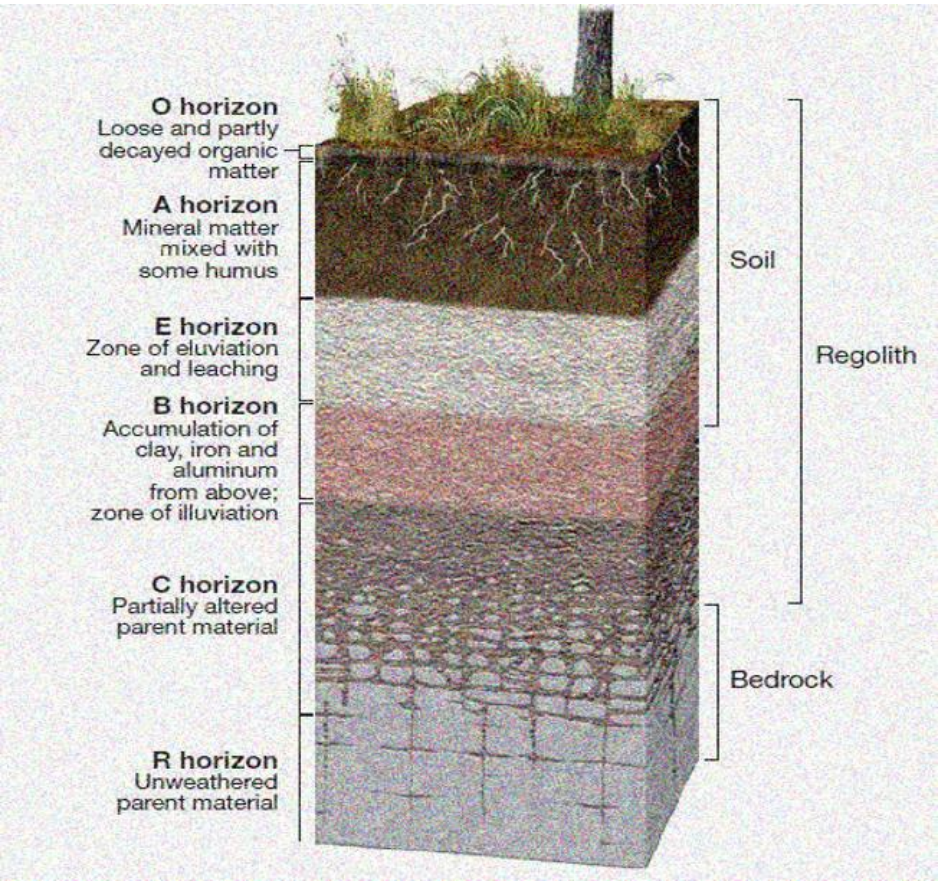


Figure 6: Different layers present in a profile

O Horizon

- It is called as organic horizon
- It is formed in the upper part of the mineral soil, dominated by fresh or partly decomposed organic materials.
- This horizon contains more than 30% organic matter, if mineral fraction has morethan 50% clay (or) more than 20% organic matter, if mineral fraction has less clay.
- The organic horizons are commonly seen in forest areas and generally absent ingrass land, cultivated soils. It consists three sub horizons
  - **O_i** – Organic horizon in which the original forms of the plant andanimal residues can be recognized through naked eye.
  - **O_e** –Organic horizon in which the original plant or animal matter can't be recognized through naked eye or partially decomposed organic matter

- **O_a**–Well decomposed organic matter

A Horizon (Eluvial)

The A horizon is a surface mineral horizon that may contain accumulated organic matter and may show loss (eluviation) of clay, iron, aluminium, or other constituents.

A_1-Top most mineral horizon formed adjacent to the surface. There will be accumulation of humified organic matter associated with mineral fraction and darker in colour than that of lower horizons due to organic matter.

A2/E horizon is a zone of maximum eluviation (leaching) of clay, iron, aluminium oxides, and/or organic matter. Loss of these constituents generally results in accumulation of quartz and other sand and silt size resistant minerals. Generally light Color than horizons above and below. It is an eluvial horizon.

A_3 - a layer that lies in between the A and B horizons and is more strongly dominated by the A_1 or A_2 features than the B-horizon underneath it. Sometimes, this horizon is not present.

B Horizon (Illuvial)

This horizon is characterized by accumulation/illuviation clay, iron, aluminum, or humus, either separately or in combination. Coatings of sesquioxides will impart darker, stronger of red colour than overlying or underlying horizons.

The illuvial horizon is the middle layer in which the substances that were leached from horizon A have been redeposited.

B_1-A transitional layer between A and B. More like A than B.

B2 - Zone of greatest clay, iron, and aluminum oxide concentration that may have moved from upper layers or may have formed in situ. Compared to A2 horizon, the organic matter content is generally higher and the colour is darker.

B_3 - Transitional horizon between B and C with characteristics that are more similar to those of the underlying B_2 than the C horizon itself.

C Horizon

- The parent material from which the soil is formed is known as horizon C.
- The horizon beneath the solum (A+B), which is comparatively lessaffected by soil-forming processes.
- It lies below the solum and is comparatively little affected by soil-forming processes.
- It may contain accumulation of carbon or sulphates, calcium, and magnesium.

R layer

It might or might not be similar to the parent rock from which the solum is generated in the underlying consolidated bedrock.

Lithological discontinuity is a phenomenon that occurs when two or more genetically unrelated (contrasting) materials are present in a profile, as in the case of alluvial or colluvial soils. Additionally, master horizon unique characteristics are denoted by lowercase characters. The case letters adhere to the master horizon subdivisions. The master horizons are prefixed with Roman letters, which serves as an indication.

Special Features

Soil Individual (Pedon/Polypedon) – The Soil Survey Staff (1960) defined the soil individual or polypedon (Pedon, Ground) as a natural unit of soil that differs from its adjoining unit on the

landscape in one or more properties. A polypedon is therefore, defined as a a contiguous group of similar pedons bounded on all sides by "not- soil or by pedons of unlike characters. It is a real physical soil body which has a minimum area of more than 1 km² and a non-specified maximum area.

Pedon – The term pedon has been proposed for small basic soil entities that are part of the continuum mantling the land. A pedon is the smallest volume that can be called "a soil". Its area is 1–10 m². The set of pedons must fit within the range of one series and occur in a contiguous group to form a polypedon.

Regolith – The layer of rock and mineral that rests on bedrock and is produced by the weathering of rocks. It includes A, B and C horizons

Significance

i. Helps in classification of soil
ii. Helps in delineating problematic areas and in development of rational land use plans
iii. Helps in assessing the agricultural value of land
iv. A Study of soil profile is important as it is historic record of all the soil forming processes and it forms the basis for the study in pedagogical investigations
v. It forms the basis for the practical utility of soils.

Subordinate Distinction Within Master Horizons and Layers

- Highly decomposed organic matter
- Buried genetic horizon
- Concretions or nodules
- Coprogenous earth
- Physical root restriction/dense unconsolidated material
- Diatomaceous earth
- Intermediate decomposed organic matter
- Frozen soil or water
- Dry permafrost
- Strong gleying
- Illuvial accumulation of organic matter and sesquioxide
- Slightly decomposed organic matter
- Accumulation of jarosite (K or Fe sulfate minerals)
- Evidence of cryoturbation
- Accumulation of carbonates
- Cementation
- Marl
- Accumulation of sodium
- Residual accumulation of sesquioxides
- Tillage and other disturbance
- Accumulation of silica
- Weathered soft bedrock

- Illuvial accumulation of sesquioxides and organic matter
- Presence of slickensides
- Accumulation of silicate clays
- Plinthite
- Development of colour or structure
- Fragipan characteristics
- Accumulation of gypsum
- Accumulation of salts more soluble than gypsum

Material required

Spade, Shovel, Auger, cutting knife, measuring tape, Compass, Munsell soil color chart, Dilute HCl (1N), Water bottle, Magnifying lance, Soil pH kit, Tray, Sample bagset c.

