

LECTURE 1

INTRODUCTION

Soils have great meaning for human kind. From the dawn of agriculture, cultivators recognized good soils being attracted to the fertile soils of river valleys. Most great civilizations have depended on good soils. Continuous replenishment of fertility by natural flooding made possible the stable, organized communities and even cities, in contrast to the nomadic, shifting societies. Mis-management of fertile soils is the only contributing factor for the down fall of the society. The careful preservation of the soil mantle can be the difference between a prosperous society and poverty. History provides lessons that modern nations have not always heeded.

The soil serves not only as a medium for plant growth and for microbiological activity *per se* but also as a sink and recycling factory for numerous waste products which might otherwise accumulate to poison our environment. More over, the soil supports our buildings and provides material for the construction of earthen structures such as dams and road beds.

In many regions, we find once- thriving agricultural fields reduced to desolation by man- induced erosion or salinization resulting from injudicious management of the soil-water system. Add to that, the shortsighted depletion of non-replenished water resources as well as the dumping of poisonous wastes is indeed a consistent pattern of mismanagement. Despite the known degradation of resource, we still continue squandering and abusing such precious resource, for the sake of population-environment -food crisis being faced by the world.

EVOLUTION OF EARTH

The origin and evolution of earth is best explained by 'Planetesimal Hypothesis' put forth by T.C. Chamberlain and F.R. Moulton in 19th century and Nebular hypothesis.

Planetesimal Hypothesis:

According to this when a big star comes closer to sun it creates certain gravitational pull because of which tearing away of the outer matter took place. The teared matter got condensed and started to move around the sun in orbits. These are called planetary nucleoids.

According to 'Nebular Hypothesis':

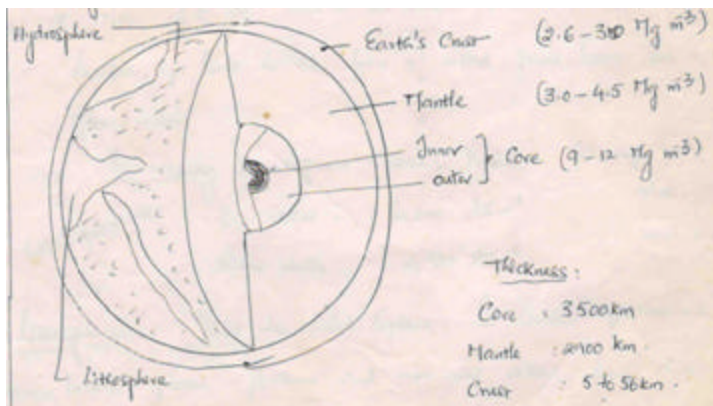
- 1 Whole solar system at one time is a cloudy (nebula) mass of matter in form of vapor or gas.

- 2 It was intensely hot and incandescent. It was in perpetual motion.
- 3 On lapse of time nebula began to cool and the vapors in the outer layer are condensed and thrown out in the form of rings. Further condensation and disruption lead to formation of planets.
- 4 The central mass which is still incandescent and not yet condensed is 'SUN'

Spheres of Earth

Geographically EARTH constitutes of three spheres corresponding to three states of matter (Solid, Liquid & Gas)

The solid zone is Lithosphere. The incomplete covering of water forming seas and oceans (liquid spheres) is Hydrosphere. The gaseous envelop over the earth surface is Atmosphere.



Atmosphere: - The atmosphere forms an envelop, 322 Km over the earth's surface. This envelop of air that covers both lithosphere and hydrosphere is called atmosphere. It contains water modules and dust, which act as nuclei for the condensation of water vapour to form cloud or fog.

N_2	-	78.054 %	O_2	-	20.946 %
CO_2	-	0.033 %	Argon	-	0.934 %

In addition, inert gases such as helium, neon, krypton and xenon are present. The water vapor content in atmosphere varies from place to place and time to time. Air becomes less dense with height until it gets too thin to support life. Atmosphere contributes only 0.03 % weight to the earth.

Hydrosphere

- 1 Covers almost 3/4th of earth crust.
- 2 The Hydrosphere is 10 Km deep and occupies 70 % of earth's surface.
- 3 Hydrosphere makes only 6.91 % of the earth mass but by volume 15 times than that of the visible land above the sea level.
- 4 It contains absorbed air and carries particles of rocks as sediments.
- 5 Most of it lies with in the ocean basins and also appears on surface of land in the form of rivers, ponds, lakes and as ground waters.
- 6 The quality of different waters, varies

Lithosphere

It is the solid sphere. It consists of continents, ocean basins, plains, plateaus and mountains, valleys, sand dunes, lava flows and fault scraps. The interior of earth consists of rocks and minerals. It is covered by gaseous and watery envelopes. It amounts to 93.06 % of earth's mass.

Composition of Earth's Crust

Most of the hard, naturally formed substance of the earth is referred to as 'rock' out of 106 elements known eight are sufficiently abundant as to constitute 98.6 % (by weight) of the earth crust (up to 16m)

Out of eight elements, two are in great abundance and comprise ¾ the total composition of the crust. The other six elements are metals.

Non metallic (%)	O ²⁻ - 46.60	Titanium - 0.41
	Si ⁴⁺ - 27.72	Hydrogen - 0.17
		Carbon - 0.12
Metallic - (%)	Al ³⁺ - 8.13	Phosphorus - 0.09
	Fe ²⁺ - 5.00	Sulphur - 0.07
	Ca ²⁺ - 3.63	Manganese - 0.07
	Na ⁺ - 2.83	Barium - 0.05
	K ⁺ - 2.59	Strontium - 0.02
	Mg ²⁺ - 2.09	Chromium, Nickel, Lithium chlorine & Fluorine - each 0.01
	Others - 1.41	

“With out life, there is no soil and with out soil, there is no life on the earth planet”

“Soil is the interface of the organic and inorganic chemistry of the terrestrial world, combining nitrogen and carbon from the atmosphere with the various elements of mineral lithosphere via the organisms anchored in the soil, intercepting energy of the sun and moisture from the hydrosphere and atmosphere.”

The word **“Soil”** is derived from Latin word **‘Solum’** means **‘Floor’ or ‘Ground’**

SOIL COMPONENTS

Mineral soil consists of four major components i.e., inorganic or mineral materials, organic matter, water and air. In a representative loam surface soil, the solid mineral particles comprise about 45% of the soil volume and organic matter 5%. At optimum moisture for plant growth, the pore space is divided roughly in half, 25 %, of volume being water space and 25 % air. The proportions of air and water are subjected to rapid and great fluctuations.

The four soil components occur in a thoroughly mixed condition in soil and this mixture encourages interactions with in and between the groups and permits marked variations in the environment for the growth of plants.

The proportion of different components in the diagram depicts the good soil condition for plant growth (Loam surface soil).The air and water are extremely variable and their proportions determine in large degree the soil’s suitability for the plant growth.

Mineral Matter: The Inorganic portion of soils is quite variable in size and composition. It is composed of small rock fragments and minerals of various kinds.

Rock Fragments

2.0	-	75.0 mm	-	gravel or pebbles
75.0	-	250.0 mm	-	cobbles (round) flags (flat)
	>	250.0 mm	-	stones or boulders

Soil Particles

0.2	-	2.0mm	-	sand (gritty)
0.02	-	0.2mm	-	fine sand (gritty)
0.002	-	0.02mm	-	silt (powdery)
	<	0.002mm	-	clay (sticky)

The proportion of different sized particles (texture) determines the nutrient supplying power of the soil, considerably. Primary minerals (original) are prominent in sand and silt fractions; whereas the secondary minerals (formed) dominate in clay fraction and in some cases the silt fraction. The inorganic fraction of soil is the original source of most of the mineral elements that are essential for plant growth.

Organic Matter

It comprises an accumulation of partially disintegrated and decomposed plant and animal residues and other organic compounds synthesized by soil microbes as the decay occurs. It is a transitory soil constituent as it is continuously broken down by soil organisms and lasts from few hours to several hundred years. It requires maintenance by regular addition to the soil of plant and/or animal residues. Organic matter content varies from 1.0 to 6.0 % by weight in top soil and very less in sub soil. In respect of soil productivity organic matter plays an indispensable role.

Soil Water

Soil water is held in soil pores with varying degrees of tenacity depending on the amount of water present and size of the pores. Soil water with its soluble constituents (nutrients) makes up soil solution, which is the critical medium for supplying nutrients to growing plants. Soil water plays significant role in controlling energy balance of the soil and regulates the gaseous exchange in the upper layer of the soil.

The presence of water in different amounts in soil governs its thermal, mechanical, physical, chemical and biological properties.

Soil Air

The content and composition of soil air are determined largely by the water content of the soil, since the air occupies those soil pores not filled with water.

Soil air always differs from atmosphere air in composition because of moisture content, root and microbial activities.

- 1 Relative humidity may approach 100% at optimum soil moisture
- 2 CO₂ content is often several hundred times higher than 0.033%
- 3 Oxygen content usually <20%. In extreme cases only 5-10%

In cases of low soil air, the diffusion rate of air in to and out of the soil would be slow and this leads to unsatisfactory conditions for optimum plant growth.

Definition of Soil

“Soil is a natural body composed of inorganic and organic constituents, having a definite genesis and a distinct nature of its own”-- **Dokuchaev (1900)**

“Soil is a natural occurring body that has been evolved owing to combined influence of climate and other organisms, acting on parent material, as conditioned by relief over a period of time” --**Jenny (1941)**

“Soil is the unconsolidated mineral matter on the immediate surface of the earth that serves as a natural medium for the growth of land plants”

“Soil is the unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate, macro and micro organisms and topography, all acting over a period of time and producing a product, that is soil, that differs from the material from which it is derived in many physical, chemical, biological and morphological properties and characteristics --**SSSA (1970)**

“Soil is a natural body synthesized in a profile form from a variable mixture of broken and weathered minerals and decaying organic matter, which covers the earth in a thin layer and which supplies, when containing proper amounts of air and water, mechanical support and in part sustenance to plants”

Modern Concepts of Soil

Knowledge about soils comes from two basic sources; farmer experience based on centuries of trial and error, and scientific investigations of soils and their management

- 1 From the dawn of agriculture, cultivators recognized good soils being attracted to fertile soils of river valleys.
- 2 More than 42 centuries ago, Chinese used a schematic soil map as a basis for taxation.
- 3 Homer (about 1000 B.C.) referred the use of manure on the land.
- 4 Early Greek and Roman writers described farming systems that involved leguminous plants and the use of ashes and sulphur as soil supplements.

Early Scientific Investigations

French agriculturist **J.B. Boussingault** (1834) proved that air and water were the primary sources of C, H, and O in plant tissue.

German chemist – **Justus Von Leibig** (1840) - Crop yields were increased by adding minerals or inorganic elements to the soil. He proposed that the mineral elements in soil and in added manures and fertilizers are essential for plant growth. He disproved the humus theory.

Leibig's research led to the concept that certain factors were essential for plant growth and that if any one of these factors was limiting, plant production would be reduced accordingly – **Law of Minimum**

R. Warrington – Nitrogen transformations are biological

S. Winogradski (1890) – Isolated two groups of bacteria responsible for nitrogen transformations. Nitrogen assimilating bacteria grow in nodules of leguminous plants

Research in USA

C G Hopkins (Illinois) Developed effective soil management system based on lime stone, rock phosphate and legumes.

Milton Whitney of USDA emphasized field studies and initiated the first National Soil Survey Systems.

F H King(Wisconsin) studied the movement and storage of water in soils in relation to root penetration and crop growth.

Branches of Soil Science

Pedology:- The Science dealing with the genesis ,survey and classification and the laws of geographical distribution of soils as a body in nature. Pedology is the study of soil as a natural body and does not focus primarily on the soil's immediate practical use.

Edaphology:- The science that deals with the influence of soils on living things, particularly plants, including man's use of land for plant growth. Edaphology is the study of soil from the stand point of higher plants.

Soil Fertility:- The quality of the soil that enables it to provide essential chemical elements in quantities and proportions for the growth of specified plants.

Soil Chemistry:- Deals with the chemical constituents , the chemical properties and the chemical reactions of soil in relation to crop needs.

Soil Physics:- Study of various physical processes that are taking place in and through the soils.

Soil Microbiology:- Deals with microscopic population of the soil, its role in various transformations and its importance in plant nutrition and crop production.

Soil Conservation:- Deals with the protection of soil against physical loss by erosion and against chemical deterioration.

Soil Genesis:- The study of the mode of origin of soils, with special reference to the processes responsible for the development of Solum or true soil from the unconsolidated parent material.

Soil Survey:- The systematic examination, description, classification and mapping of soils in an area.

LECTURE 2

ROCKS

The materials of earths crust are nothing but rocks and minerals. These are the out come of the geological forces or processes which operate on the surface and the interior of the earth to bring about changes to produce rocks.

Rock may be defined as a hard mass of mineral matter comprising two or more rock forming minerals.

Earth crust - Igneous rocks **95%** and Sedimentary rocks **5%**

Upper 5km of earth crust : Igneous rocks 18%
Sedimentary rocks 74%
Others 8%

Formation of Rocks: - The various processes that lead to the formation of rocks are:

- 1 **Cooling and consolidation of Magma:-** Rocks are formed by cooling and consolidation of molten magma with in or on the surface of the earth e.g. **igneous or primary rocks**. (Magma is defined as the complex hot solution of silicates containing water vapour and gases having a temperature ranging from 700 – 1400°C and originating at great depths in the earth crust)

2 Transportation and Cementation of Fragmentary Material:- Disintegration and decomposition lead to the breaking down of pre-existing rocks. The resulting fragmentary material is either compacted *in situ* or transported in solution by the natural agencies of wind, water and ice to low lying areas like oceans. Consolidation of these materials after their deposition results in the formation of rocks called **sedimentary or secondary rocks.**

3 Alteration of Pre-existing rocks:- The primary and secondary rocks when subjected to earth's movement and to high temperature and pressure are partially or wholly reconstituted or altered to new rocks called **metamorphic rocks.**

Igneous rocks : These are characterized by non-laminar massive structure and on the whole make up 95% of the earth crust. They are the source of parent material for the others rocks. Igneous rocks can be classified based on the mode of origin and chemical composition. Based on the mode of origin they are classified as Extrusive or Volcanic rocks and Intrusive or Plutonic rocks.

Volcanic rocks	Plutonic Rocks
<ol style="list-style-type: none"> 1. Formed on the surface of earth 2. Cooling of magma is quick 3. Fine size crystals are formed 4. Mineral grains can be observed only under a microscope or magnifying lenses 5. Rocks have a glassy structure Ex:- Basalt, Andesite 6. These are called extrusive rocks. 	<ol style="list-style-type: none"> 1. Formed with in earth's crust 2. Cooling of magma is slow and the time taken for crystallization is quite long 3. Coarse crystals are formed 4. Mineral grains can be seen with naked eye 5. Rocks have hard and massive structure eg. Granite & syenite 6. These are called intrusive rocks

Igneous rocks are further classified based on the relative amounts of acid and basic components.

An acid component is silicic acid or silica.

Basic components are soda, potash, alumina, lime, manganese and iron oxides.

Acid rocks - >65% silica Ex:- Granite, Pitchstone

Sub acid rocks - 60-65% silica Ex: - Syenite, Trachyte

Sub basic rocks	-	55-60% silica Ex: - Diorite, Andesite
Basic rocks	-	45-55% silica Ex: - Gabbro, Basalt
Ultra basic rocks	-	< 45% silica

Composition of Igneous Rocks (Crystalline rocks)

- 1 **Basalt:-** This is the most abundantly formed rock form molten material. It is fine grained and dark colored rock which contains 50% feldspars and 50% Ferro magnesium minerals, including pyroxene and olivine (The coarse grained rock with comparable composition is 'gabbro')
- 2 **Granite:-** A coarse textured and light colored rock that contains 60-70% feldspars of which orthoclase 40-45%, plagioclase 20-25% ferromagnesian minerals 3-10% and quartz 20-30% (The fine grained rock with above composition is 'rhyolite')
- 3 **Pumice:-** A light weight, light colored cellular extrusive rock formed by the escaping of volatile constituents. The cellular structure is due to the lava which has been frothed up to many times its original volume by expansion of its gases. It has a lower specific weight than water. So it floats on water. In composition it is comparable to granite / rhyolite and in texture it is like a sponge.

Sedimentary rocks:- The sedimentary rocks are formed from sediments, derived from the breaking down of pre-existing rocks. The sediments are transported to new places and deposited in new arrangements and cemented to form secondary rocks. These rocks are also called as **stratified rocks or aqueous rocks.**

Formation of Sedimentary rocks:- Four stages are recognized in the formation of sedimentary rocks.

- o **Weathering:-** The igneous rocks (Primary rocks) disintegrate owing to physical, chemical and biological weathering and provide basic materials for the formation of sedimentary rocks.
- o **Transportation:-** The disintegrated material is transported by the agencies, such as water, wind, glaciers, runoff and gravity. Transportation is a function of speed of water
- o **Deposition or Sedimentation:-** The detrital materials, comprising minerals and rock fragments are deposited when the carrying agent has no longer energy

enough to move it further. In this process, coarser particles settle first and the finer particles later. This kind of deposition is called 'graded bedding'

o **Digenesis:-** It refers to the transformation of unconsolidated sediments to hard rock. It involves compaction and cementation.

? **Compaction:-** The weight of the upper incumbent layers with thousands of meters thickness, causes compression of the lower layers or deposits. The sediments consolidate and the interstitial water and air are removed by the pressure of overlying sediments. The fine grained deposits under such environments are transformed to clays, shales etc.

? **Cementation:-** The most common materials that serve as cementing agents are lime, silica, iron oxide. Water that percolates, carries the binding minerals / materials in solution deposits these in the voids of the loose sediments and binds the sediments together on desiccation. The interior of the earth is sufficiently hot to help in consolidation of the sediments.

Classification of sedimentary rocks

Based on origin, sedimentary rocks are classified in to different groups

Residual:- When the products of weathering settle at that place where they have been formed, they form in to hard mass Ex: - Bauxite

Mechanical or Detrietal:- Weathered fragments are transported , deposited in beds of varying thickness and cemented. Ex: Sand Stone, Shale, Conglomerate

Inorganic or Chemically Formed :- These are formed by evaporation or precipitation of material in sea or lake water

Formed through evaporation: - Halite (Rock salt) , Gypsum

Formed through precipitation and flocculation: - Lime stone, Dolomite

Organic Sedimentary rocks or bio-chemically formed rocks

These are formed by the accumulation and partial decomposition of organic remains under anaerobic conditions. When the plants decompose under restricted air supply in lower layers of earth, a greater portion of their carbon content is retained and the material is slowly converted in to coal. Ex: - Peat, Lignite and anthracite (hard coal).

METAMORPHIC ROCKS : The word 'metamorphic' means "change in form"

Metamorphosis is used as a general term for all those changes that alter more or less completely the original characters of rock.

FORMATION: Igneous and sedimentary rocks subjected to tremendous pressures and high temperatures succumb to metamorphism. The changes in the deeply buried rocks are brought about by the combined action of chemically active fluids, internal heat and pressure. The structure and mineralogical composition of metamorphic rocks depend on the composition of original rock and the kind of metamorphism.

In addition to the minerals, commonly observed in igneous and sedimentary rocks, there are certain minerals such as tremolite, garnet, talc, mica and chlorite, which are the characteristics of metamorphic rocks. The banded or laminated character is the most peculiar feature of metamorphic rocks.

Changes brought about by chemically activated waters - **Hydro-metamorphism** Ex: Sand stone to Quartzite; Granite or Basalt to Laterite.

Changes brought about by Heat -- **Thermo-metamorphism** Ex: Limestone to crystalline marble

Changes brought about by Pressure -- **Dynamo-metamorphism**

Ex: Granite - Granite-gneiss (Partial foliation)

Gneiss - Schist (Complete foliation); Shale - Slate

Changes brought about by Heat & Pressure - **Dynamo-thermal metamorphism**. Many crystalline gneisses, schists and marbles are formed.

Pre – Existing or Original Rock	Metamorphic Rock
Granite or Syenite	→ Gneiss? Mica-schist
Conglomerate	→ Gneiss
Sand Stone	? Quartzite ? Quartz-schist
Clayey Sandstone	→ Quartzite ? Mica-schist
Shale	→ Slate? Phyllite ? Mica-schist
Limestone	→ Marble
Dolomite	→ Dolomite marble ? Soap stone or serpentine

Iron ores	→	Haematite – Schists
Coal	→	Graphite

Classification of Metamorphic Rocks: Based on the texture and structure of minerals, the metamorphic rocks are divided into three groups i.e. foliated, unfoliated and granulated.

Foliated (Parallel structure) (Leaved or leafy): These rocks contain micas and ferro-magnesian minerals and show foliation as the minerals are flattened and arranged in parallel layers. Ex: Gneiss, Schist (Coarse grained); Phyllite (medium grained); Slate (Very fine grained)

Unfoliated (massive structure): These rocks contain quartz and feldspars and do not show foliation even under pressure because of large sized crystals. EX; Talc-schist, amphibolite and graphite.

Granular: These consisting of mostly equidimensional grains. Ex: Quartzite, Marble

Weatherability of rocks: Rocks made up of ferromagnesian minerals like olivines, pyroxenes etc., are more weatherable than rocks with non ferromagnesian minerals.

LECTURE 3

MINERALS

Mineral is a naturally occurring, homogenous element or inorganic compound that has a definite chemical composition and a characteristic geometric form.

Two or more elements combined – Gypsum : $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

Olivine – $(\text{Mg, Fe})_2\text{SiO}_4$

Feldspar – KAlSi_3O_8

Only one element – Metal – Cu, Fe, Ca. Non Metal – C, S, Si

Formation & Distribution in the Earth's crust

When the molten magma solidifies, the different elements present there in freely arrange themselves in accordance with attractive forces and geometric form. Of the more than 2000 known minerals only a few occur in abundance in the earth crust.

Minerals (Arranged in order of their crystallization)	Important constituents (other than 'Si' and 'O')	% Distribution
A. Primary Minerals		
<i>Ferromagnesians</i>		
?? Ortho or Inosilicates		
Olivines	Fe, Mg	
Pyroxenes	Ca, Na, Fe, Mg	16.8
Amphiboles etc	Ca, Na, Fe, Mg, Al, OH	
?? Phyllo – silicates		
Biotite	K, Fe, Mg, Al, OH	3.6
Muscovite	K, Al, OH	
<i>Non – Ferro Magnesians</i>		
?? Tecto silicates – <i>Feldspars</i>		
Albite	Na, Al	
Anorthite	Ca, Al	61.0
Orthoclase /Microcline	K, Al	
Quartz		11.6
B. Secondary clay minerals	Na, K, Ca, Mg, Fe, Al, OH	6.0
C. Others		
Total		100

Silicate minerals occupy 90% of the mineral composition of rocks of the earth's crust. The silica tetrahedron is the fundamental building block of all the silicate minerals of the earth's crust.

CLASSIFICATION OF MINERALS

1. Based on mode of origin
 - o Primary Minerals
 - o Secondary Minerals
2. Based on Chemical composition
 - * Native elements
 - * Oxides and hydroxides
 - * Sulphates
 - * Sulphides
 - * Carbonates
 - * Halides
 - * Silicates
3. Based on the Quantity
 - o Essential Minerals
 - o Accessory Minerals
4. Based on Specific Gravity
 - o Light Minerals
 - o Heavy Minerals

Primary Minerals: The primary minerals are those which are formed owing to the crystallization of the molten magma. Depending up on the tetrahedral linkage, the silicate minerals are divided in to four groups.

- 1 Orthosilicates : Olivine
- 2 Inosilicates :
 - o Single chained : Pyroxenes
 - o Double chained : Amphiboles
- 3 Phyllosilicates : Biotite, Muscovite
- 4 Tectosilicates : Quartz, Feldspars
- 5 **Ferro - Magnesian Minerals**

Olivines, Pyroxenes, Amphiboles, Biotite

Non Ferro Magnesian Minerals

Muscovite, Orthoclase, Albite, Anorthite, Quartz

Secondary minerals: Minerals formed due to weathering action of primary mineral s.

PRIMARY SILICATE MINERALS

Quartz: The frame works of quartz is very densely packed and occurs in a high degree of purity. It is resistant to physical and chemical weathering as the structure is densely packed electrically neutral and prevents any form of substitution. It is ubiquitous in soils but its abundance is next only to feldspars.

Feldspars: Its frame work is less dense that quartz. There are most abundant among rock forming minerals in the earth's crust. These are non ferro - magesian minerals and act as store house of sodium, calcium , potassium minerals and many trace elements in soils.

Micas: Occur most extensively in soils. Muscovite (white mica) a non- ferromagnesian mineral is resistant for weathering. Biotite (black mica) a ferro- magesian is highly susceptible for weathering. Muscovite is present only in acid igneous rocks.

Pyroxenes and Amphiboles: These two minerals are two groups of ferro- magesian minerals and their structure consists of long chains of linked silica tetrehedra (Inosilicates). Due to variety of substitutions these minerals are excellent host minerals for trace cations in soils and also for main constituent cations like Ca, Mg and Fe. Their weatherability is quite favourable to provide sufficient amounts of these ions in available form for plant nutrition.

Pyroxenes - Single chain eg. Augite $(Ca, Na)(Mg, Fe, Al)(Si, Al)_2O_6$

Olivines: Olive green colored minerals. Olivines are relatively easily weathered. It is called island silicate. Ex: Forsterite – Mg_2SiO_4 ; Fayalite – Fe_2SiO_4

Weatherability of primary minerals.

Early stage of weathering

Olivine $(Fe, Mg)_2SiO_4$

Pyroxenes (Augite - $Ca_2(Al, Fe)_4(Mg, Fe)_4Si_6O_{24}$)

Amphiboles (Hornblende - $Ca_2Al_2Mg_2Fe_3Al_6O_{22}(OH)_2$)

Biotite $KAl(Mg, Fe)_3Si_3O_{10}(OH)_2$

Albite (Sodium feldspar - $NaAlSi_3O_8$)

Anorthite (Calcium feldspar – $CaAl_2Si_2O_8$)

2. Intermediate weathering stage

Orthoclase (Potassium feldspar - $KAlSi_3O_8$)

Muscovite $KAl_3Si_3O_{10}(OH)_2$

Quartz SiO_2

3. Advanced stage of weathering

No primary mineral is observed in advanced stage of weathering.

Hence young soils contain several primary minerals but highly weathered soils do not contain any primary minerals.

Essential Minerals : The minerals which form the chief constituents of rock and which are regarded as the characteristic components of that rock are known as “Essential Minerals” eg. Quartz, Feldspars and Micas

Accessory Minerals : These minerals occur only in small quantities and whose presence or absence is of no consequence as far as the character of the rock is concerned, are called as accessory minerals eg. Tourmaline, Pyrite, Magnetite.

Light Minerals : Are the minerals which have specific gravity below 2.85 eg. Quartz (2.60), Feldspar (2.65), Muscovite (2.50-2.75)

Heavy Minerals : Having specific gravity above 2.85 g/cc e.g. Haematite (5.30), Pyrite (5.0), Limonite (3.8), Augite (pyroxene) (3.1 – 3.6), Hornblende (amphiboles) (2.9 – 3.8), Olivine (3.5)

LECTURE 4

SECONDARY MINERALS: The secondary minerals are formed at the earth's surface by the weathering of the pre-existing primary minerals under variable conditions of temperature and pressure. Due to the action of weathering processes primary minerals are altered or decomposed. They are two types.

- a. Silicate minerals
- b. Non-silicate minerals

Silicate minerals: These are the minerals that contain silica along with other elements.

Basic structural units of Secondary minerals:

Silica Tetrahedron: Geometrically it is possible to arrange only four oxygen atoms (with radius of 1.32 \AA) around a central silicon cation (with radius of 0.42 \AA), so that all are touching each other. To attain neutrality silicon would have to combine with two oxygen atoms only. But to attain geometrically stable structure silicon ion combines with four oxygen ions and the resultant silica tetrahedron (SiO_4)⁴⁻ carries a net negative charge of four. This is called a silica Tetrahedron

In nature, the geometry and valence constraints are reconciled; first by linking together tetrahedra so that oxygen ions are shared between neighbouring silicon thus reducing the negative charge deficit; second by making use of the positive charges of other metal cations, to balance the negative charge. Both these occur to produce a neutral mineral. Like wise, the basic tetrahedra arrange themselves in an orderly manner, according to a fixed plan.

IMPORTANT SECONDARY MINERALS

Silicates

-Clay minerals : Illite, Montmorillonite, Kaolinite

Non Silicates

- Oxides, Hydroxides of Al and Fe : Hematite, Goethite, Gibbsite

- Carbonates: Calcite, Dolomite

- Sulphates: Gypsum

- Phosphates: Apatite

Weatherability of Minerals in sequence:

Early stage of weathering:

Gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$

Calcite CaCO_3

Dolomite $\text{CaCO}_3 \cdot \text{MgCO}_3$

Intermediate stage of weathering

Secondary clay minerals like

Illite, Vermiculite, Montmorillonite

Advanced stage of weathering:

Silicate minerals like Kaolinite and Halloysite.