Procedure

1. **Selection of site** (as per soil sampling)
2. Digging of soil profile– The pit should be dug in such a way that the sun is at the back of the person with a dimensions of 2 × 1.25 × 1.5 m (deep soil), up to bedrock or parent material (shallow soil), and up to the water table (water logged soil).

General description of soil profile and its site

- Profile no e.g., S1, S2
- Location (longitude, latitude, direction, distance etc. from a referencepoint)
- Date of examination
- Author's name
- Soil name (family, series e.g., coarse, loamy, mixed, hyperthermic, loamy sand)
- Higher category of classification (USDA Soil Taxonomy)
- Climate conditions (rainfall and temperature)
- Area
- Slope
- Stoniness
- Additional remark
- Vegetation and land use
- Parent material
- Physiographic positions (terrace, flood plain, depression, plateau, valleybottom etc.)
- Landforms (flat having slope <1%, undulating having slope 1–5%, rolling having slope 5–15%, hilly having slope 15–25%, mountainous having much slope)
- Elevation
- Drainage conditions (drainage class like – runoff and permeability, thedrainage facilities are poor, imperfect or excessive
- Depth of ground water (meters)
- Moisture conditions
- Artificial drainage
- Biological activities (krotovinas and agrotubules, root development)

- Erosion (slight-e1, moderate-e2, severe-e3)
- Presence of salt and alkali
- Human influence (tillage, leveling, fertilization etc.)

Nature of the Boundaries with the Horizons (Five classes)

Abrupt (a)	Change Takes Place within 2 cm
Sharp (s)	Change Takes Place within 2-5 cm
Clear (c)	Change Takes Place within 5-10 cm
Gradual (g)	Change Takes Place within 10-20 cm
Diffuse (d)	Change Takes Place within >20 cm

Nature of Boundaries from Soil to Soil

Smooth (s)	almost straight
Wavy (w)	gently undulating
Irregular (ir)	with regular lobes
Irregular(ir)	strongly undulating mamillated
Tongued (t)	forming tongues into the underlying horizons shallow and deep tongues

When a horizon is thin, the change in distinctness is sharp and when it is thick,they tend to have merging boundaries.

Exercise No. 7
Determination of Soil Colour

Classification of Soil Colour

1. Lithochronic colour – This colour is inherited from the original parent material. Red from hematite, yellow from limonite, white from calcite and silica
2. Acquired or genetic colour – This colour is formed by some special factors and conditions at the time of soil formation. For example, colours may be inherited from schist or granite and modified during soil formation.

Causes of Soil Colour

- **Organic matter –** black or dark brown
- Iron and other compounds – red (dry area), red to yellow (due to FeO in moist area), red (due to ferric iron in aerobic condition), brown (due to ferrous iron in anaerobic conditions)
- **Silica, lime and other compounds –**brown (Si and Al), grey (SiO_2)

Determination of Soil Colour

Soil colour is measured with Munsell soil colour chart with the help of hue, value, and chroma

Hue

It is the dominant spectral colour (Red, yellow, green etc.) and related to the wavelength of light. It identifies the quality of colour perceived by the eye. Thus 5YR lies between the red and yellow-red hue ranges which extend from 10R (0 YR) - 10YR (0 Y). The standard chart for soil colour has cards from 10R through 5YR hue, a total of seven cards

Value

It is a measure of degree of darkness or lightness of colour (brilliance) and related to the total amount of light reflected in relation to a neutral grey colour. It is a function of total light absorbed. On a neutral grey (achromatic) scale, value extends from pure black (0) to pure white (10).

Chroma

It is a measure of relative purity or strength of spectral colour. Chroma indicates the degree of dilution of colour by neutral grey of the same value. The scales of chroma for soils extend from 0 for neutral colours to a chroma of 8 as the strongest expression of colours for soils. Chroma increases with decreasing grayness or increasing chroma. For absolute achromatic colours (pure grey, white and black) which have 0 chroma and no hue, the letter N (neutral) takes the place of hue designation. In the soil colour chart, the units of a value are arranged vertically and the units of chroma are arranged horizontally on a page. Opposite to each page of colour chips is a colour notation, symbols and corresponding English name. Elements of soil colour description are the colour names, the Munsell notation, the water state (dry/moist) and the physical state. The colour of soil varies with its moisture content, a decision has to be made at what moisture condition soil colours should be determined. If it is done in the field, the only practical thing is to use moist soil. The moisture content should be high enough to show maximum darkness

Procedure

- Take a soil ped and select an appropriate hue chart by holding the ped or crushed soil

mass under the chart and match through the holes meant for the purpose in colour chart.

- Determine the colour chips with which soil colour closely matches by moving the ped vertically or horizontally
- Record the hue, value and chroma and write the Munsell notation
- Note the colour name opposite to colour chip page
- Determine the soil colour under dry and moist condition
- Write all elements of soil colour in sequence like: Pale brown (10YR 6/3), dry and moist

Where

Hue : 10YR (Chip No. 10, Yellow Red)

Value : 6

Chroma : 3

Name of Soil Colour : Pale Brown

Importance of Soil Colour

- It is an index of soil parent material, physical, chemical and biological properties
- It indicates soil fertility status
- Deep coloured soils absorb more radiation than light coloured soils
- It is basis of soil classification
- It helps in differentiation of soil horizons
- It can determine drainage conditions of soil

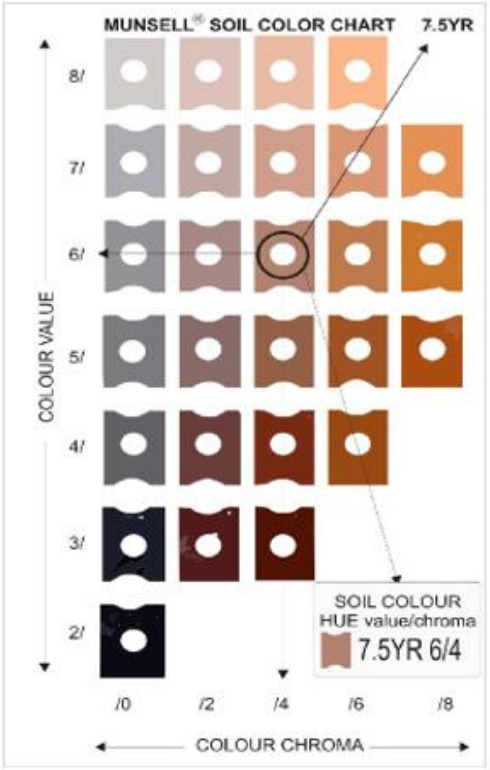


Figure 7: Schematic view of Munsell's Colour Chart

Practice Exercise:

Soil Colour in Dry Conditions

Soil sample	Hue	Value	Chroma	Munsell colour notation	Soil colour
1					
2					
3					

Soil Colour in Wet Conditions

Soil sample	Hue	Value	Chroma	Munsell colour notation	Soil colour
1					
2					
3					

Exercise No. 8
Determination of Bulk Density by Core Sampler – Undisturbed Method

Soil bulk density (ρb) is defined as the oven-dry mass of soil per unit bulk volume. Bulk volume includes the volume of soil solids plus pore space. It is expressed in g cm^{-3}. Bulk density is affected by texture, structure, organic matter content, packing, and compaction. Fine-textured soils generally have lower bulk density and higher total porosity than coarse-textured soils. Typical bulk-density ranges are about 1.1–1.5 g cm^{-3} for loams and clay loams, 1.4–1.8 g cm^{-3} for sandy soils, and as low as about 0.5 g cm^{-3} for organic soils. Bulk density commonly increases with depth because organic matter decreases and compaction/illuviation may increase.

$$\text{Bulk density (Db)} = \frac{\text{Mass of soil}}{\text{Volume of the soil}}$$

Importance:

Bulk density of a soil influences the following. Hence it is important to know pb: for determining the degree of compactness as a measure of soil structure, for calculating soil pore space, as an indicator of aeration status (for which the water content is also required), to convert soil water and nutrient values from the gravimetric to the volumetric basis, and to provide information on the environment available to the many soil micro - organisms, which live within them.

Principle:

In order to determine the mass of solids and the water content of the core, the method involves taking a soil sample from a desired depth in its most natural state using a core sampler (cylindrical metal sampler), weighing the wet core, drying it to a constant weight in an oven at 105 °C, and reweighing it after cooling (A core may take 24 hours or more to dry). Using the core length and cutting-edge diameter of the sampler, the bulk density is then determined from the bulk volume measurement.

Equipment and Apparatus:

Core sampler, vernier caliper, can boxes, oven, balance, desiccator, knife.

Procedure:

- Drive the core sampler into level ground vertically and deep enough to fill the sampler container.
- Use a khurpi or spade to remove the sampler, and then remove the sample can without damaging the soil core inside.
- With a sharp knife, remove any extra soil from the sample can's both ends.
- Weigh the sample can along with the soil to the nearest 1 g. Take out the sample and weigh the can again.
- Put some of the moist soil in a can and dry it in a 105 °C oven to determine its water content.
- Measure the length and inside diameter of the sample can.
- Volume of soil = inside volume of the can = $\pi r^2 l$

Data Sheet

Observation:

Radius (r) = _____ cm; **Length (l)** = _____ cm of the soil sample

Sr. No.	Observation	Value
a.	Weight of can box	= _____ g
b.	Weight of can box + moist soil	= _____ g
c.	Weight of can box + dry soil	= _____ g

Calculation:

Sr. No.	Calculation	Value
d.	Volume of the soil (Whole core) = $\pi r^2 l = 3.14 \times r^2 \times l$	= _____ cm^{-3}
e.	Weight of moist soil (whole core) (b − a)	= _____ g
f.	Weight of oven-dry soil (c − a)	= _____ g
g.	Dry Bulk density of the soil (f/d)	= _____ g cm^{-3}
h.	Wet Bulk density of the soil (e/d)	= _____ g cm^{-3}

Result:

The Dry Bulk density of the soil is _____ g cm^{-3}

The Wet Bulk density of the soil is _____ g cm^{-3}

Exercise No. 9
Determination of Bulk Density by Pycnometer – Disturbed Soil Method

Principle:

Bulk density or apparent density or apparent specific gravity is the mass per unit volume of the soil bulk including both solid and pore space. It is expressed as $gcm{-}3$

$$\text{Bulk density (Db)} = \frac{\text{Mass of soil}}{\text{Volume of the soil}}$$

BD has greater importance than PD in understanding the physical behavior of soils. Bulk density increases with soil depth due to decrease in organic matter. The bulk density of sandy soil is 1.6 $gcm{-}3$, loamy or clay soil has 1.1 $g\ cm{-}3$. For good plant growth, bulk density should generally be below about 1.4 g cm^{-3} in fine-textured soils $gcm{-}3$ for clays and 1.6 $g\ cm{-}3$ for sands. Normal soil bulk density generally ranges from 1.2-1.8 $g\ cm{-}3$ (1.65$g\ cm{-}3$)

Material Required:

Pycnometer bottle or Relative density bottle (RD Bottle) 50 mL capacity, Electrical balance, Weight box, Burette, Funnel etc.

Procedure:

1. Weigh an empty RD bottle
2. Fill with soil and tap the bottle on the table gently (20-25 times) and weigh it again
3. Fill the RD bottle with soil up to the brim and weigh it again
4. The volume of the filled soil equal to the volume of the RD bottle
5. Remove the soil from bottle and fill with water up to the brim with the help of buretteand note the volume of water

Observations:

Sr. No.	Observation	Value
1.	Weight of empty RD bottle (W_1)	= _____ g
2.	Weight of bottle + soil (W_2)	= _____ g
3.	Volume of water needed to fill the bottle (V)	= _____ g
4.	Weight of soil ($W_2 - W_1$)	= _____ g
5.	Volume of soil (V)	= _____ g

Calculations:

Bulk density (D_b) $= \frac{\text{Weight of soil bulk}}{\text{Volume of soil bulk}}$ *or* $\frac{\text{W2-W1}}{\text{V}}$ ……g cm^{-3}

Result:

The Bulk density of the soil is……$g\ cm^{-3}$

Exercise No. 10
Determination of Particle Density with the Help of Pycnometer

Introduction:

Particle density (p) is the mass (weight) of a unit volume of soil solids and is expressed in metric units in grams per cubic centimeter. The particle density for most mineral soil varies from 2.60 to 2.75 g cm^{-3}, with an average value of 2.65 g cm^{-3}, as the bulk of the soil consists of quartz, feldspars, and colloidal silicates. Values >2.75 are, however, achieved when heavy mineral particles, such as magnetite, garnet, epidote, zircon, tourmaline, and hornblende, are present in very high concentrations. Particle density in soils with significant levels of organic matter will be about 2.4, as one cubic centimeter of organic matter weighs less than an equivalent volume of mineral solids. Because of this, subsurface soils have a higher particle density than surface soils. Fineness as well as arrangement of soil particles do not affect particle density.

Importance:

Understanding the particle density of soil is crucial for understanding volume relations such as porosity, bulk density, and void ratio. During particle size analysis, particle density is utilized to determine the settling velocity of particles of various sizes.

Method of Determination:

The weight and volume of solids are measured to determine the particle density. Weighing a sample of oven-dried soil determines the weight of soil solid while volume of solid determined by immersion. The "Pycnometer technique" is the approach described here.

Principle:

A given amount of dry soil when immersed in a definite volume of water expels air and results in the displacement of equal volume of water. The volume of soil particles is determined by measuring the volume of water displaced in the pycnometer bottle.

Apparatus:

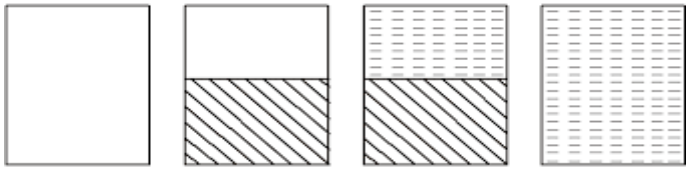
A pycnometer, pipette (20 mL cap): an analytical balance; a water bath or hot plate, filter papers.

Precautions

- All air must be expelled from the soil sample while saturating it with water
- Clean and dry the outer surface of pycnometer before each weighing
- With every weighing, always keep the lid along with the RD bottle

Procedure

- Weight the RD bottle
- Place a small amount of dry soil (10 g) in the RD bottle and weigh it
- Add a small amount of hot water and shake for about 10 minutes to expel entrapped air from the soil
- Fill the bottle completely with hot water and weigh again
- Empty the bottle, wash it properly and fill boiled and cool distilled water and record the weight of bottle



Observations

1. Weight of empty Pycnometer (RD bottle) …….……g
2. Weight of pycnometer (RD bottle) + soil …..……..…g
3. Weight of pycnometer (RD bottle) + water + soil …….…..g
4. Weight of pycnometer (RD bottle) with water ……...…...g

Calculation:

Particle density (g cm^{-3}) = $\frac{\text{Mass of the soil}}{\text{Volume of the soil solids}}$ or $\frac{\text{b-a}}{\text{(d - a) - (c - b)}}$ …….g cm^{-3}

Results: The Particle density of the soil is……$g\ cm^{-3}$

Figure 8: Schematic view of Pycnometer (RD bottle)

Exercise No. 11
Determination of Soil Texture by Feel Method

Soil is composed of both organic and inorganic solid particles. The inorganic fraction directly comes from the decomposition of rocks and minerals. The breakdown of large masses of rocks and minerals leads to their fragmentation into smaller size individual grains. Many times besides changing their physical behavior, they change their chemical characteristics during this process. The reduction in size is the basic criterion to term these fragmented portions of rocks and minerals as soil solids, only those grains having diameter less than 2 mm in size are considered as soil. The term texture means the surface characteristics of a body, characteristics is the manifestation of the distribution of the constituent soil grains in a mass of soil. It refers to the relative proportion of the soil grains or particles in various sized groups within the 2 mm size range as mentioned earlier. The various size groups are termed sand, silt and clay depending upon their size. The nomenclature based on the size of particles is somewhat arbitrary. Besides there are a number of systems followed in different parts of the world. However, the systems adopted by United States Department of Agriculture (USDA) and International Society of Soil Science (ISSS) based on the former two, are the most common. These are as under.