Non silicate minerals like

Gibbsite $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$; Hematite - Fe_2O_3 ; Goethite FeOOH

Rutile and Anatase TiO_2

Zircon ZrSiO_4

Formulae of Different Rock Forming Minerals ;

Phosphorus containing minerals

Fluorapatite $\text{Ca}_{10}(\text{PO}_4)_6\text{F}_2$; Apatite: $\text{Ca}_{10}(\text{PO}_4)_6^{2+}$

Variscite $\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$; Vivianite $\text{Fe}_3(\text{PO}_4)_2$

Strengite $\text{FePO}_4 \cdot 2\text{H}_2\text{O}$

Boron containing minerals

Tourmaline $\text{-Na}(\text{Mg,Fe})_3\text{Al}_6(\text{BO}_3)_3\text{Si}_6\text{O}_{18}$

Iron containing minerals

Limonite - $\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ Vivianite $\text{Fe}_3(\text{PO}_4)_2$

Ilmenite - FeTiO_3 ; Siderite - FeCO_3

Pyrite - FeS_2 ; Hematite: Fe_2O_3

Chalcopyrite - CuFeS_2 ; Magnetite - Fe_3O_4

Zinc containing minerals :

Sphalerite - ZnS ; Smithsonite - ZnCO_3

Mg containing minerals : Epsom - $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$; Magnesite - MgCO_3

Dolomite - $\text{CaCO}_3 \cdot \text{MgCO}_3$; Epsomite - $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$

Cu containing minerals:

Chalcorite - Cu_2S

Covellite - CuS Chalcopyrite - CuFeS_2

Mn containing minerals: Pyrolusite - MnO_2 ; Manganite - MnOOH

Rhodocrosite - MnCO_3

Mo containing minerals : Molybdenite : MoS_2

Wulfenite : PbMoO_4 ; Powellite CaMoO_4

LECTURE 5

WEATHERING

Weathering is the process of disintegration and decomposition of rocks and minerals, brought about by physical and chemical means, respectively, leading to the formation of **regolith** (Unconsolidated residues of the weathering rock on the earth's surface or above the solid rocks)

Types of Weathering

- 1 Physical / Mechanical Weathering (Disintegration)
- 2 Chemical Weathering (Decomposition)
- 3 Biological Weathering (Disintegration and decomposition)

Physical Weathering

Physical weathering is a mechanical process, causing disintegration of consolidated massive rocks into smaller pieces. In this weathering rock size will be reduced without any change in chemical composition of rock. The agents responsible for physical weathering are: the physical condition of rock, changes in temperature, action of water, action of wind and atmospheric electric phenomena.

Physical condition of rock:- The permeability of rock is probably the most important single factor which determines the rate at which the rocks weather. Ex:- Coarse textured sand stone (porous) weathers more rapidly than a fine textured (almost solid) basalt. Unconsolidated fine deposits of volcanic ash weather rather quickly as compared with unconsolidated coarse deposits, such as gravels, which may take much longer, because the water percolates between and not through the gravels.

Temperature : As a result of diurnal temperature changes the rocks heated during day and cooled during night. Different minerals in poly-mineral rocks have different co-efficient of expansion and thus heating and cooling of rocks results in differential expansion and contraction of rocks, which eventually produce cracks in rocks, thus facilitating mechanical break down. Ex: The cubical expansion of quartz is twice as that of feldspars; the dark colored rocks are subjected to fast changes in temperature as compared to light colored rocks.

More over, the temperature of rocks at its surface is very different from that of the part beneath. This creates stress and strain between heated surfaces and the cooled unexpanded parts, resulting in fragmentation of rocks. This process with time may cause the surface layer to peel off from the parent mass and the rock may ultimately disintegrate. This phenomenon is called '**Exfoliation**'

Water: Of all the agents of physical weathering the effect of water is more pronounced and widespread. Water acts as disintegrating, transporting and depositing agent. A current moving at a speed of 15cm, 30cm, 1.2m and 9.0m per second can carry fine sand, gravel, stones, and boulders of several tonnes respectively. The greater the amount of suspended matter the quicker will be the disintegration of rocks. Hence the disintegration of rocks is greater near the source of a river than at its mouth.

In cold regions, the water in the cracks and crevices freezes in to ice, which increases the volume of water by nine percent. If the space is not available to accommodate the increased volume, it exerts pressure on rock equivalent to 1465 Mgm^{-2} , which leads to widening of cracks in huge boulders and dislodging of mineral grains from smaller fragments.

In colder regions, the moving glaciers cause great deal of cutting and crushing of bed rocks.

Wind : Wind has both erosive and transporting effect. Wind when laden with fine particles (fine sand, silt and clay) has a serious abrasive effect on the rocks.

Atmospheric Electric Phenomena: This is also an important phenomenon, during rainy season, when lightning breaks up rocks and / or widens cracks.

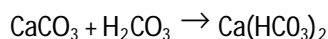
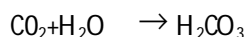
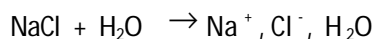
LECTURE 6

Chemical Weathering

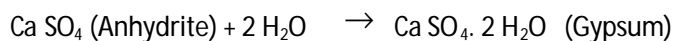
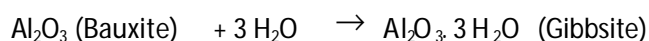
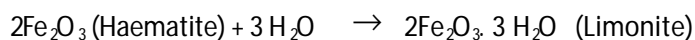
Chemical weathering is more complex in nature and involves the transformation of the original material into some new compounds by bringing about alteration in minerals.

Chemical weathering takes place mainly at the surface of the rocks. Chemical weathering is highly pronounced in humid tropical regions. Its effectiveness is closely related to the mineral composition of rocks. The plants and animals also contribute directly or indirectly to chemical weathering as they produce O_2 , CO_2 , and certain acids that react with earth materials. Various chemical processes are:

Solution : Water is a universal solvent. Its solubility action is enhanced when it contains dissolved CO_2 , organic and inorganic acids or salts in it. Most of the minerals are affected by solubilizing action of water, though by varying degrees. When the soluble substances are removed by the continuous action of flowing or percolating waters, the rock no longer remains solid and develops holes, rills or rough surface and ultimately decomposes. Solubilization of rock minerals under the influence



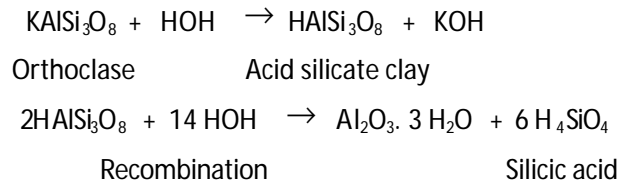
Hydration : It is the chemical combination of water molecules with a mineral to form a new mineral. Owing to hydration, the mineral swells, loses luster, becomes softer and tends to fall apart. This is a major chemical weathering process in secondary minerals



Hydrolysis : Hydrolysis is one of the most important processes in chemical weathering and results in complete disintegration or drastic modification (in structure and composition) of minerals. It is a major chemical process in primary minerals.

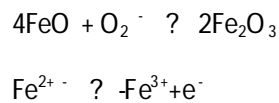
Hydrolysis involves the partial dissociation of water into H^+ and OH^- ions, which combine with minerals and bring about changes such as exchange, decomposition of crystalline structure and formation of new minerals. The hydrolytic activity of water gets accelerated in the

presence of dissolved CO₂, minerals and organic acids. In a way, hydrolysis reactions may be considered as the forerunners of the clay formation.



Muscovite → **Illite** : Muscovite is a 2:1 primary mineral with a non-expandable crystal structure and with a formula of KAl₃Si₃O₁₀(OH)₂. As weathering occurs, the mineral is broken down in size to the colloidal range; part of K is lost and some silica is added from weathering solutions. The net result is illite mineral with a less rigid crystal structure and an electronegative charge.

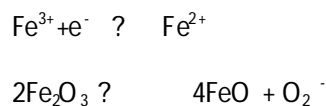
Oxidation: The process of combination of oxygen is known as oxidation. Moisture aids in oxidation process and this process mostly occur after hydrolysis



Oxidation of iron reduces its size and increased the electrical charge and creates electrical and structural imbalance in iron containing minerals such as pyroxenes, amphiboles and biotite.

Reduction:

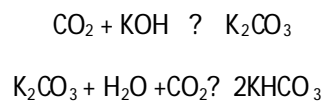
The process of removal or loss of oxygen is called reduction. It occurs in submerged areas. In reduction reaction iron reduces to highly soluble ferrous form.



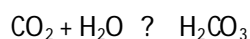
Oxidation and reduction are more common in minerals with Fe, Mn and S

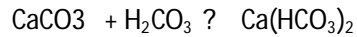
Carbonation:

Combination of carbon dioxide with any base . This effectively decompose the minerals of rocks and organic matter accelerates this due to more CO₂ production.



In this way the bases present in rocks can be solubilized and removed making the rock weak.





The carbonic acid or carbonated water has an etching effect on rocks like limestone or other rocks containing calcium or magnesium carbonates as cementing materials leading to their breakage and formation of new minerals.

It may be concluded that chemical weathering involves destruction of rocks and minerals in to simple new compounds.

Biological Weathering

Unlike physical and chemical weathering, the biological or living agents are responsible for both decomposition and disintegration of rocks and minerals. The biological life is controlled largely by the prevailing environments.

Man, animals, higher plants, earth worms, termites and micro-organisms are responsible for biological weathering.

FAUNA:

- The disintegration of rocks by cutting action of hills and rocks to build dams, roads etc., by humans
- The animals, insects live in rocks make burrows and holes in rocks leading to weakening of rocks. Their excreta and other materials lead to chemical decomposition of rocks.
- Ants and termites built galleries and passages and carries material from lower to upper horizons. Water percolate through the channels and galleries and help in weathering of materials in subsurface horizons. They secrete some acids like formic acid, which aid in decomposition of rocks

FLORA:

- The roots of the plants penetrate into small cracks of rocks. As they grow they exert disruptive force due to which even hard rocks break into pieces.
- Some roots grow deep in to soil and make open channels for percolation of water in to deeper layers.
- Roots produce acids, which have solubilizing action of constituents of rocks making them weak.

- The decomposition of organic matter due to microbial activity also produces several products which play a role in chemical weathering.

The physical, chemical and biological weathering processes occur simultaneously in nature. Like wise different chemical weathering processes occur simultaneously and are interdependent.

LECTURE 7

PARENT MATERIAL

Parent material is the unconsolidated and more or less chemically weathered mineral or organic matter, from which the solum of soils is developed by pedogenic processes.

The 'C' horizon in the profile is referred as parent material.

Jenny (1941) defines parent material as the initial stage of soil system.

Parent materials differ as widely as the rocks of the earths crust. Parent materials are broadly classified as

- 1 Sedentary (Still at original site - residual)
- 2 Transported: The transported group is further subdivided according to the agencies of transportation and deposition.

Different Transporting agents – Parent Material

Transporting agent	Deposited by Or in	Name of the deposit or Parent material
Water	River	Alluvium
	Lake	Lacustrine
	Ocean	Marine
Wind	Wind	Dune (sand & silt) Aeolian / Loess's (fine silt & clay)
Gravity	Gravity action	Colluviums
Ice (Glaciers)	Ice	Till, Moraine

Residual Parent Material: It develops in place from underlying rock. It varies with the varied nature of the rocks from which these materials are evolved. It symbolizes long and intensive

weathering and generally low in calcium and magnesium because of leaching. Besides the nature of rocks, the influence of climate and vegetation is profound on these materials.

COLLUVIAL DEBRIS: It is made up of fragments of rock detached from heights above and carried down the slopes mostly by gravity. Frost action is much to do with the development of such debris.

- 1 Parent material develop from colluvial debris is dependant on sources of material.
- 2 This material is coarse and stony because of predominant physical weathering.
- 3 These materials are not of great agricultural importance because of their small area, inaccessibility and unfavourable physical and chemical characteristics.

ALLUVIAL DEPOSITS: River transported parent material consists of sand, silt and clay. Alluvium based on the method of deposition is sub-divided in to flood plains, alluvial fans and delta deposits.

Flood Plains: Sediments carried by swollen stream are deposited during the flood, with the coarser materials being laid down near the river channel and finer materials farther away.

Alluvial Fans : Streams that leave a narrow valley in upland area and suddenly descend to a much boarder valley below, deposit sediment in the shape of a fan. Fan material is generally gravelly and stony but often proves agriculturally productive.

Delta Deposits: Suspended material settles near the mouth of river, forming a delta. Delta often is a continuation of flood plain. It is clayey in nature and is likely to be swampy as well. Areas of delta sediments that are subjected to flood control and drainage become rather important agriculturally.

MARINE DEPOSITS : Fine sediments deposited at the bottom of the sea and get exposed at the surface due to change in sea level.

SAND DUNES : Sand deposited by the wind action forming ridges of various shapes, common in arid zones.

LOESS / AEOLIAN : Very fine material transported and deposited by the action of wind in usually yellowish in color and comprise fine silt and clay fractions.

TILL / MORAINES : It is an unstratified glacial drift deposited directly by ice, and consisting of clay, sand, gravel and boulders intermingled in any proportion.

LECTURE 8

SOIL FORMATION

SOIL FORMING FACTORS

Soil formation is a process of two consecutive but overlapping stages

- 1 The weathering of rock (R) in to parent material,
- 2 The formation of the soil from parent material

Weathering

Soil forming processes

Rock-----? Parent material-----? Soil

Dokuchaev (1889) was the first person to show that soils usually form a pattern in the landscape and established that they develop as a result of the interplay of soil forming factors viz: parent material, climate and organism, which he put forward in the form of an equation

$$S = f(P, Cl, O)$$

Jenny (1941) formulated the following equation

$$S = F(Cl, B, R, P, T, \dots)$$

S= any soil property **Cl**= Climate **B** = Biosphere **R** = Relief / topography **P**=Parent Material **T**= Time **---**: additional unspecified factors.

Soil can be defined in terms of soil forming factors. "Soil is a dynamic natural body having properties derived from the combined effect of climate and biotic activities as modified by topography acting on parent materials over a period of time.

Joffe divided the soil forming factors into active and passive factors.

Parent material, Relief / Topography and Time – Passive factors

Climate, Vegetation & Organisms ----- Active factors

Active soil forming factors

The active soil forming factors are those which supply energy that acts on the mass for the purpose of soil formation.

Climate : Temperature and rainfall are the two climatic agents, that influence the process of soil formation. Amongst all the soil forming factors, climate perhaps is the most influential in soil development. Climate affects the soil formation directly and indirectly. Directly climate affects

the soil formation by supplying water and heat to react with parent material. Indirectly it determines the flora and fauna activities which furnish a source of energy in the form of organic matter. This energy acts on the rocks and minerals in form of acids and salts that are released, during decomposition of the organic matter. The climate i.e. precipitation and temperature affects the rate of chemical, physical and biological processes responsible for profile development.

Soils formed under the predominant influence of climate, where the parent material effects are obliterated, are known as 'Ectodynamomorphic soils'. Soils are formed under the supreme influence of parent material are known as 'Endodynamomorphic soils'

Rainfall:

- Humid regions: If precipitation or rain fall $>$ PET (Potential evapo transpiration) leaching of bases take place. pH of the soils is decreased. Soils become acidic. Vegetation will be more. The soils have more organic matter due to less decomposition. Soils exhibits good horizonation.
- High rain fall leads to loss of soil through runoff and erosion in sloppy areas and accumulation of materials in plains leading to the development of different soils..
- Arid and semi arid regions: Rainfall $<$ PET. Here percolation of water will be less. So bases accumulate. pH of soils will be more. Soil horizonation is poor.

Temperature:

- According to Vant Hoff's law For every 10°C rise in temperature , the chemical reactions are increased by a factor of 2 or 3. Hence as temperature increases the weathering of rocks increases due to more biological activity and faster chemical reactions. Usually weathering will be more in tropical climate than temperate climate.
- In cold humid climate the soils are grayish and in warm humid climate the soils redder in colour.

Biota (Vegetation and Organisms): The nature of vegetation in an area is influenced by the type of parent material in the initial stages, but with time, it is the climate which controls the kind of vegetation i.e. grasses, forests, shrubs etc., The nature of the soil thus developed to a great extent is governed by the type of vegetation.

- The organic matter content of the grass land soils is generally higher than that of soils in forested areas, especially in sub surface horizons. Structural stability of soil aggregates is more under grass land vegetation.
- Under coniferous vegetation soil acidity is likely, because the leaves of cone trees are low in basic cations i.e. Ca, Mg,K,Na ; and also the leaching is rapid under this vegetation.
- Under deciduous trees (oaks and maples) cycling of nutrients through continuous litter is more and soils would be rich with base saturation.

With organic enrichment of soils, microbial activity would be enhanced and soil is likely to be enriched with available nutrients .Soil organisms play a major role in profile differentiation. Organic matter accumulation profile mixing, nutrient cycling and structural stability are all enhanced by the activities of organisms in soil. Vegetative cover reduces natural soil erosion rates, there by slowing down the rate of mineral surface removal.

Human activity like deforestation, tilling soils, irrigation and fertilization significantly influences soil forming processes.

Parent Material : Parent material as such exerts significant influence on soil characteristics during the initial stages of soil development. The nature of parent material profoundly influences soil characteristics like texture, which is the basic property of the soil and can not be altered easily. Soil texture controls downward movement of water, there by affecting the translocation of fine soil particles and plant nutrients.

The role of parent material in soil formation is passive and so there would be weak correlation between the parent material and soils formed from them. In the initial stages soil properties are mainly determined by the kind of parent material.

Basalt ----- Red Soils (Ultisols)

Basalt ----- Black Cotton Soils (Vertisols)

Acid igneous rocks----- light textured podzolic soils

Basic igneous rocks----- fine textured cracking clay soils (Vertisols)

Basic alluvium materials --- fine to coarse textured soils (Entisols or Inceptisols)

The nature of the elements released during the decaying of rocks has a specific role in soil formation.

- 1 Silicon and aluminum furnish the skeleton for the production of secondary minerals.

- 2 Fe and Mn are important for imparting red color to soils and for oxidation and reduction phenomena.
- 3 Na and K are important dispersing agents for clay and humus colloids.
- 4 Ca and Mg have a flocculating effect and result in favourable and stable soil structure for plant growth.

Relief : Relief or topography relates to the configuration of the land surface and is described in terms of difference in elevation, slope and so on. The topography of the land can hasten or delay the work of climatic forces.

- The significance of topography, as a genetic factor, is more noticeable locally as it influences the climate and vegetation of an area.
- Topography influences the thickness of the profile. The soils on flat topography tend to be thick, but as the slope increases, so does the erosion hazard resulting in thin stony soils.
- Soil climate is more humid on gentle slopes than steeply sloping lands and still moist or wet in valleys and depressions or valley land.
- The soils on steep slopes are generally shallow, stony and have a weakly developed profile with less distinct horizonization. It is due to accelerated erosion which removes surface material before it has time to develop.

Red soils----- Higher topographic position

Black cotton soil----- Lower topographic position.

Time : The length of time required for a soil to develop the distinct layers, called as genetic horizons (Matured soil with A,B,C horizons) depends on many interrelated factors of climate, nature of plant material, organism and topography.

- Horizons tend to develop more rapidly under the warm humid and forested conditions than in cold or hot, and arid climates.
- Generally soils age faster on flat to gently sloping uplands than on flat low lands or on steeply sloping positions.
- Soils on river flood plains remain younger due to periodic erosion or accumulation of soil material.

Weathering stages:

Initial stage: Unweathered parent material

Juvenile stage: Weathering has just started but much of original material can be seen.

Virile stage: Easily weathered minerals are not seen (completely decomposed)

Senile stage: Only most resistant minerals like quartz survive in these soils.

Final stage: Soil development is complete under the prevailing conditions.

LECTURE 9**PEDOGENIC OR SOIL FORMING PROCESSES**

The geological weathering produces weathered rock material i.e. the parent material and when the genetic factors set the stage for soil development . The pedogenic processes change the parent material in to soil with varying horizonations.

The pedogenic processes are extremely complex and dynamic involving many chemical and biological reactions, and usually operate simultaneously in a given area. One process may counteract another, or two other processes may work simultaneously to achieve the same result.

The relationship between pedogenic processes and genetic factors contributes in some manner or another, to the pedogenic development of each mature soil. All the genetic factors contribute to the development of each soil, but no single soil is influenced by all pedogenic processes.

The basic pedogenic processes involved in soil formation, according to Simonson (1959) include:

- * *Gains or additions of water (mostly as rainfall) organic and mineral matter to the soil.*
- * *Losses of above material from soil.*
- * *Transformation of mineral and organic substances with in the soil.*
- * *Translocation or movement of soil materials from one point to another with in the soil. It is usually divided in to i) movement in solution (leaching) and ii) movement in suspension (eluviation) of clay, organic matter and hydrous oxides.*

In contrast, the major changes that retard or offset horizon differentiation are due to :

- ✓ Mixing of materials by burrowing animals.
- ✓ Removal of surface soil by erosion (water or wind)
- ✓ Creep (by shifting old and its replacement by new materials); and
- ✓ Accretion of sediments in cultivated flood – plain areas, for instance silting of irrigated areas

BASIC / FUNDAMENTAL PEDOGENIC PROCESSES:

HUMIFICATION: Humification is the process of transformation (decomposition) of raw organic matter in to 'HUMUS'. It is an extremely complex process involving various organisms such as bacteria, fungi, actinomycetes, earth worms and termites.

The decomposition of organic matter takes place in two phases: mineralization and humification. Mineralization is a biochemical breakdown of dead plant tissues by soil microorganisms to produce simple structured soluble organic substances, mineral compounds, metal cations and gases (CO₂). During the second phase, that is humification, soluble organic substances regroup themselves in to large molecules by polymerization and become poorly soluble. They form major part of soil humus and provide site for retention of cations. The other part of humus is the polysaccharides – gummy products of microbial excretions, which help in soil aggregation.

The activities of microorganisms and soil formation are as under:

Mor : It refers to surface soil horizon developed under acid litter and humus from coniferous and heath vegetation, where fungi activity predominates.

Mull : Designated as forest soil horizon (A₁) is of intimately mixed mineral matter and amorphous humus. It is slightly acid and is best developed under base rich litter, where bacterial activity predominates.

Sward: Is a dominantly rhizogenous A₁ horizon in grasslands as contrasted with zoogenous mull horizon of forest soils. This includes mollic epipedon or Ap horizon formed by cultivation of forest soils, in general.

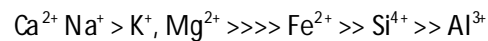
Orterde: Is a humus rich B horizon in podzols.

ELUVIATION : Eluviation means “Washing out”. It is the process of removal of constituents in suspension or solution by the percolating water from the upper to lower layers. The eluviation encompasses mobilization and translocation of mobile constituents resulting in textural differences.

Mechanical movement of clay and iron oxides from ‘A’ horizon without undergoing chemical alteration – Lessivage (Dachaufour, 1977).

Leaching refers to the movement and removal of material in solution from the soil. It connotes the removal of the dissolved material from the entire solum.

Elemental mobility



(Most mobile) (Least mobile)

The leaching of an element depends not only on its relative mobility but also on the rate of water percolation through the soil. The effect of leaching is well illustrated with the depth of accumulation of CaCO_3 in soils (Jenny, 1941).

Hot arid zone	-	< 50 cm
Less hot semi arid zone	-	100 – 150 cm
Sub humid zone	-	>150 cm

Illuvation

The process of deposition of soil materials (removed from the eluvial horizon “E”) in the lower layer (or horizon of gains having the property of stabilizing translocated clay materials) is termed as “illuviation”. The horizons formed by this process are termed as illuvial horizons (B-horizon especially Bt).

All these basic pedogenic processes, combine to result in a number of wide ranging soils that are observed on surface of the earth.

Hot semi arid	-	Calcisol
Cool humid	-	Podsol
Hot humid	-	Ferralsol

Specific pedogenic processes

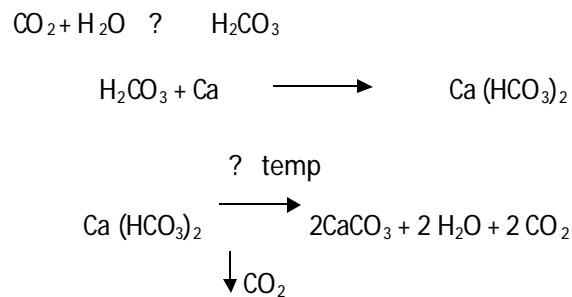
The basic pedogenic processes provide a frame work for later operation of more specific processes.

Calcification

The process of precipitation and accumulation of calcium carbonate in some part of the profile is called calcification. This is a common process in arid and semi-arid regions, which are low in rainfall (Rainfall < PET).

The illuviated horizon of CaCO_3 is designated as 'calic horizon'.

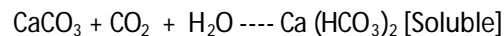
Whenever high carbon dioxide is produced in soils, it combines with water and forms into carbonic acid. This dissolves the calcium carbonate in soils into soluble calcium bicarbonate, which moves along the percolating water. Again wherever a situation of high temperature and low carbon dioxide prevails, there calcium carbonate precipitates.



The calcium compounds are in solution as long as the CO_2 concentration or supply is maintained. The depth of "calic horizon" depends on percolating rain water, ground water depth, amount of rainfall and the texture of the soil.

The depth of calcareous layer In hot arid zone < 50cm, in semi arid zone 100-150cm and in sub-humid zone the calcium carbonate accumulates at a depth of > 150cm

DECALCIFICATION : It is the reverse of calcification that is the process of removal of CaCO_3 or calcium ions from the soil by leaching.



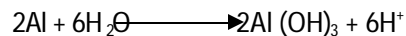
This occurs mostly in high rainfall or humid regions.

PODZOLIZATION : (Russian term) Pod = under and zola = ashlike

It is a process of soil formation resulting in the formation of podzols and podzolic soils. It is the process of accumulation of silica and eluviation of sesquioxides It is almost a reverse of

calcification process due to leaching of all bases including calcium. The favourable conditions for podzolization are

- A cool and humid climate (Invariably found at high altitudes)
- Siliceous (sandy) or acidic parent material, having poor reserves of weatherable minerals, favor the operation of podsolization, as it helps in easy percolation of water.
- Acid loving vegetation, such as coniferous pines (*Pinus roxburghii*), hemlock (*Tsuga Canadensis*) and heath (*Calluna vulgaris*) are essential for this process.
- Under calcium free, acidic environment (pH <5.0), fungi plays active role in organic matter decomposition.
- Less microbial activity declines the polysaccharide production and keeps the soluble organic products in soluble form.
- The soluble organic acids react with sesquioxides and the remaining clay minerals, forming organic - sesquioxide and organic - clay complexes, which are soluble and move with the percolating water to the lower horizons .
- Alluminium ions in solution hydrolyse and make the soil solution very acidic.



As the materials move out, it gives a bleached appearance (E-horizon) below the surface. The eluviated materials deposit in B horizon as dark coloured Bh (precipitated humus), reddish brown Bs (deposition of sesquioxides) and a yellowishish brown(silicate clay) layer which gradually merges with parent material. Hence a mature podzol has well developed horization. Podzols are highly acidic, low in fertility and used for forestry or pastures. Rarely crops like oats. Potato and clover can be cultivated.

LATERIZATION :

The term laterite is derived from the word "later" means "brick" or "tile".

In tropics, certain soils are massively impregnated with sesquioxides to the extent of 70 to 80% of the total mass, and forms a cemented horizon, which when dried becomes very hard like a brick. This soil forming process is called "laterization" or "Lotozation" Eg: Soils of Malabar hills of Kerala.

In laterization, unlike podzolisation, silica is removed leaving sesquioxides to remain in solum. The favorable conditions are

- ✓ Warm and humid (tropical) climate with 2000 to 2500 mm rainfall and continuous high temperature ($\pm 25^{\circ}\text{C}$) throughout the year. Rapid decomposition of parent material and organic matter, and intensive leaching are very likely in this climate.
- ✓ The rain forests of tropical areas are the suitable vegetation for this process. Under this vegetation organic additions are low but organic matter decomposition is at very high rate.
- ✓ Basic parent materials, having sufficient ferro-magnesian minerals (Pyroxenes, amphiboles, biotite and chlorite) are congenial for the development of laterites.

The iron released during weathering is oxidized to form FeO , Fe_2O_3 and coats clay, silt or sand particles imparting characteristic red color to soils. The Al-oxides /hydroxides imparts grey coatings to the soil particles.

The high temperature, intense leaching and basic kind of parent material all favor the removal of silica (de-silication) and accumulation of sesquioxides. The soluble basic cations are quickly released during weathering, moves freely in the soil profile and shoots up the pH to neutrality. Under this basic environment silica liberated from parent material is solubilized and leached. The solubility of quartz and amorphous silica increases with increased temperature. The sesquioxides are left behind as these are more stable under these conditions. As the alkaline bases are removed from the seat of their formation, the residual soil is acidic in reaction. Though considerable eluviation takes place, there is no marked horizonsiation as the eluviated materials are not re-deposited in the lower layers.

Laterite soils are non-plastic, non cohesive and have granular structure. They are low in cation exchange capacity and fertility. Phosphorus fixation is high in these soils. Plantation crops are usually grown on these soils.

GLEIZATION

“Glei” means blue, grey or green clay.

The gleization is a process of soil formation resulting in the development of a glei (or gley) horizon in the lower part of the profile above the parent material due to poor drainage conditions or water logged conditions. Such soils are called “hydromorphic soils”. This process is not particularly dependant on climate (high rainfall as in humid regions) but often on drainage conditions.