Diameter range (mm)		**Diameter range (mm)**		**Diameter range (mm)**	
Name of particles	**Diameter range (mm)**	**Name of Particles**	**Diameter of Particles**	Coarse sand	2.0–0.2
Fine gravel	2.0-1.0	Very coarse sand	2.0-1.0	Fine sand	0.2–0.02
Coarse sand	1.0-0.2	Coarse sand	1.0-0.5	Silt	0.02–0.002
Fine sand	0.2-0.04	Medium sand	0.5-0.25	Clay	<0.002
Coarse silt	0.04-0.01	Fine sand	0.25-0.10	Fine sand	0.2-0.02
Fine silt	0.01-0.001	Very fine sand	0.10-0.05		
Clay	<0.002	Silt	0.05-0.002	Silt	0.02-0.002
		Clay	<0.002	Clay	<0.002

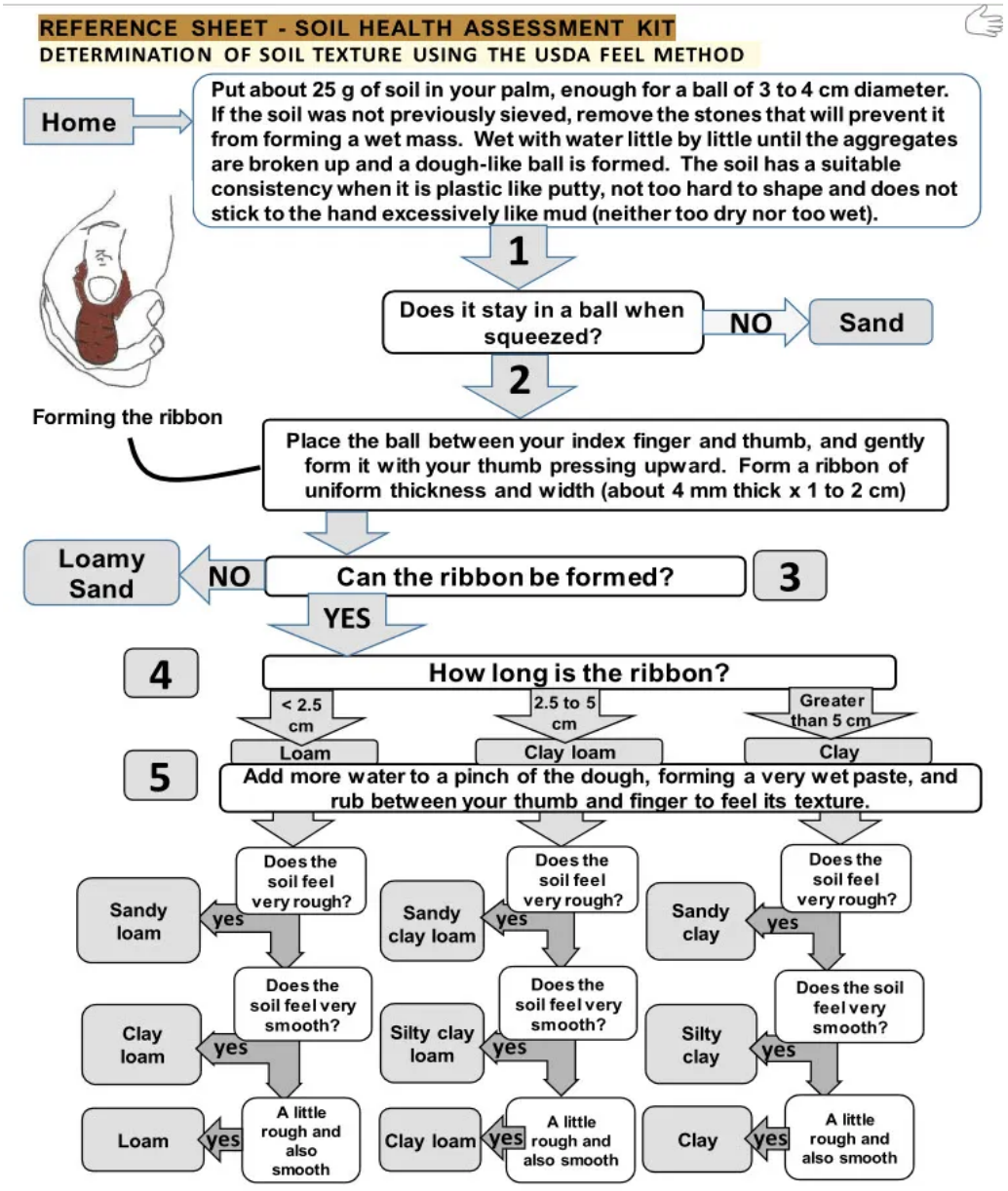
Soil texture by feel method

The soil textural class can be determined in the field by feel of the soil between the fingers. The method is based on the differential feeling of moist soil. As the term texture indicates, individual soil particles feel differently. The sand particles feel gritty when the soil is rubbed in between fingers. The silt particles feel smooth and powdery. The clay particles feel smooth, sticky and plastic when the soil is moist. Different soil particles and texture class exhibit different degree of ball formation and ribbon formation. These properties are used to define soil textural class in the field by feel method. This method is however arbitrary and requires skill and experience for arriving at a definite degree of accuracy of the determination.

Procedure:

1. Take about 25 g of soil in your hand,
2. Moisten the soil with a few drops of water.

3. Feel the grittiness or smoothness of the soil by rubbing it in between fingers,
4. Press the moist soil in between your thumb and forefinger.
5. Observe whether it stains the fingers
6. Observe whether balls or ribbons can be formed by rolling the moist soil in between thumb andfingers.
7. Name the soil textural class from the observations as given in table 2



Data Sheet

Observations

Feel of finger	Ball formation	Stickiness	Ribbon formation	Textural class

Exercise No. 12
Determination of soil texture by the hydrometer method

The Hydrometer method (Bouyoucos, 1927) measures the density of soil-water suspension at the elevation of its bulb, which is related to the amount of sediment still suspended at that elevation. It is based on the principle of continuous reduction in the density of the soil suspension with time at a rate at which soil particles drop below the level of Hydrometer. This method is based on stokes law, which states that the rate of fall of particles in a suspension is directly proportional to their size.

G. G. Stokes (1851) suggested the relation between the radius of a particle and its rate of fall in a liquid. Accordingly, larger particles will settle first, followed by silt and then by clay. He stated that the resistance offered by the liquid to the fall of the particle varies with the radius and is inversely proportional to the viscosity of the medium. This law is used to calculate the settling time of soil fraction in soil suspension. The law relates the settling velocity of a particle to its radius

$$V = \frac{2gr(D-d)}{9\eta} \; or \; (gr2)$$

Where,

V = Rate of fall of particles in suspension (cm/second)

G = Acceleration due to gravity (cm s^{-2})

r = Radius of particles (cm)

D = density of the particle or particle density (g/cm^3)

d = Density of water (g/cm^3)

Ƞ = absolute viscosity of the liquid (poise)

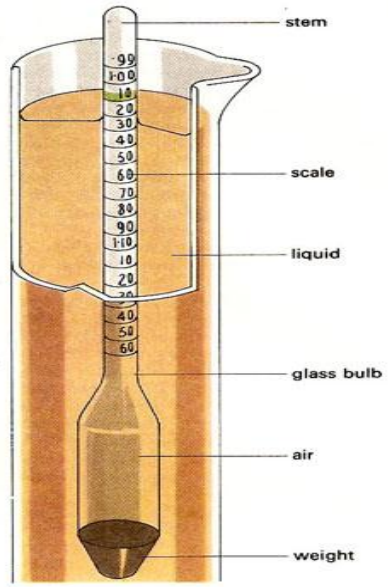


Figure 9: Schematic view of Hydrometer for soil texture

Material required:

Hydrometer (Bouyoucos), Thermometer, Electrical stirrer, Metal cup, Stopwatch, measuring cylinder 1 liter

Reagent:

Dispersing agent (10% Calgon solution): - 100g Sodium Hexa-metaphosphate in 1-liter distilled water and filter paper (Whatman no. 1). It gives hydrometer reading of 40-42 at 20° C

Procedure:

- Weigh 50 g fine-textured soil or 100 g coarse-textured soil (>75-80 % sand) which have been passed through a 2 mm sieve based on oven-dry condition into a 500 ml beaker.
- Add 50 ml of 6% H_2O_2 and cover the beaker with a watch glass and place it on a water bath until oxidation of organic matter is completed.
- Remove the beaker and cool. After cessation of frothing, transfer the contents into a dispersing cup with about 400 mL of distilled water. Add to it 100 mL of calgon solution.
- Stir the suspension for 10 minutes by an electric stirrer. Transfer the suspension into a litre graduated cylinder and make up the suspension up to 1 L mark with distilled water.
- Stopper the cylinder mouth and shake vigorously upside down and back several times for about 1 minute.
- Place the cylinder on a table and note the time immediately.
- Dip the hydrometer into the suspension and take the first reading after 40 seconds for the sand + silt fraction under the stated method (Start inserting the hydrometer 10 seconds in advance of the reading time)
- Carefully remove the hydrometer and wash with distilled water and note down the temperature of the suspension.
- Calculate the percentages of sand, silt, and clay and determine the textural class using ISSS textural triangle.

Temperature correction

The Hydrometer is calibrated at 68 °F. The temperature correction is 0.2 times °F. The product above 68 °F is added to the Hydrometer reading and the product below 68 °F is subtracted. If required, the conversion formula is: $5/9 \times (F - 32)$ for °C and $9/5 \times C + 32$ for °F

Observations

Sr. No.	Observation	Value
1.	Weight of empty RD bottle (W_1)	= _____ g
2.	Weight of bottle + soil (W_2)	= _____ g
3.	Volume of water needed to fill the bottle (V)	= _____ g
4.	Weight of soil ($W_2 - W_1$)	= _____ g
5.	Volume of soil (V)	= _____ g

Exercise No. 13
Determination of Soil Texture by the International Pipette Method

The various size groups present in soil are sand, silt and clay. Each size group is known as "soil separates," which have different sizes. According to the International Society of Soil Science (ISSS), the diameter of the soil separates are as follows:

Separate	Diameter limit (mm)
Coarse sand	2.0-0.2
Fine sand	0.2-0.02
Silt	0.02-0.002
Clay	<0.002

Method for the estimation of soil separates

By particle size analysis, the proportion of sand, silt, and clay present in a soil can be determined. There are two methods for particle size analysis: the Hydrometer method and the International Pipette method. The hydrometer method is a rapid method. However, the International Pipette method is considered to be the most accurate method.

Material required: Beakers (50, 100 and 500 ml), Electric stirrer, Hot plate, graduated 1000 ml cylinder, watch glasses, Pipette, Oven, Desiccators, Moisture cans, Balance, set of sieves having diameters of 0.2 mm, and 0.02 mm

Reagents: 35% hydrogen peroxide (H_2O_2), 0.3 M sodium citrate (Dissolve 88 gms sodium citrate in 1 litre distilled water), 1 M sodium bicarbonate (Dissolve 84 gms sodium bicarbonate in 1 litre distilled water), sodium dithionite, sodium hydroxide solution.

Procedure:

- Place 20 g of a 2 mm air-dry sample into a 500 mL beaker
- Add about 10 mL of 35% H_2O_2 and cover with a watch glass.
- After the reaction has subsided, add another 5 mL of 35% H_2O_2 and leave the sample overnight for digestion.
- Place the sample on a hot plate at a low temperature for further digestion, with additional H_2O_2, until frothing ceases. Allow the digestion process to continue on the hot plate to remove excess H_2O_2, but the sample should not be allowed to dry out.
- Soil adhering to the sides of the beaker or watch glass is washed down with distilled water.
- Add 45 mL 0.3 M sodium citrate and 5 ml 1 M sodium bicarbonate to the soil solution. Add 1 g sodium dithionite thrice with stirring every time.
- Add 10 mL of sodium hydroxide solution to disperse the soil materials.
- Transfer the contents of the beaker into a stirrer cup and stir for 10 minutes at medium speed.
- Place a sieve of 500 mesh in a large funnel held above a 1000 mL cylinder. Transfer the contents of the cup into the sieve and wash until the water passing through is clear.
- Transfer the sand into a tarred 100 mL beaker.
- Siphon off excess water from the beaker and dry the sand at 105°C. Cool in a desiccator and weigh the fine sand fraction.

- Transfer the sand through a 72 mesh sieve.
- Weigh and record the coarse sand fraction.

Separation of silt and clay

- Bring the volume of the cylinder containing the silt and clay suspensions up to 1000 mL by adding distilled water and cover with a watch glass.
- Insert a perforated plunger into the bottom of the cylinder and stir vigorously for several seconds to loosen any sediment.
- Remove plunger and draw off a 25 mL aliquot from a depth of 10 cm. Place aliquot into a tarred 50 mL beaker, along with rinse water from pipette.
- Dry at 105oC, cool in a desiccator and weigh to 4 decimal places.

Separation of clay

- Maintain the cylinder in a controlled temperature until the silt greater than 0.002 mm settles below 10 cm. (See Table 1).
- Remove a 25 mL aliquot from a 10 cm depth below the suspension surface. Put the aliquot into a 50 mL beaker along with rinse water from the pipette.
- Dry, cool, and weigh as previously described.

Observations and Calculations

Observation and Calculations

Soil Sample No. = _____

Sr. No.	Observation / Calculation	Value
a.	Weight of the soil taken	= **W g** = _____
b.	Weight of dish	= **W_1 g** = _____
c.	Weight of dish + total sand	= **W_2 g** = _____
d.	Weight of total sand	= **($W_2 - W_1$) g** = _____
e.	**Per cent coarse sand**	= _____ × 100 = _____ %
f.	Weight of the soil taken	= **W g** = _____
g.	Weight of dish	= **W_3 g** = _____
h.	Weight of dish + fine sand	= **W_4 g** = _____
i.	Weight of fine sand	= **($W_4 - W_3$) g** = _____
j.	**Per cent fine sand**	= _____ × 100 = _____ %
k.	Weight of the soil taken	= **W_5 g** = _____
l.	Volume of suspension taken for analysis	= **25 mL** = _____
m.	Weight of dish + (silt + clay)	= **W_6 g** = _____
n.	Weight of silt + clay	= **($W_6 - W_5$) g** = _____
o.	**Per cent (silt + clay)**	= _____ × 100 = _____ %
p.	Weight of the soil taken	= **W_7 g** = _____
q.	Volume of suspension taken for analysis	= **25 mL** = _____
r.	Weight of dish + clay	= **W_8 g** = _____
s.	Weight of clay	= **($W_8 - W_7$) g** = _____
t.	**Per cent clay**	= _____ × 100 = _____ %

Calculation of Fine Sand

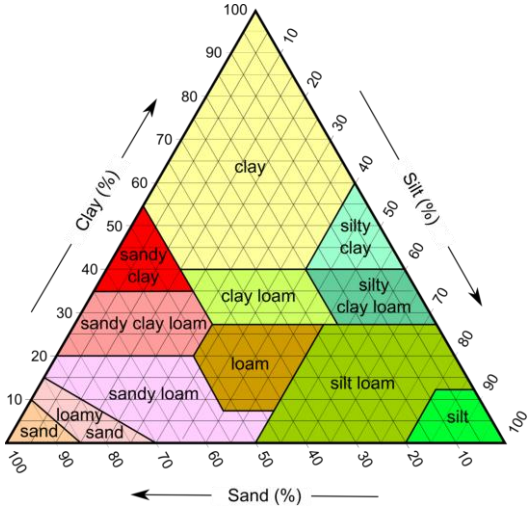
Fine sand (k) can also be calculated by subtracting coarse sand (%), silt (%) and clay (%) from 100.

i.e. Fine sand (%) = 100 − (e + o) = _____ %

Table 1: Setting time for silt and clay (10 cm depth) at different temperatures (Sedimentation Time Chart)