Poor drainage may be due to lower topographic position, impervious soil parent material and lack of aeration.

Under anaerobic conditions, iron compounds are reduced to soluble ferrous forms. The reduction of iron is primarily biological and requires both organic matter and the micro organisms capable of respiring anaerobically. Iron exists as Fe^{2+} organo-complexes in solution or as a mixed precipitate of ferric and ferrous hydroxides, which is responsible for the production of typical bluish to grayish horizon. Due to seasonal fluctuations of ground waters, the gley shows distinct mottling of yellow and rusty brown colors caused by the alternate oxidation and reduction phenomena.

SALINIZATION

It is the process of accumulation of salts such as sulphates, chlorides of calcium, magnesium, sodium and potassium in soils in the form of salty (salic) horizon. As a result of the accumulation of salts, solonchaks or saline soils develop with an electrical conductivity of $> 4 \text{ dSm}^{-1}$. The soils are called saline soils, which have ESP less than 15 per cent and pH between 7 and 8.5.

The responsible factors :

- ✓ Arid or semi-arid climatic conditions, associated with shallow and brackish (high amounts of sulphates and chlorides) ground waters.
- ✓ Lower topographic positions / depression land forms.
- ✓ Imperfect or poor drainage conditions
- ✓ Old lake bottoms
- ✓ Alluvial deposits along the sea coasts
- ✓ Use of saline irrigation waters.

The ground water containing high salts moves in an upward direction by capillary action. The water on evaporation leaves the salts behind, which accumulate at the surface or at some depth depending upon the capillary fringe. Surface accumulation of salts gives white appearance to soils. Hence the soils are called as white alkali soils.

These soils can be managed by leaching of salts followed by provision of sub-surface drainage.

SOLONIZATION OR ALKALIZATION

The process involves the accumulation of sodium ions on the exchange complex of the clay to an extent of >15%, resulting in the formation of sodic soils (solonetz) under arid and semi-arid conditions. This occurs when anions like carbonates and bicarbonates predominate in soil.

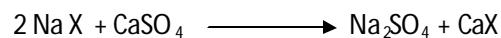
The calcium and magnesium in soil solution will precipitate as corresponding carbonates or bicarbonate when ever the ionic product of solution exceeds the solubility products of respective carbonates. This reduces the concentration of Ca and Mg in soil solution , there by releasing them from exchange complex. As this process continues, the sodium concentration on exchangeable complex increase. When the ESP in soils exceeds 15 %, the soil is designated as alkali soil with a high pH of >8.5, which results in less nutrient availability.

The high pH in soils results in dissolution of humus, which moves upward along the capillary water giving black colour to soils. Hence the soils are called black alkali soils. High sodium on clay minerals results in dispersion of soil aggregates leading to physical problems like poor aeration, low infiltration and percolation of water.

This process results in a very thin, friable horizon followed by a dark horizon of hard and impermeable heavy soils generally with illuviated day and having a typical columnar structure, which is characteristic of "solonetz".

SOLODIZATION OR DEALKALIZATION

This process refers to the removal of Na⁺ from exchange sites. The Na⁺ can be eliminated by increasing the concentration of Ca²⁺ or Mg²⁺ in the water, followed by improved drainage facilities.



PEDOTURBATION

It is the process of mixing of the soils. Mixing to some extent takes place in all soils.

- ❖ Faunal pedoturbation : Mixing by animals such as ants, earthworms, moles, rodents and man himself.
- ❖ Floral pedoturbation : Mixing by plants, as in tree tipping that forms pits and mounds.
- ❖ Argillopedoturbation : Mixing of materials in solum by churning process caused by swell - shrink clays as is observed in deep black cotton soil.

- ❖ Calcification, podzolization and laterization are zonal soil forming processes, where in the profile characteristics are influenced by prevailing conditions of climate and vegetation.
- ❖ Gleization, salinization, solonization and solodization are the Intra-zonal soil forming processes, wherein, the profile characteristics are more influenced by certain local conditions, such as relief (topography) and / or parent material than the climate and vegetation.
- ❖ Salinization, alkalization and dealcalization processes operate in sequence and advance the soil to a certain point in transition until the zonal soils are formed.

LECTURE 10

SOIL PROFILE

A vertical section of soil through all its horizons and extending in to the parent material. A vertical exposure of the horizon sequence is termed as "soil profile".

Theoretical Soil Profile

	O _i : Organic, slightly decomposed
	O _e : Organic, moderately decomposed
	O _a : Organic, highly decomposed
	A: Top Mineral layer, mixed with humus, dark in color
	E: Horizon of max. eluviation of silicate clays, sesquioxides etc.,
	AB or EB: Transition to B, more like A or E than B.
	BA or BE: Transition to A or E, more like B than A /E.
	B: Illuviated B horizon, with clear expression
	BC: Transition to C, more like B than C.
	C: Zone of least weathering, accumulation of Ca, Mg carbonates, cementation, may be high bulk density
	R: Bed Rock

A soil horizon is a layer of soil, approximately parallel to the soil surface, differing in properties and characteristics from adjacent layers below or above it.

Soil profile is an historic record of all the soil forming processes and it forms the unit of study in pedological investigations. Practically, soil profile is an important tool for soil classification which is applicable for thorough understanding of the soils.

Five master horizons are recognized in soil profile and are designated using capital letters O, A, E, B and C. Sub-ordinate layers or distinctions within these master horizons are designated by lower case letter e.g., a, e, i, t, k etc.

O Horizons:(Organic) It comprises of organic horizons that form above the mineral soil. They result from litter derived from dead plants and animals. 'O' horizons usually occur in forested areas and are generally absent in grassland regions.

A - Horizon: It is the top most mineral horizon. It contains a strong mixture of decomposed (humified) organic matter, which tends to impart a darker color than that of the lower horizons.

E - Horizon: It is an eluviated horizon. Clay and sesquioxides are invariably leached out, leaving a concentration of resistant minerals such as quartz. An 'E' horizon is generally lighter in color than the 'A' horizon and is found under 'A' horizon.

"B" – Horizon : (Illuvial) The sub-surface 'B' horizons include layers in which illuviation of materials has taken place from above and even from below. In humid regions, the B horizons are the layers of maximum accumulation of materials such as sesquioxides and silicate clays. In arid and semi-arid regions Ca CO_3 , Ca SO_4 and other salts may accumulate in the B horizon.

'C' – Horizon: It is the unconsolidated material underlying the 'Solum' (A & B). It may or may not be the same as the parent material from which the solum formed. The 'C' horizon is outside the zones of major biological activities and is generally little affected by the processes that formed the horizons above it.

'R'- Layer : Underlying consolidated rock, with little evidence of weathering.

Sub – Ordinate Distinctions with in Master Horizons:

p: plough layer disturbance

h : illuvial accumulation of organic matter

n : accumulation of sodium

t : accumulation of silicate clays

s : illuvial accumulation of organic matter and sesquioxides

y : accumulation of gypsum

z : accumulation of soluble salts

Differences Between Surface and Sub -surface soils

SURFACE SOIL	SUB-SURFACE SOIL
1. Soil up to a depth 30cm	Soil layers beyond 30cm depth
2. Physically loose and granular	Comparatively compact
3 More porosity	Less porosity
4. More organic matter content	Less organic matter content
5. Biological activity is more	Microbial activity is less
6. Mostly manipulated zone	Relatively un manipulated
7. Root activity is more	Comparatively less excepting in cases of long duration / perennial crops
8. It is completely weathered	It is partially weathered
9 most of the essential nutrients are present in available form	Less content of essential nutrients in available form.

LECTURE 11

SOIL PHYSICS :Soil Physics is a branch of Soil Science dealing with physical properties of soil, as well as with the measurement, prediction and control of different processes taking place in and through the soil.

SOIL PHYSICAL PROPERTIES: The physical properties include texture, structure, density, porosity, consistency, temperature, colour and water content. The physical properties depend on the amount, size, shape and arrangement and mineral composition of its particles , kind and amount of organic matter and the volume and form of its pores and the way they are occupied by water, air at a particular time.

SOIL TEXTURE : Soil texture may be defined as the relative proportion of particles of various sizes (Soil separates / Mechanical fractions) such as sand, silt and clay. It is almost a permanent property of the soil and may change slowly with time.

Textural components and their properties: Soil contains various sized particles; some of which (Gravels, Stones, Cobbles and Boulders) obviously do not behave like soil, but are reported (

volume fraction and size range) if occupy enough of soil volume to influence soil physical processes significantly. Conventionally the particles smaller than 2.0 mm diameter are considered as soil material.

Soil Separates	ISSS system (mm)	USDA system (mm)
* Very Coarse Sand	--	2.00 – 1.00
* Coarse Sand	2.00 – 0.20	1.00 – 0.50
* Medium Sand	---	0.50 – 0.25
* Fine Sand	0.20 – 0.02	0.25 – 0.10
* Very Fine Sand	--	0.10 – 0.05
* Silt	0.02 – 0.002	0.05 – 0.002
* Clay	< 0.002	< 0.002

ISSS : International Society of Soil Science

USDA : United States Department of Agriculture

Gravel / Pebbles : 2.0 – 75.0 mm

Cobbles(Round) / Flags (Flat) : 75.0 – 250.0 mm

Stones: 250.0 - 600 mm: Boulders- >600mm

Nature and Properties of Soil Separates

Stones, cobbles and Gravel: Because of their sizes, function as separate particles. Stones, cobbles and gravel may be more or less rounded, irregularly angular or even flat.

Sand: Sand particles may be rounded or irregular with quite jagged surfaces depending on the abrasion they receive. These particles exhibit no plasticity and stickiness and hence less influenced by changes in moisture content. Their water holding capacity is low, percolation rate is high and facilitate good drainage and good air movement. Soils dominated by sand and other particles bigger than sand are invariably open, loose and in friable condition. As these fractions

are the fragments of the rocks with quartz as chief component, they are chemically inactive and insoluble.

Silt is intermediate between sand and clay in size (ISSS – 0.02 – 0.002 mm; USDA – 0.05 – 0.002 mm) and irregular in shape. Mineralogically and physically, silt particles greatly resemble sand particles, but since they are smaller and have a greater surface area per unit mass and are often coated with strongly adherent clay, they may exhibit some of the physico-chemical attributes of clay. Silt is dominated by quartz and micas like primary minerals; and possess some plasticity, cohesion and adsorption. They hold moisture but lesser than clay.

Clay fraction is less than 0.002 mm in size and forms the decisive fraction of the soil, which has most influence on soil behaviour. Clay particles are characteristically plate like or needle like in shape. Clay particles adsorb water and hydrate, thereby causing the soil to swell upon wetting and then shrink upon drying. They are very plastic and sticky in moist condition; and become hard and cloddy when dry. High tenacity of clay makes the cultivation difficult.

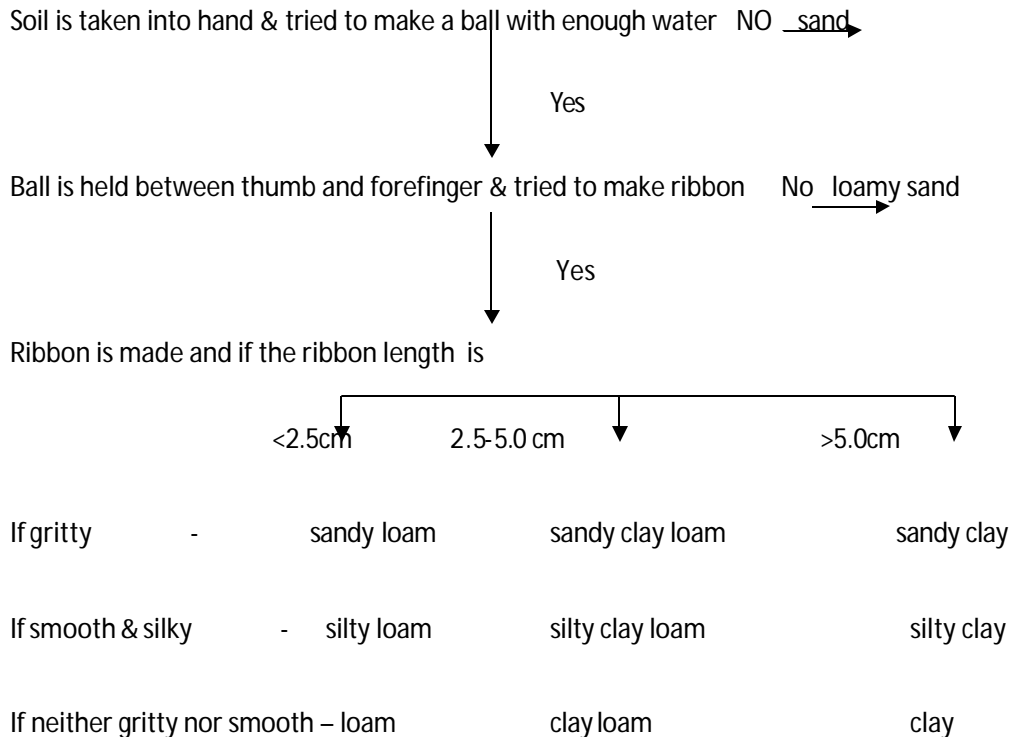
The relatively inert sand and silt fractions can be called the 'Soil Skeleton', while the clay, by analogy, can be thought of as the "Flesh" of the soil.

METHODS OF DETERMINATION OF SOIL TEXTURE

Soil texture may be assessed subjectively in the field or more rigorously by particle size analysis in the laboratory.

FIELD or FEEL METHOD: The common field method of determining the textural class of a soil is by its FEEL. Feel method is of great practical value in Soil Survey, Soil Classification and in any other investigation in which Soil Texture may play a role. Accuracy depends on experience. A soil surveyor determines texture by moistening a soil sample and kneading it between fingers and thumb until aggregates are broken down and the soil grains thoroughly wetted. The way the wet soil sticks out gives a good idea of the quantity of clay content. The sand particles are gritty; the silt has a floury or talcum powder feel when dry and is only moderately plastic and sticky when wet; persistent cloddiness generally is imparted by silt and clay.

Flow chart to determine soil texture by feel method:



LABARATORY METHOD : PARTICLE SIZE ANALYSIS / MECHANICAL ANALYSIS: The procedure of separating out different sized soil fractions i.e., sand, silt and clay and of measuring their proportional distribution is called particle size analysis or mechanical analysis. The result is expressed as Mechanical composition of soil or Soil Texture. There are two steps in mechanical analysis

- a. Dispersion
- b. Sedimentation

Dispersion: Dispersion of soil particles is achieved by breaking down the cementing agents viz., organic matter, calcium carbonate and iron oxides; and flocculating agents like salts and ions. Removal of organic matter is usually achieved by oxidation with hydrogen peroxide and calcium carbonate can be dissolved by addition of dilute hydrochloric acid. Treating the soil with sodium citrate. Sodium bicarbonate and sodium dithionate does remove iron and aluminum oxides, which are significantly present in red and laterite soils. Through repeated washings salts and ions can be eliminated. Dispersion or deflocculation is carried by means of a chemical dispersing agent like sodium hexametaphosphate and by mechanical agitation.

Other peptizing agents or deflocculating agents, which are commonly used, are sodium oxalate, sodium phosphate, and sodium metaphosphate and sodium pyrophosphate.

Now particles of 2 to 0.2 mm (coarse sand) are separated by sieving through 0.2 mm sieve. For separation of remaining particle sedimentation technique is used

Sedimentation: It is based on measuring the relative settling velocities of particles of various sizes from aqueous suspension. In a given medium larger particles settle more quickly than smaller ones of the same density. The relation between particle density and rate of fall is expressed by Stokes' law.

There are two widely accepted methods, which obey Stoke's law of sedimentation.

- 1) **Robinson's Pipette Method:** Also called as International pipette method. It is based on the sedimentation principle i.e., particles with different sizes and weights fall at different velocities. If a sample of soil suspension is taken at a given depth at particular time interval, this contains all the particles which are in suspension at that time at that depth. In this method a definite volume of soil suspension is taken from a required depth at definite time intervals using Robinson's pipette.

At 25°C a sample collected at 4min 15 sec time at 10 cm depth in the sedimentation cylinder contains silt and clay particles, while sample collected at 7 hrs 6 min interval contains only clay fraction. After drying the samples to constant weight silt and clay contents can be calculated. Fine sand left at the bottom can be separated out, dried and weighed.

- 2) **Bouyoucos Hydrometer Method:** It is based on the principle that there is a continuous decrease in the density of soil suspension over a period of time. So by knowing the density of soil suspension at required time intervals with a calibrated hydrometer the proportion of different fractions can be known.

. The pipette method is regarded as the standard method for particle size analysis because of its accuracy. It is however very time consuming and difficult to be employed in mechanical analysis of large n o. of samples.

. The hydrometer method is rapid but less accurate than the pipette method. This method gives erroneous results in soils having high CaCO_3 and organic matter contents and high salinity.

1st Reading at 40 seconds (sand fraction) or reading at 4min. (silt +clay)

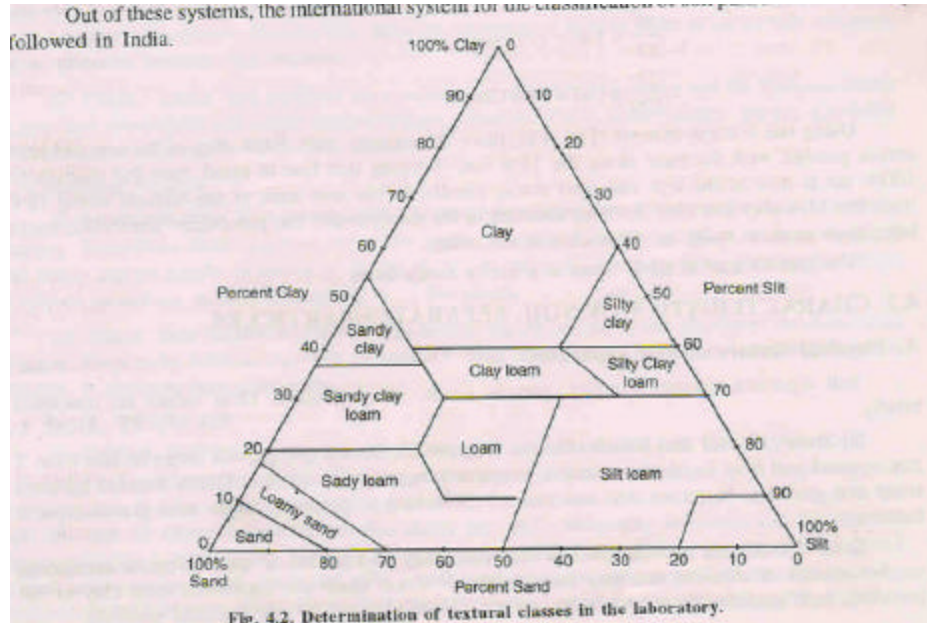
2nd reading after two hours (Clay fraction) : silt = (silt+clay) - clay

Silt = 100 – [Sand + Clay]; sand =100 – (silt + clay)

Soil Property	Sand	Loam	Silt Loam	Clay Soil
Feel	Gritty	Gritty	Silky	Cloddy/ Plastic
Identification	Loose	Cohesive	Shows finger print	Gives shiny streak
Internal Drainage	Excessive	Good	Fair	Fair to poor
Plant -Available Water	Low	Medium	High	High
Drawbar Pull	Light	Light	Medium	Heavy
Tillability	Easy	Easy	Medium	Difficult
Run-off Potential	Low	Low-medium	High	Medum-High
Water detachability	High	Medium	Medium	Low
Water transportability	Low	Medium	High	High
Wind Erodibility	High	Medium	Low	Low

SOIL TEXTURAL CLASSES: Textural names are given to the soils based on each of the three soil separates – sand, silt and clay. Soils that are preponderantly clay are called CLAY; those with high silt content are SILT and those with high sand percentage are SAND. Three broad and fundamental groups of soil textural classes are recognized: SANDS, LOAMS and CLAYS.

Soil textural diagram (ISSS): Considering the amounts of sand, silt and clay soil textural class can be determined with the helps of textural triangle.



Lecture 12

STOKES' LAW

According to Stokes' Law the terminal velocity of a spherical particle settling under the influence of gravity in a fluid of a given density and viscosity is proportional to the square of the particle's radius.

$$V = \frac{2gr^2}{9h} (p_s - p_f)$$

v = Settling velocity (cm/sec.)

r = Radius of the particle

p_s = Density of the solid particle (Mg/m^3) p_f = Density of the fluid (Mg/m^3)

h = Viscosity of the fluid

Assumptions of STOKES' LAW

1. Particles must be spherical, smooth and rigid.
2. Particles must be of uniform density.
3. Particles must be sufficiently large ($>0.001\text{mm}$) as compared to molecules of fluid so as to be unaffected by the thermal (Brownian) motion of the fluid molecules.
4. The particles should not interfere with one another and should settle independently. (Unhindered fall).
5. The suspension must be still with out any turbulence.

LIMITATIONS OF STOKES' LAW

1. Some colloidal particles are plate shaped and fall slower than spherical particles of the same mass.
2. Soil particles are not all of the same density. Most silicates have . density values of 2.6-2.7 gm/cm^3 where as iron oxides and other heavy minerals may have density values of 5.0 gm/cm^3 or even more.
3. The larger limit of particles exhibiting Brownian movement is approximately 0.0002 mm. so soil particles smaller than this exhibit Brownian movement.
4. Many fast falling particles may drag finer particles down along with them.
5. Particles >0.08 mm diameter settle quickly and cause turbulence

The greatest shortcoming in mechanical analysis is that, it does not account for differences in type of clay, which can be of decisive importance in determining soil behaviour.

Significance of Soil Texture:

1. Knowledge of texture of the soil is important to assess the value of the land
2. Land capability and methods of soil management are determined by soil texture.
3. Texture determines the suitability of land to raise different crops in different seasons and
4. Also its suitability for foundation of buildings and construction of roads.
5. Texture determines the total pore space and the distribution of macro and micro pores of soil, which in turn influence the retention and transmission of water as well as air.
6. Soil texture largely governs the nutrient holding and nutrient supplying abilities of the soils.
7. It is the most stable property and used as an index of several other properties of soils, which determines the agricultural potential of the soils.
8. It helps in evaluating the amount of amendment needed for the soil reclamation
9. Soil texture is of considerable importance in the study of morphology, genesis of soil, classification and mapping.
10. Texture has pronounced effect on soil temperature.

Lecture 13

SOIL CONSISTENCE Soil consistence is a dynamic physical property of soils, which varies with the variation of soil moisture and applied stress. It implies that the knowledge about soil water and its attraction for soil materials is a prerequisite, to know about soil consistency.

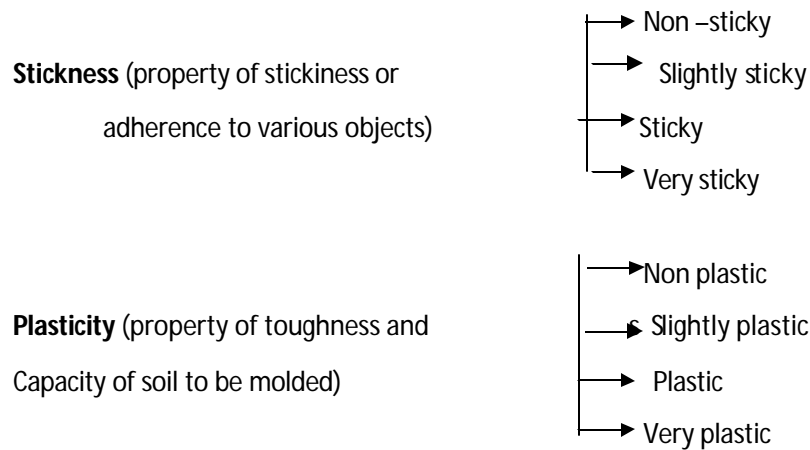
Soil consistency is defined as the manifestation of the physical forces of cohesion and adhesion acting within the soil at various moisture constants. These manifestations include the behaviour toward gravity, pressure, thrust and pull; the tendency of soil mass to adhere to foreign bodies or substances; the sensations, which are evidenced as feel by the fingers of the observer.

Cohesion refers to the attraction of substances of like characteristics such as that of one water molecule to another. Adhesion is the attraction of unlike materials i.e., attraction of water molecule for the soil particle.

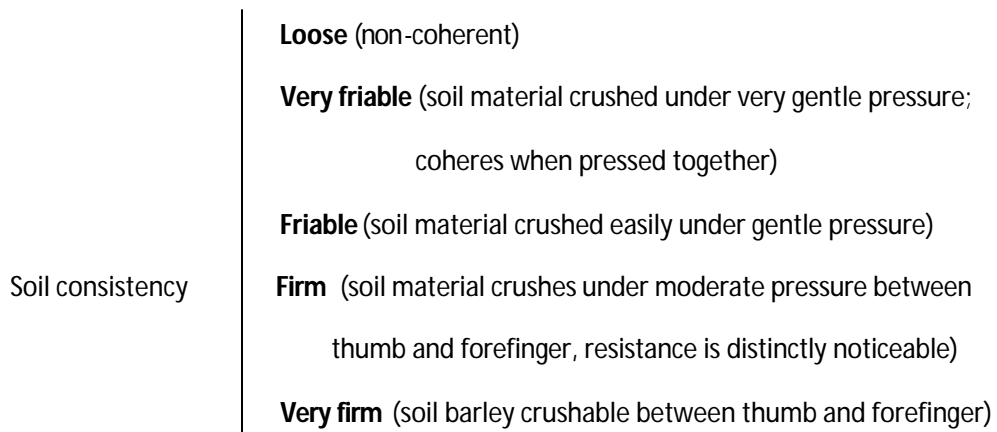
Soil consistency depends on the texture, nature and amount of inorganic and organic colloids, structure and moisture content etc., With decreasing moisture content, the soils lose their stickiness and plasticity and become friable and soft and finally when dry become hard and coherent.

Consistency is expressed based on moisture levels like wet, moist and dry

Wet soils: Soils are saturated with water.



Moist soils: Moist consistency is determined, at a moisture content approximately mid way between air-dry and field capacity. It is very important as it describes the condition of soils, when they are tilled in the field.

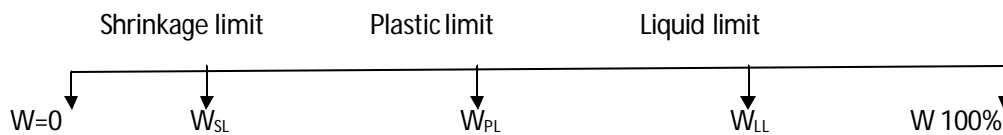


Extremely firm (soil can not be crushed between thumb and fore finger)

Dry soils: Rigidity, brittleness, maximum resistance to pressure, tendency to crush to a powder and inability of a crushed material to cohere again when pressed together, characterize consistency of soils in dry soils.

- Loose (non coherent)
- Soft (soil mass is very weakly coherent, breaks easily to powder)
- Slightly hard (easily broken between thumb and forefinger)
- Hard (Moderately resistant to pressure, can be broken in the hands without difficulty but is barely breakable between thumb and forefinger)
- Very hard (can be broken in the hands only with difficulty)
- Extremely hard (can not be broken in the hands)

Atterberg's consistency limits: Atterberg's limits are used to relate soil water content limits and various states of soil consistency. The state of consistency between solid and liquid range is divided into a number of distinct stages. Water content limits have been imposed for various states of consistency. These limits are called Atterberg's limits.



{? Solid state? } {? Semi solid state ? } {? Plastic state? } {? liquid state ? }

Liquid limit (W_{LL}) : It is the water content at which soils is practically liquid but possesses a small shearing strength. This is also termed as upper plastic limit. At this point the water film becomes so thick that cohesion is decreased and soil mass flows under an applied force. It is the water content above, which a mixture of soil and water flows as a viscous liquid and below which the material is plastic.

Plastic limit (W_{pl}) : It is the minimum water content at which a soil is plastic and the soil threads start to crumble. This is also known as lower plastic limit. At this point sufficient water is available like a film around each particle, lead to sliding of particles one over other with maximum cohesion. The number of water film around particles and total water adsorbed is regulated by nature and quantity of colloidal material present in the soil.

Shrinkage limit : It is the water content of soil at which soil transforms from the semi-solid state to the solid state. The shrinkage limit is attained at that water content at which the volume of soil remains constant regardless of drying. As drying proceeds a meniscus begins to form at the surface and react against soil grains producing a compression effect between the grains due to surface tension. When water tension is maximum further recession of mensci would cause no increase in stress and shrinkage. This water content is called shrinkage limit.

Soil plasticity : It is the pliability or capacity of the soil to be molded. It is one range of consistence of soil. Plasticity is defined as the property which enables a clay / soil to take-up water, to form a mass that can be deformed in to any desirable shape and to maint ain the shape after the deformation pressure is removed.

Plasticity results from plate like nature of clay particles and the combined binding / lubricating effect of adsorbed water. With the adsorption of water, thin films are formed around the particles. With applied pressure or force the particles slide over each other and are held in that condition by the tension of moisture films even after the pressure is removed. Any soil can exhibit plasticity, if it contains more than 15% clay.

Plastic limits or Indices of plasticity : Plasticity exhibited over a range of moisture contents are referred as plastic limits. There are three indices called the lower plastic limit or simply the plastic limit; the upper plastic limit or liquid limit and the plasticity index.