Temperature (°C)	Pipetting Time (Upper limit) for silt (0.02 mm diameter)	Pipetting Time (Upper limit) for clay (0.002 mm diameter)
15	5 min 30 sec	9 hrs 05 min
16	5 min 20 sec	8 hrs 50 min
17	5 min 30 sec	8 hrs 35 min
18	5 min 00 sec	8 hrs 25 min
19	5 min 00 sec	8 hrs 10 min
20	4 min 48 sec	8 hrs 00 min
21	4 min 40 sec	7 hrs 50 min
22	4 min 30 sec	7 hrs 40 min
23	4 min 30 sec	7 hrs 25 min
24	4 min 20 sec	7 hrs 15 min
25	4 min 15 sec	7 hrs 07 min
26	4 min 10 sec	6 hrs 55 min
27	4 min 05 sec	6 hrs 45 min
28	4 min 00 sec	6 hrs 40 min
29	3 min 55 sec	6 hrs 30 min
30	3 min 50 sec	6 hrs 20 min
31	3 min 45 sec	6 hrs 15 min
32	3 min 40 sec	6 hrs 10 min
33	3 min 35 sec	5 hrs 55 min

A textural triangle has been developed with different classes of textures as shown in the figure.



Data Sheet

Sl. No	Per cent Soil Fraction				Texture
	Coarse Sand	Fine Sand	Silt	Clay	

Exercise No. 14
Determination of Soil Structure

Soil structure refers to an arrangement of soil particles, both primary and secondary. Soil structure is an important property because as it influences soil aeration, soil moisture attributes, soil temperature, permeability, water capacity and soil erosion. Improvement in soil structure increases infiltration and permeability which in turn reduces soil erosion.

There are different types of soil structure:

1. Platy: In this type, the aggregates are horizontal plates. The horizontal axes are larger than the vertical axis.
2. Prismatic: the vertical axis is more developed than the horizontal axis which gives a pillar like shape.
3. blocky: Here all three dimensions are about the same size and the aggregates appears to be blocks. It may be angular blocky or subangular blocky.
4. Spheroidal (sphere like): All rounded aggregates (peds) may be placed in this category. The aggregates of this group are usually termed as granular which are relatively less porous. When the granules are very porous, it is termed as crumb. This is specific to surface soil particularly high in organic matter.
5. Structureless: Represents a condition in which there is no observable aggregation of soil. It is called 'massive' if the soil mass is coherent and 'single grain' if the soil mass is non-coherent.

Soil Structure and Structural Code

Structure	Code (S)
Very fine granular	= 1
Fine granular	= 2
Medium or coarse granular	= 3
Blocky (subangular/angular), massive	= 4

Observations and Calculations

Particulars	Observation
Soil Sample No.	= _____
Soil Structure	= _____
Structural Code	= _____

Exercise No. 15
Assessment of Aggregate Status in Soil Using Yoder Apparatus

Primary soil particles come together and adhere to each other due to action of different aggregating agents to form secondary larger sized particles called aggregates. The presence of these aggregates serves to maintain a good physical condition of the soil for plant growth. The stability of these aggregates against the action of water is an important parameter that helps maintain proper soil permeabi8lity to air, water and plant roots especially during the early stages of growth. Aggregates stability has often been found to correlate well with water retention and transmission parameters. The size distribution of aggregates determines the vulnerability of soil to wind and water erosion and dimension of pore space in cultivated soils.

Determination of size distribution of aggregates depends upon them purpose for which it required. Since the purpose often varies, the methodology adopted also differs. In general resistance of the aggregates in different size ranges against breaking down in any arbitrary water treatment. The treatment may consist of stirring, shaking, elutriation or impact of dropping water. The two most common methods of determination are described here.

Dry sieving

This method determines the size distribution of aggregates in the dry state and approximately represents conditions relevant to wind erosion.

Equipment and materials.

Rotary-sieve machine; concentric sieves of various mesh sizes; balance

Sampling

Collection of samples with least disturbance is important as the aggregates must not be subjected to any other force for breakdown. Hence the sample should preferably bed collected at the dry condition. A large dry sunk of soil mass should be excavated and carefully placed on a tray.

Sieving

- A nest of sieves of appropriate mesh sizes is arranged on a rotary sieve shaker in descending order of mesh size.
- Place a pan of same size at the bottom of the series of sieves.
- Place about 50 gms of the dry sample on the top sieve.
- At the same time determine the water content in the sample by placing it in a hot air oven.
- Cover the top sieve with another pan of same size. This is to prevent materials from being lost during shaking. Place the nest of sieves on the shaker and bolt it tightly.
- Run the machine for 5 minutes if the soil is coarse textured and for 10 minutes if the soil is fine textured.
- Remove the sieves of various sizes and collect the aggregates on it in an weighing dish.
- Record the weight of the materials on each sieve
- Place the materials on each sieve back on it
- Add water to each sieve so that the aggregates are broken and the stones remain on the sieves.

- Record the weight of the stones in each size range.
- Sum up the each size fraction of stones and aggregates separately and thus obtain the total amount of soil taken.

Calculation:

Particulars	Value / Formula
Weight of a particular size of aggregate in sieve	W g
Per cent water content in the sample	θ
Water content in the aggregate	$W_1 = W \times (\theta / 100)$ g
Weight of stones in each size range	W_3 g
Corrected oven-dry weight of aggregate	$W_4 = (W - W_1 - W_3)$ g
Total weight of aggregates in sieve	W_1 g
Per cent content of aggregate	$W_p = (W_x / W_t) \times 100$

Size	**W**	**θ**	**W_1**	**W_3**	**W_4**	**W_p**

Wet aggregates

Water can break down unstable aggregates, reducing the proportion of aggregates in larger size classes. The magnitude of breakdown depends on the strength and nature of the bonding agents and varies with soil type and management. Wet-sieving procedures approximately simulate aggregate disruption by water. Unlike dry aggregates, in this case also care is taken not to disrupt the natural aggregates due to action of other forces except that of water. Distribution of aggregates in a mass of soil is determined after imposing water treatments to assess the magnitude of stability with the help of several indices for its characterization. The water stable aggregates are collected in different sieve s in a nest of sieves like that of dry sieving.

Very small crumbs may remain intact during wet sieving; therefore, the lower sieve limit is selected according to the standard method being followed. Water temperature can affect aggregate stability, so water at room temperature is generally preferred unless the method specifies otherwise.

Sampling: Same as that of dry sieving

Equipment and materials.

A Yoder type sieve shaking electrically operated machine (3/4 inch stroke at 29 strokes per minute), concentric sieves of various sizes to fit into the machine sieve-hold of the machine, balance.

Procedure

- Dry sieve the sample to separate the 3-5 mm size range of aggregates
- Determine the water content of the sample as in dry sieving
- Prepare a nest of sieves starting from 2 mm at the top to 0.05 mm at the bottom
- Place a pan at the bottom of the nest of sieves.
- Place around 50 g of this 3-5 mm sized sample on the 2 mm sieve at the top.
- Carefully and slowly immerse the sample and sieves into the water tank of the machine.
- Pre-soak for around 1 minute

- Shake the nest of sieves with the sample in the machine for the time specified by the Yoder wet-sieving procedure being followed.
- Remove the nest of sieves carefully and slowly so that jerking action does not affect the distribution. Place the materials in each sieve and the pan on weighing dish.
- Oven dry the materials in the weighing dish at 105 °C in a hot air oven.
- Determine the percentage of aggregates in the sample.

Calculation

Particulars	Value / Formula
Weight of a particular size of aggregate in sieve	W g
Per cent water content in the sample	q
Water content in the aggregate	$W_1 = W \times (q / 100)$ g
Weight of stones in each size range	W_3 g
Corrected oven-dry weight of aggregate	$W_4 = (W - W_1 - W_3)$ g
Total weight of aggregates in sieve	W_t g
Per cent content of aggregate	$W_p = (W_4 / W_t) \times 100$

Size	W	g	W_1	W_3	W_4	W_p

Computation of different indices of characterization

Higher percentage of large sized aggregates in a soil mass is always helpful for agricultural purposes. The expression of size distribution of aggregates of different sizes individually, often does not indicate the proper implications of the distribution. Hence attempt is made to arrive at a single parameter indicate of the distribution and its implications. Several parameters can be computed for this purpose.