Plastic limit is the lowest moisture content at which a soil can be deformed without cracking. It is the upper limit of moisture content for tillage operation for most crops except rice. Tilling at moisture content above plastic limit, results in smearing and puddling of soil. The upper plastic limit or liquid limit is the moisture content at which soil ceases to be plastic. It becomes semi fluid and tends to flow like a liquid under an applied force.

The difference in moisture content between upper and lower plastic limits is the range over which a soil remains plastic is called plasticity index. Soils with high plasticity indices are difficult to plough.

Factors effecting plastic limits

- ❖ High clay content in soil, offers more surface area, thereby increases plasticity number.
- ❖ 2:1 expanding type clay colloids i.e., montmorillonite increases the plasticity index or number.
- ❖ Sodium saturated montmorillonite has the highest plastic limit as compared to K, Ca and Mg saturated montmorillonite clay.
- ❖ Higher the hydration energy of adsorbed cation, higher is the plastic number.

Organic matter decreases the plastic number of a given clay soil. Hydration of organic matter must be complete before sufficient water is available for film.

LECTURE 14

SOIL STRUCTURE

Studying the properties of soil separates is not enough to understand the behaviour of the composite soil body, but the manner in which the various particles are packed and held together in a continuous spatial network (Soil matrix or fabric) is to be considered to understand the soil. The primary particles do not exist as such but are bound together with varying degrees of tenacity in to larger units or aggregates usually termed as Secondary Particles. These are naturally occurring semi-permanent clusters or groups of soil particles, the binding forces between which are much stronger than the forces between adjacent aggregates.

Soil Structure may be defined as 'the arrangement of primary particles (sand, silt and clay), secondary particles (aggregates) and voids (pores) in to a certain definite pattern under field conditions'. In the broad sense Soil Structure denotes: a) the size, shape and arrangement of particles and aggregates; b) the size, shape and arrangement of the voids or spaces separating

the particles and aggregates; and c) the combination of voids and aggregates in to various types of structures.

Peds – Natural aggregates which vary in their water stability. **Clod** – It is used for a coherent mass of soil broken in to any shape by artificial means such as by tillage. **Fragment** - It is a broken ped. **Concretion** – It is a coherent mass formed with in the soil by the precipitation of certain chemicals dissolved in percolating waters. Concretions are usually small like shotgun lead pellets.

Classification of Structure: Classification of soil structure for field description is based on i) the **type** as determined by the shape and arrangement of peds ii) the **class**, as differentiated by the size of the peds and iii) the **grade**, as determined by distinctness and durability of peds.

TYPES: As per the geometric shape, the aggregates can be broadly divided in to two types.

1. Simple structure
2. Compound structure

1. Simple structure: In this the natural cleavage plains are absent or indistinct.

a. Single grain structure: Occur in sandy soils

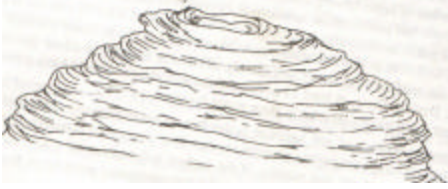
b. Massive structure: Coherent mass with high bulk density occur in soil crusts, paddy soils

c. Vesicular or honeycomb structure: Massive or loose aggregates of nodular ferruginous mass. seen in laterites.

Compound Structure: The natural cleavage plains are distinct. Described with relative length of horizontal and vertical axes and shape of peds.

Spheroidal: Small rounded peds with irregular faces and are usually separated from each other in a loosely packed arrangement. When spheroidal peds are porous, the structure is called as Crumb, while less porous peds are called granular. Usually granular peds are <1cm, while crumb peds are <0.5 cm in diameter. The diameter typically ranged from 1.0 to 10.0 mm.

Granular and crumb structures are characteristic of many surface soils (A horizon) particularly those high in organic matter. They are prominent in grassland soils and soils that have been worked by earth worms. This structure is invariably subjected to management practices.



Platy Structure

Plate like: Relatively thin horizontal pedes or plates characterize this structure. The thicker units are called **Platy** and thinner ones are called **Laminar**. The platy types are often inherited from parent materials, especially those laid down by water or ice. Sometimes, compaction of clayey soils with heavy machinery can create platy structure. Found in surface layers of some virgin soils.

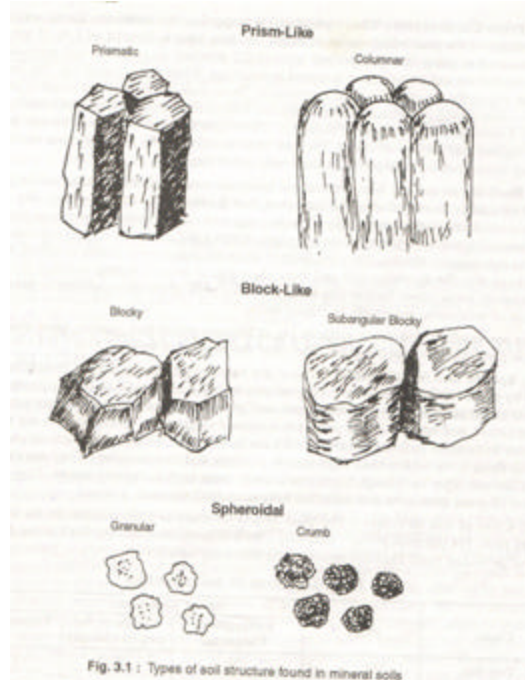


Fig. 3.1 : Types of soil structure found in mineral soils

Block Like: Blocky pedes are irregular, roughly cube-like and range from 5 to 50 mm across. The individual blocks are not shaped independently but are molded by the shapes of the surrounding blocks. When the edges of the blocks are sharp and rectangular faces distinct, they are called **angular blocky**, and when faces and edges are somewhat rounded they are referred to as **sub-angular blocky**. These types are usually found in B horizons, where they promote good drainage, aeration and root penetration.

Prism – Like: These are vertically oriented pillar-like pedes with varying heights among different soils and may have a diameter of 150 mm or more.

In **columnar** structure pillars have distinct rounded tops, and are invariably found in subsoils high in sodium (nitric horizon). If the tops of the pillars are relatively angular and flat horizontally, the structure is designated as **Prismatic**. These structures are associated with swelling types of clay and commonly occur in sub surface horizons in arid and semi-arid regions.

CLASS: Based on the size of the individual peds, the primary structural types are differentiated in to five sub-classes.

Size or class	Granular (mm)	Platy (mm)	Blocky(mm)	Prismatic(mm)
Very fine or very thin	<1	<1	<5	<10
Fine or thin	1-2	1-2	5-10	10-20
Medium	2-5	2-5	1-20	20-50
Coarse or thick	5-10	5-10	20-50	50-100
Very coarse or very thick.	>10	>10	>50	>100

In case of crumb structure, less than 1.0 mm is very fine; 1-2 mm is fine and 2-5 mm is medium class. The terms thin and thick are used for platy type (very fine <1 mm and very thick >10 mm), while the terms fine and coarse are used for other structural types (very fine blocky <5 mm and very coarse blocky >50 mm)

GRADES: Grade determines the degree of distinctness and durability of individual peds.

Structure less or simple structure: When there is no observable aggregation or there is no line of cleavage indicating the presence of peds e.g. single grain, soil particles in sand dune areas and massive structure(no cleavage lines) in puddle soil from a rice field.

Weak: Poorly formed, non-durable, indistinct peds and break in to a mixture of a few entire and many broken peds and much unaggregated material.

Moderate: Moderately well developed peds which are fairly durable and distinct.

Strong: Very well formed peds, which are quite durable and distinct.

Importance of soil structure

- Influences the amount and nature of porosity in soils.
- Governs the water and air permeability in to soils.
- Influences water holding capacity, soil-water relationship and growth of microorganisms.

- Influences soil drainage and availability of plant nutrients.

Management of soil structure: Soil structure management aims at the improvement and maintenance of soil structure, which are the major challenges in cultivated lands. The general principles relevant to structure management are :

- Tilling soils at optimum moisture conditions to ensure least destruction of soil structure.
- Suitable tillage and minimum tillage practices to minimize the loss of aggregate stabilizing organic substances.
- Covering soil surface with organic materials (mulch) to mitigate the beating action of rain and to add organics to soil.
- Incorporation of crop residues and animal manures in to soil, which upon decomposition, would stabilize soil aggregates.
- Suitable cropping systems, application of phosphatic fertilizers, inclusion of grasses and sod crops in the rotation, would enhance organic matter and favor stable aggregation.
- Green manuring and cover crops are good sources of organic matter.
- Use of synthetic organic amendments or soil conditioners

COLE: (Coefficient of Linear Extensibility) The expansiveness of a soil can be quantified as the coefficient of linear extensibility. If the value is >0.03 it indicates that soils are black soils with considerable expandable minerals (smectite). If > 0.09 Vertisols

$$COLE = \left[\frac{(L_m - L_d)}{L_d} \right] \times 100$$

L_m = Length of bar shaped soil, when moistened to its plastic limit

L_d = Length of bar shaped soil, when air dried.

Soil crusting: Soil crusting is the phenomena associated with deterioration of soil structure, where the natural aggregates break and disperse due to impact of rain drops, followed by rapid drying due to radiant energy of the sun.

When the rain droops strike the exposed dry soil surface, there is disintegration and dispersion of the aggregates. The finer clay particles move down along with infiltrating water and clog the pores, immediately beneath the surface thereby sealing the soil surface. Later

when drying starts surface tension forces pull the soil particles together, tending to form a dense and strong layer known as soil crust. Larger is the rain drop thicker may be the crust. Invariably crust thickness is about 5.0 mm.

Crust can form on all soils, excepting sands, but is severe on silty clay loams of older alluvial terraces and levees due to thin unstable structure.

Soil factors that are commonly associated with crusting are low organic matter, high silt and high exchangeable sodium.

The thickness of crust increases with increase in clay content. Montmorillonite clay forms thick and hard crust, whereas kaolinite clay form thin crust.

Soil crusting is the important factor affecting emergence and early growth of seedling and largely determines the crop stand. It is characterized by high B.D., very low non-capillary pores, very low hydraulic conductivity, very low aeration, high penetration resistance and high run-off of water.

Soil **crust strength** can be evaluated by using **penetrometer, balloon pressure technique and modulus of rupture test.**

Management or Control of Soil Crusting:

- ❖ Surface mulches minimize formation of soil crust
- ❖ Addition of organic matter
- ❖ Close growing crops and grasses which cover the soil
- ❖ Application of SSP or gypsum
- ❖ Application of artificial conditioners
- ❖ A light tillage when the soil is still moist will break up the crust before it hardens.
- ❖ Crop rotation
- ❖ Seed line mulch technology
- ❖ Deep ploughing
- ❖ Frequent inter cultivation and light irrigation
- ❖ Crop residual recycling technology

LECTURE 15

DENSITY OF SOIL

Density is the weight per unit volume of a substance. It is expressed as gram per cubic centimeter or pound per cubic feet or mega gram per cubic meter (Mg m^{-3}). Two density measurements like particle density and bulk density are common for soils.

Particle density

It is the mass per unit volume of soil solids. Particle density is essentially the same as the specific gravity of solid substances. The chemical composition and crystal structure of a mineral determines its particle density. Particle density is not affected by pore space and therefore is not related to particle size or to the arrangement of particles (Soil structure).

Particle densities for most mineral soils vary between the narrow limits of 2.60 to 2.75 Mg m^{-3} . The particle density of soils with very high organic matter content may vary from 0.9 to 1.3 Mg m^{-3} . Particle density of soils is almost a permanent character which is not influenced by addition of organic matter, tillage or depth.

Humus	1.3-1.5	Clay	2.2-2.6
Orthoclase	2.5-2.6	Quartz	2.5-2.8
Calcite	2.6-2.8	Muscovite	2.7-3.0
Biotite	2.8-3.1	Apatite	3.2-3.3
Pyrite	4.9-5.2	Hematite	4.9-5.3

Bulk density

It is the mass per unit volume of dry soil (volume of solid and pore spaces). The bulk density of a soil is always smaller than its particle density.

Loose and porous soils have low bulk densities as compared to compacted soils. Bulk density is of importance than particle density in understanding physical behaviour of soils. Generally in normal soils bulk density ranges from 1.0 to 1.60 Mg m^{-3} . Finer the texture of the soil, lesser is the bulk density.

Sand dominated soils	1.7 Mgm ⁻³
Organic peat soils	0.5 Mgm ⁻³
Compacted sub soils	2.0 Mgm ⁻³

Factors affecting bulk density

- More is the pore space, per unit volume of soil, less is the bulk density.
- Higher is the compactness; more will be the bulk density.
- Higher is the depth of soil, more will be the bulk density.
- Finer is the texture of the soil, lesser is the bulk density.
- High organic matter contents, lead to reduced bulk density.
- Crumb soil structure shows low bulk density than that of platy structure.
- Tillage temporarily reduces the bulk density.
- Cropping increases the bulk density of top soils.

Importance of bulk density

- Bulk density of the soil determines not only total pore space but the macro and micro pore space also, which in turn governs the soil – water – air relationship, thereby facilitate better crop growth.
- Infiltration, permeability, percolation of water and water retention in soil system, have direct relation with bulk density of soil.

Methods of Determination of Bulk Density: 1) Weighing bottle method 2) Clod saturation method 3) Clod coating method 4) Core sampler method. Among all core sampler method is widely used.

Porosity of soils : Porosity refers to the percentage of soil volume occupied by pore space. Pore spaces (voids) in a soil constitute portion of soil volume not occupied by solids, either mineral or organic. The pore spaces under field conditions are occupied at all times by air

and water. Pore spaces directly control the amount of water and air in the soil and indirectly influence the plant growth and crop production.

- Soil pores
- a. Macro pores
 - b. Micro pores or capillary pores

Macropores : Large sized pores (>0.06mm) invariably exist in between sand sized granules and allow air and water movement readily.

Micro or capillary pores: Smaller sized pores(<0.06mm) in which movement of air and water are restricted to some extent. These pores are very important for crop growth. Generally clays and clayey soils have a greater number of capillary pores.

Coarse pores : > 20 μ ; Medium pores : 20-200 μ

Fine pores: 2-20 μ Very fine pores : <2 μ

The existence of approximately equal number of macro and micro pores would facilitate better aeration, permeability, drainage and water retention. Porosity of soil is always prone for changes.