Mean weight diameter (MWD)

It was suggested originally by van Bavel (1949). Later Yonker and McGuiness (1956) suggested a summation equation type calculation. The MWD is calculated as follow:

$$MWD = \sum_{i=1}^{n} d_i W_i$$

Where,

d_i = mean diameter of each size fraction

W_i = the proportion of the total sample weight occurring in the size fraction.

n = number of size classes of aggregates.

Observations and results

Wet aggregates

Size	W	q	W_1	W_3	W_4	W_p
					MWD =	

Exercise No. 16
Determination of Soil Moisture Content

Direct or indirect measurements of soil water content are needed in practically every every type of study. Soil water content has generally been reported as the ratio of the mass of water present in a soil sample to the mass of the sample after it has been dried to a constant weight, or as the volume of water present in a unit volume of the sample. Water content is usually a dimensionless ratio of two masses or two volumes or is given as a mass per unit volume. When either of the dimensionless ratio is multiplied by 100, such values become percentages and the basis (mass or volume) should be stated. Where no indication is given, the value generally may be assumed to be on a mass basis because the determination usually involves getting mass basis values first and then converting them to volume basis values. There are several methods for determining soil moisture content. These are:

1. Gravimetric method
2. Volumetric method
3. Neutron scattering method
4. Gamma ray attenuation method
5. Soil moisture tension method

Direct Method (Gravimetric method)

Principle

This is the simplest and most widely used method for measuring soil moisture. The principle involves sampling a mass of soil from the desired depth and then measuring its moist weight. Then the sample is dried to a constant weight in hot air oven and measured its dry weight after cooling. The loss in weight is expressed as percentage of dry soil mass.

Equipment

Sampling auger; moisture cans (Numbered); balance with weights; drying oven; desiccator

Procedure

1. Collect soil samples by a tube or auger from a number of points within the experimental site and mix thoroughly
2. Place composite sub-samples of about 50 gm to 100 gm of soil in moisture cans with tight fitting lids.
3. Take at least three sub-samples
4. The moist samples are weighed immediately
5. Put the moist soil in can in a hot air oven at 105 °C for 24 hrs.
6. Take out the soil with can and reweigh after cooling in desiccator
7. Determine the tare weight of the moisture cans.
8. Calculate the soil moisture content by determining the loss in weight on drying and the weight of the oven-dry soil as follows.

Observations and calculations

Sr. No.	Particulars	Value
a.	Weight of moist soil with can (W_1)	= _____ gm
b.	Weight of dry soil with can (W_2)	= _____ gm
c.	Weight of can (W_3)	= _____ gm
d.	Weight of water present ($W_2 - W_1$)	= _____ gm
e.	Weight of dry soil ($W_2 - W_3$)	= _____ gm
f.	$\frac{Weight\ of\ water}{\text{Weight of dry soil}}$f. Moisture content by weightt (%)	= x 100……%

Volumetric method

Sometimes, it is more expressive to denote the moisture content as the ratio of the volume of water to the bulk volume of the soil or the equivalent ratio of the depth of water in a given soil area to a given depth of soil.

Equipments

Sampling tube or core sampler; moisture cans; balance and weights; hot air oven desiccator.

Procedure:

1. Collect soil sample as outlined in determination of bulk density.
2. Weigh the wet sample in a moisture can.
3. Follow the procedure as gravimetric determination
4. Calculate the volume of soil as inner volume of the core sampler
5. Express the moisture content on volume basis.

Observations and Calculationss.

Sr. No.	Particulars	Value
a.	Weight of moist soil with can, W_1	= _____ gm
b.	Weight of dry soil with can, W_2	= _____ gm
c.	Weight of can, W_3	= _____ gm
d.	Weight of water present ($W_1 - W_2$)	= _____ gm
e.	Weight of dry soil ($W_2 - W_3$)	= _____ gm
f.	Internal radius of the core (r)	= _____ cm
g.	Length of the core sampler (l)	= _____ cm
h.	Moisture content by weight	= _____ %
i.	Volume of water present	= _____ cm^3
j.	Volume of the soil (whole core), ($\pi r^2 l$)	= _____ cm^3
k.	Moisture content by volume = (Volume of water / Volume of soil) × 100	= _____ %

Relationship between percentage of moisture on weight basis and percentage of moisture on volume basis.

Volumetric water content (%) = gravimetric water content (%) × bulk density (g cm^{-3}).

Exercise No. 17
Determination of Single-Value Soil Constants by Hilgard Apparatus or Keen–Raczowski Box

A number of soil parameters that can be used as a single-value constants by a single apparatus are:

a. Bulk density of processed soil
b. Particle density of soil
c. Total porosity
d. Maximum water holding capacity
e. Water per cent in air-dry soil
f. Volume expansion

Introduction

The soil properties which can be used as a single number (unlike mechanical analysis which is a group of figures) for characterizing soils are known as 'single value constants. Some of them as listed above can be determined in a single test with the help of the maximum water-holding capacity is measured when the soil is in hydraulic equilibrium with a free-water surface touching its lower surface.

Importance

A knowledge of water holding/retaining capacity of soil together with its bulk density helps in calculating the pore volume of soil in studies related to dynamics of salts or nutrients.

Principle

With the capillary rise of water, the soil immediately above a water table gets saturated. The height up to which the soil is saturated depends upon the texture, structure and packing of the soil mass. The experimental technique discussed herein permits approximation of a few physical soil constants, while determining the amount of water held in soil at the point of saturation.

Apparatus

Keen box (K.Box,2); flat bottomed soaking tray; vernier calipers; spatula; physical balance; sieve (2 mm); watch glass; oven; scissors and filter paper.

Procedure

- Measure the radius and depth of a K. box with a vernier. Clean and dry the dish of the K. box and weigh the box alone – W1-
- Cut out a Whatman No. 1 or 44 filter paper and place it at the bottom of the box W2-
- Pass the air-dried soil through a 2 mm sieve and fill the box with repeated tappings (20 – 30 times) on the top of a table for complete and uniform packing. Level the surface with the spatula.
- Weigh the K. box with air dry soil – W_3-
- Place the box in the soaking tray and gradually fill the tray with water from the side till the water level is about 1 cm above the base of the box.

- Cover the tray to prevent evaporation from soil surface and let it rest for 12 hr or more for equilibrium. This is confirmed by a continuous and shining film of water at the soil surface.
- Carefully remove the box from water, wipe the box dry from outside and weigh it quickly – W5-
- Cut off the expanded soil (above dish's rim). With spatula and transfer it to a previously weighed watch glass – W_7-
- Weigh the watch glass with expanded out wet soil –W_8-
- Dry the soil of watch glass and K. box dish in the oven at 105 °C and record the constant weights W9 and W10- respectively.
- A blank test (only K. box and filter paper) should also be run simultaneously to find the weight of water absorbed by the filter paper alone – W_6-

Precautions

- All weights should be recorded immediately with the precision of 0.01 gm (to avoid any loss of water by evaporation or drainage).
- Soil should be filled with repeated tappings to ensure uniform and complete packing.

Observations

Sr. No.	Particulars	Value
1.	Depth of K. box (h)	= _____ cm
2.	Radius of K. box (r)	= _____ cm
3.	Weight of K. box alone (W_1)	= _____ gm
4.	Weight of K. box + filter paper (W_2)	= _____ gm
5.	Weight of K. box + filter paper + air-dry soil (W_3)	= _____ gm
6.	Weight of K. box + filter paper (blank) (W_4)	= _____ gm
7.	Weight of K. box + filter paper + wet soil (W_5)	= _____ gm
8.	Weight of K. box + wet filter paper (blank) (W_6)	= _____ gm
9.	Weight of watch glass (W_7)	= _____ gm
10.	Weight of watch glass + expanded wet soil (W_8)	= _____ gm
11.	Weight of watch glass + expanded dry soil (W_9)	= _____ gm
12.	Weight of K. box + oven-dry remaining soil (W_{10})	= _____ gm

Calculations

Sr. No.	Particulars	Value
1.	Volume of the air-dry soil = volume of K. box ($\pi r^2 h$)	= _____ cm^3
2.	Weight of dry filter paper (d − c)	= _____ gm
3.	Weight of air-dry soil (e − f)	= _____ gm
4.	Water absorbed by the filter paper (h − f)	= _____ gm
5.	Dry weight of expanded soil (k − i)	= _____ gm
6.	Dry weight of remaining soil in K. box (l − d)	= _____ gm
7.	Oven-dry weight of the total soil (q + r)	= _____ gm
8.	Total weight in the wet soil (g − d − s − p)	= _____ gm

9.	Weight of air-dry soil (e − d)	= _____ gm
10.	Water in the air-dry soil (u − s)	= _____ gm
11.	Volume of the expanded soil (q × m) / r	= _____ cm^3
12.	Volume of soil particles (m + w − t)	= _____ cm^3

Results

Parameter	Result
A. Bulk density of the processed soil	= _____ g cm^{-3}
B. Particle density of the soil	= _____ g cm^{-3}
C. Total porosity = [1 − (Bulk density / Particle density)] × 100	= _____ %
D. Maximum water-holding capacity = (Weight of water / Oven-dry soil weight) × 100	= _____ %
E. Water in the air-dry soil	= _____ %
F. Volume expansion	= _____ %

Exercise No. 18
Determination of available water capacity of soil

Available water capacity is the amount of water available to plants at any time. It is calculated by taking the difference between Field Capacity (FC) and Permanent Wilting Point (PWP). Field capacity refers to the amount of water held in the soil after the excess gravitational water has drained away and after the rate of downward movement of water decreased. Such a stage is generally reached after approximately 48–72 h after saturation, depending on soil texture and drainage. Sandy soils reach field capacity earlier than clay soils. The field capacity is the upper limit of available moisture range in soil water-plant relationship. At field capacity moisture is held in the soil at a force between 0.1 to 0.33 bar.

The permanent wilting point (PWP) is the soil moisture content at which permanent wilting of a plant takes place. It is the lower limit of available moisture range in soil water-plant relationship. At permanent wilting point moisture is held in the soil at a force of 15 bar. The field capacity and available water content can be determined by pressure membrane and pressure plate apparatus.

Pressure membrane and pressure plate apparatus

Pressure membrane and pressure plate apparatus (developed primarily by Richards) is generally used to estimate field capacity, permanent wilting point and moisture content at different pressures. The apparatus consists of airtight metallic chamber in which porous ceramic pressure plate is placed. The pressure plate and soil samples are saturated and are placed in the metallic chamber. The required pressure, say 0.33 bar (Field capacity) or 15 bar (Permanent wilting point) is applied through a compressor. As a result water flows out of the sample from the soil. When equilibrium is reached, water flow ceases and the applied pressure corresponds to the water potential in the soil. At that point soil samples are taken out and oven-dried for determining the moisture content. It gives the soil moisture content for the corresponding pressure.

Observations and Calculationss

Sr. No.	Particulars	Field Capacity (0.33 bar)	PWP (15 bar)
1.	Weight of moist soil with can (W_1)	= _____ gm	= _____ gm
2.	Weight of dry soil with can (W_2)	= _____ gm	= _____ gm
3.	Weight of can (W_3)	= _____ gm	= _____ gm
4.	Weight of water present ($W_1 - W_2$)	= _____ gm	= _____ gm
5.	Weight of dry soil ($W_2 - W_3$)	= _____ gm	= _____ gm
6.	Moisture % (d/e)	= _____ %	= _____ %
7.	Available water (FC − PWP)		= _____ %

Inference:

Exercise No. 19
Determination of Saturated Hydraulic Conductivity of Soil

The ability of soil to transmit water through its conducting pores and the rate of such transmission influences infiltration, runoff, and soil erosion. When the entry of water into the soil either from rainfall or irrigation increases runoff decreases and thereby soil erosion also decreases. Based on Darcy's law the conductivity of water through soil can be determined. The law states that – the quantity of water (Q) flowing through unit area. (A) per unit time (t) is directly proportional to the hydraulic head difference (Hi-Ho) and inversely proportional to the distance of flow (L). It can be expressed in the form of

$$\frac{Q}{At} \alpha \frac{\mathrm{Hi} - \mathrm{Ho}}{\mathrm{L}}$$

By incorporating a proportionality constant K, the above equation can be written as:

$$\frac{Q}{At} = \mathrm{K} \frac{\mathrm{Hi} - \mathrm{Ho}}{\mathrm{L}}$$

The proportionality constant K is the hydraulic conductivity of the soil. Since the flow process takes place under saturated condition of the soil i.e. the soil pores are saturated with water, the term conductivity K can also be expressed as Ks. The driving force to move the water from the point of inflow (i) to point of outflow (o) is expressed as the negative gradient of the hydraulic head comprised of gravitational (Z) and pressure head (h). The potential at the two boundaries is computed as

$$\mathrm{H_i} = \mathrm{h} + \mathrm{L}$$

$$\mathrm{H_o} = 0$$

Under the condition that the reference level lies at Ho, where h is the height of water above the soil column, L is the length of the soil column.

Now, in order to compute the Ks, eq. 2 can be given the form of

$$\frac{Q}{At} = \mathrm{Ks} \frac{\mathrm{h} - \mathrm{L}}{\mathrm{L}}$$

Or,

$$\mathrm{Ks} = \frac{\mathrm{QL}}{\mathrm{At}\,(\mathrm{h} + \mathrm{L})}$$

Where, Q is the flow volume in mL (cm^3), A is the area in cm^2, t is the time in seconds, L and h in cm. Thus, the unit of Ks will be cm s^{-1} (may also be expressed in cm h^{-1}).

Procedure

A. Collection of core sample

1. Clean the surface soil of weeds and other debris and smoothen the surface with a Khurpi.
2. Place a clean core sampler on the soil surface and the plate above the core sample.
3. Gently hammer the plate from uniform height
4. Leave about 1 cm empty space in the core sampler at the top.
5. Dig out the core sampler with the Khurpi.
6. Cut the lower end of the core sample smoothly without exerting any pressure to soil.

7. Cover both the ends with filter paper and bring it to the laboratory.

B. Flow experiment

1. Saturate the soil of core sampler from below by placing it in a tray filled with water.
2. Do not pour water from above the sampler. This will entrap air inside the pore spaces creating impeded drainage due to artificial barrier caused by the entrapped air.
3. After 24 h (or about 48 h for heavy-textured soil),, bring out the core sampler.
4. Close the lower end of the sampler by covering it with a filter paper, holding it tightly with a rubber band.
5. Place it in the permeameter assembly.
6. Fill up the empty portion of the core sampler with water.
7. Take a volumetric flask (about 50 ml) and fill it up with water.
8. Place the water-filled flask over the surface of water of core sampler in the inverted position.
9. Water in the column will start flowing out of the column due to action of gravity and the pressure head created by the water overlying the soil column.
10. Place a measuring cylinder below the soil column with a funnel in it.
11. Record the volume of water coming out of the column every 30 minutes
12. Record three determinations of the volume of outflow.
13. Take the average flow of the 3 observations.

Rating and code of Permeability

Permeability	Rating	Code
>12.50 cm hr^{-1}	= Rapid	= 1
6.25-12.50 cm hr^{-1}	= Moderately rapid	= 2
2.0-6.25 cm hr^{-1}	= Moderate	= 3
0.50-2.0 cm hr^{-1}	= Moderately slow	= 4
0.125-0.50 cm hr^{-1}	= Slow	= 5

Observations and Calculation:

Soil sample No			
1. Area of the core sampler	= A cm^2 =	r^2	
2. Height of water column	= h cm		
3. Length of the soil column	= L cm		
4. Time of observation	= t minutes		
5. Volume of outflow in t minutes	= Q ml		
6. Hydraulic conductivity (K_S)			
7. Permeability code of the soil sample			

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