Calculation of porosity

$$\% \text{ solid space} = \text{Bulk density} / \text{particle density} \times 100$$

$$\% \text{ pore space} + \% \text{ solid space} = 100$$

$$\% \text{ pore space} = 100 - \% \text{ solid space}$$

$$= 100 - (\text{B.D}/\text{P.D}) \times 100$$

$$= 100 [1 - \text{BD}/\text{PD}]$$

Problem

A soil core was taken for the determination of porosity. The measurements were:

Cylinder volume 73.5 cc

Dry soil weight	87.8g
Particle density	2.65 g cc ⁻¹
Soil weight	87.8g
Soil volume	73.6cc
Bulk density	= Weight of soil / Volume of soil = 1.19g/cc
% pore space	= 100 - (1.19 / 2.65) = 55.10

Factors Affecting Porosity:

- 1) **Soil Structure** : A soil having granular or crumb structure contains more pore spaces than that of prismatic and platy soil structure. So the well aggregated soil structure has more porosity than that of structure less or single grained soils.
- 2) **Soil Texture**: In sandy soils the total pore space is small, where as in fine textured clay and clay loams total pore space and micro pores are higher .
- 3) **Organic Matter Content**: OM facilitates more aggregation there by more porosity.
- 4) **Depth of Soil**: With increase in depth of soil the porosity will decrease because of compactness in sub -soil.
- 5) **Organisms**: Macro organisms like earth worms, rodents, insects etc., increase macro pores
- 6) **Cultivation**: Intensive cultivation tends to lower the porosity of soil as compared to fallow soils. The decrease in porosity is due to reduction in organic matter content.

Soil compaction : Compaction encompasses compression plus increase in density of soil. It is the dynamic behaviour of soil. The degree of compaction depends upon the nature of soil, amount of energy applied, water content and extent of manipulation of the soil. Compaction is also associated with the rearrangement of the soil solid particles so that soil water and soil air are compressed with in the pore space.

Because of the incompressible nature of the soil particles and high internal friction, dry soils can not be compacted to high densities. An increase in water content decreases cohesion between the particles and internal friction, thereby facilitating compaction. During compaction,

the density of soil under a load increases with increase in soil water content up to a certain limit, beyond which further addition of water does not increase compaction because of incompressible nature of soils solids and water. This critical limit is called **procter moisture content**.

In many soils, a compacted layer is commonly found at the bottom of the zone of ploughing. This layer is termed as "Plough-sole".

Tilling the soils with wooden plough and other farm practices like use of tractor and other heavy farm equipments create the problem of surface and sub surface compaction in soils. Soil compaction changes the soil moisture and thermal regimes and mechanical resistance in soils. This leads to restricted root penetration and uptake of water and nutrients.

In highly coarse textured sandy, loamy sand soils compaction would be helpful to enhance water retention and to reduce percolation loss of water, through increasing the micro pore space.

LECTURE 16

Soil strength

It is a measure of the capacity of a soil mass to withstand stresses without giving way to those stresses by rupturing or becoming deformed.

Soil strength is largely affected by water content, particle size distribution, fluid polarity, cation species and its concentration, and type of clay mineral. At a given water content, the strength of the soil increases with compaction. For a given density, soil strength decreases with increasing water content.

The fine structured soils, which are invariably more cohesive at low moisture content, exhibit more strength. But, with increasing moisture content, particularly when all pores are filled with water, the strength dramatically declines, leads to mudslides.

SOIL COLOUR

Soil color is one of the obvious characteristics of soil and is frequently used to describe soil, than any other. Soil color, as such, does not have any influence on plant growth, but through its influence on soil temperature and soil moisture, it indirectly influences the plant growth.

Soil colour can be an indicator of the climatic condition (acquired or pedochromic) color under which a soil was developed or of its parent material (litho chromic color). Soil color is also taken as criteria for assessing soil productivity.

Practically all colours occur in soils, except pure blue and pure green. Predominantly, soil colors are not pure but mixtures, such as grey, brown and rust. Frequently, two or three colours occur in patches, which is called as "mottling".

The colour of the soil is a composite of the colours of its components. The effect of these components on the color of the composite soil is roughly proportional to their total surface, which is equal to their specific surface times their volume percentage in the soil. So- the colloidal material will have greatest impact on soil color i.e., iron oxides and humus.

Humus – brown or dark brown.

Iron oxides – red, rust – brown, or yellow depending upon degree of hydration.

Reduced iron – blue green

Quartz - white

Lime stones – white, gray or sometimes olive green.

The colour of an object depends upon the kind of light which it is capable of reflecting to the eye. Soils reflect light of a great variety of wavelengths. It may be possible to distinguish the great many colours, but, describing them accurately is a bit difficult, because of confused colour vocabulary.

Colour components: As the soil color is the important parameter, used to classify the soils, a standard system for accurate colour description has been developed using **Munsell color charts**. In this system, a small piece of soil is compared to standard colour chips in a soil colour book. Each colour chip is described by the **three components of colour i.e., hue, value and chroma**

Hue refers to the **dominant spectral colour** or quality which distinguishes red from yellow etc.

Value or brilliance expresses **apparent lightness** as compared to absolute white. It refers to relative brightness or darkness of colour with in a scale of (0 –10) as compared to absolute white. It refers to gradations white to black (lightness or darkness).

Chroma defines the gradations of **purity of colour** , or the apparent degree of departure from neutral grays to white (intensity or brightness) (strength of colour), with in a scale ranging from (0 –20).

The numerical notation 2.5 YR 5/6 suggests a hue of 2.5 YR, value of 5 and chroma of 6.

Significance of soil colour

- Colour is taken as a diagnostic criterion for classifying soils e.g. the comprehensive system uses color as formative element in its nomenclature as alb (white), ochr (light coloured), umbr (dark), sambr (dark).
- Soil color can be guide to the climatic soil group, to the parent material, or to the physiographic location.
 - Humid temperate regions – Grayish;
 - Tropics and sub tropics – red and yellow
- The productivity of the soils is assessed based on soil color e.g. dark color is an indication of high productivity.

Black > brown > rust brown > gray brown > red > gray > yellow > white.

- Colour indicates the presence / domination of the constituent minerals in the soil e.g. light colour results from preponderance of quartz mineral, red colour remits from domination of iron rich compounds.
- Colour is used to describe soil profile.
- Colour indicates the process involved in soil formation extent of leaching and erosion etc.
- Soil color is indicative of presence of excessive salts.
- Soils in depression are darker than adjacent uplands.
- Soils derived from basic rocks are darker than soils derived from acidic rocks.

LECTURE 17

SOIL WATER

Soil serves as a regulated reservoir for water, as it receives precipitation and irrigation. Water is an excellent solvent of most of the plant nutrients and is a primary requisite for plant growth.

The water that fills part of the pore spaces established between the solid particles of soil is known as soil water. It is the liquid phase of the soil and is important as the other two phases of the soil system. It has profound influence on the life of the plant, at all the stages.

Source of water retention: All the water required by the plants come from the soil. Water supplied to the soil is first adsorbed and held by soil colloids until the adsorption capacity of the soil is satisfied. If more moisture is available then it moves downward by gravity and drains off.

It is mainly clay or other colloidal particles that are responsible for adsorbing water. Silt and sand particles do not adsorb water or very little, if at all. The water so held on the surface of the clay particle is believed to be different from ordinary liquid water. It is non-liquid, more dense and viscous compared to ordinary water.

The electrostatic forces exist on colloidal particles would attract water molecules. Water molecule by virtue of dipolar nature, gets attached to colloidal particle with its positively charged end, leaving its negative charge end outward. In this fashion water molecules will be oriented or arranged on the surface of clay particles. Now, another layer of water molecules will be attached to the negative end of water molecules, in a successive manner. This results in thickness of water layers around colloidal particles. As the water molecular layer gets thicker, the orientation becomes weaker, and at a certain distance from the particle surface, the water molecules cease to orient and liquid water or capillary water begins to appear.

Soil water Retention curves or soil moisture characteristic curves:

The curves obtained from the graph, which are plotted using the water retained by soil at different matric suction values, are called 'soil moisture retention curves' or 'soil moisture characteristic curves'. The retention term is considered to cover both the process i.e., uptake and release. The desorption curve starts at saturation and shows retentivity at progressively increasing suction value.

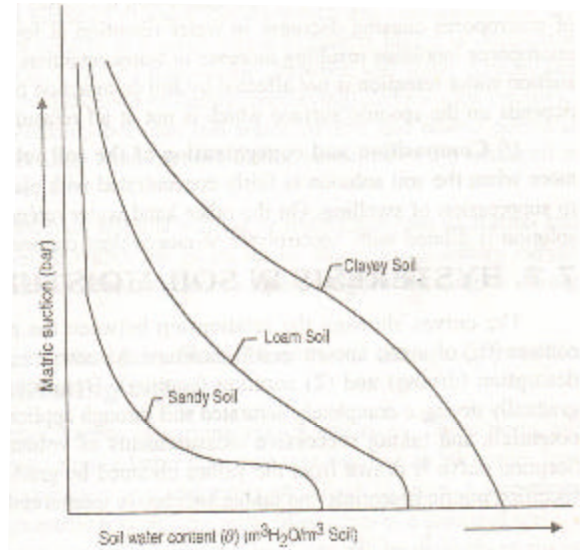


Fig. 7.4 : Schematic representation of soil moisture characteristics curves during sorption of water for three mineral soils having different textures.

SMCC are very nonlinear indicating that for a given change in water content the change in matric potential will be different.

Inference:

- Gradual decrease in tension with increased soil water content and vice versa
- Clay soils hold more water at a given tension than loam or sandy soils
- At a given moisture content water is held more tenaciously in clay soils compared to loams or sands.
- Much of water in clay soils is held more tightly (can not be removed by plants)
- At 15 bars matric tension sandy loam contains 5 %, silty clay loam contains 12 % moisture
- Well granulated soil has more total pore space than compact soil. Compact soils hold water with greater suction than loose soils.

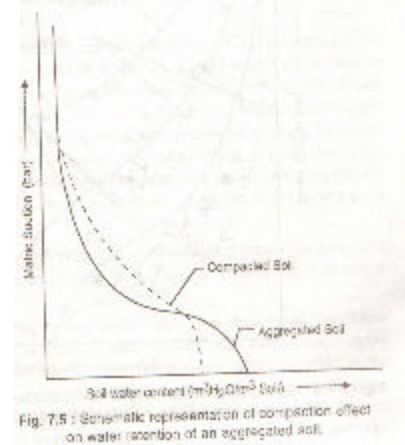


Fig. 7.5 : Schematic representation of compaction effect on water retention of an aggregated soil.

The curves are important in understanding the movement of water in soil and uptake by plants.

Importance of soil water

- It dissolves and carries nutrients to the plant.
- It helps in soil formation
- It makes soil biological active by supporting flora and fauna.
- It carries dissolved oxygen in to the soil
- It keeps soil from getting too cold or too hot.

LECTURE 18

SOIL WATER POTENTIAL

Soil Water Energy Concept : Soil water like other bodies contains energy in different quantities and different forms. The retention of water, its movement, uptake and translocation in plants, its loss to the atmosphere are all related to the energy. Different kinds of energy are involved like potential, osmotic and electrical.

Kinetic Energy: This is the energy, which matter has by virtue of its motion and quantitatively it is $\frac{1}{2} mv^2$ where 'm' is the mass and 'v' is the velocity. Since the movement of water is very slow its K.E. is also very less.

Potential Energy: This is the energy, which a body has by virtue of its position in a force field. Thus the potential energy is measured by the force required to move a body against the force field and is equal to the product of force and distance moved (i.e., $F \times d$) . Work must be done when body is moving against the force field and the body will do work when it is moving with the field.

In addition to these two energies, water energy is related to some other forces acting on water like electrical, matric and osmotic force. The resultant energy of all these energies to do some work is known as " Free Energy", which says about the energy status of water. " Free Energy" may be defined as a measure of escaping tendency or the tendency to change. Water will have the tendency to move from higher free energy to lower free energy points. Water will always move from saturated soils to dry soils.

Factors Effecting Free Energy of water: -

- Attraction of soil colloids to water by adhesive and cohesive force (matric forces)

- attraction of ions and other solutes to water (**Osmotic force**),
They reduce the free energy of water
- **Gravitational Force:** This is the major force acting on water, which tends to pull the water downwardly. The free energy of water at a given elevation in the soil is higher than that of pure water at lower level. So the free energy of soil water depends on a) moisture content

Higher the moisture more is the free energy. Smaller the matric force higher the free energy. Higher the temperature greater is the free energy. Lower the content dissolved more is the free energy.

SOIL WATER POTENTIAL: The term potential may be defined as the amount of work done (or potential energy stored) per unit mass in bringing any mass 'm' from any distance to the point where potential is to be considered. The work need to be done on soil water to change it to pure water at reference state against the force fields acting is called soil water potential.

Total Water Potential : The water in a system at rest , the sum of all potentials or the total potential at a point will be either constant or zero(This depends on the reference taken).

$$\text{Total Potential } (\psi_T) = (\psi_m) + (\psi_g) + (\psi_o) + (\psi_p) \dots$$

ψ_m - matric force (ψ_g) - Gravitational potential

(ψ_o) - osmotic potential (ψ_p) - Pressure potential $(\psi - \text{psi})$

If the total potential of water is constant through out the soil mass , then the water mass is said to be in 'static equilibrium' i.e., the net force acting on water to move is zero. If this is not zero, water movement occurs.

Gravitational Potential: The force of gravity acts on soil water, the attraction being towards the earth's center. The gravitational potential at any point in a gravitational field is defined as the 'work done per unit mass in carrying any mass'm' infinity to that point.

$$(\psi_g) = \frac{\text{work}}{\text{mass}} = \frac{mgh}{m} = gh$$

The point of reference is usually chosen with in the soil at a lower point so that gravitational potential is always positive. That is why the gravitational water always moves downwardly. This force is important as it removes excess water from the upper rooting zone following heavy irrigation or precipitation.

Matric Potential: Matric potential is the result of two phenomena i.e., adhesion or adsorption and capillarity. The attraction of soil solids and their exchangeable ions for water and the loss of energy (heat of wetting) when the water is adsorbed are the processes involved in the phenomena. In addition to this attraction, surface tension of water also accounts for capillary force. The net effect of these two forces is to reduce the free energy of water. Matric potential is always negative, because of reduced free energy.

Osmotic Potential: The osmotic potential is attributed to the presence of solutes in the soil. The solutes may be inorganic salts or organic compounds. They reduce the free energy of water. Osmotic potential is the result of hydration of ions in the soil solution. Due to dipolar nature of water molecules, the ions or compounds are attached on both sides reduces the free energy and the osmotic potential is the work to be done to detach these ions from water molecules. More the attachment, more the osmotic potential and less is the free energy. Unlike the matric potential, osmotic potential has little effect on the mass movement of water. But its effect is prominent in the uptake of water by plant roots. But in soils of high soluble salts osmotic potential may be greater than in plant roots. It is also negative

Pressure Potential: It is another component of soil water potential, which is due to the weight of water at a point under consideration or gas pressure exerted on water. With the change in elevation, the pressure potential in a soil with reference to water table may be either positive (below water table) or negative (above water table). The positive pressure potential is due to the weight of water column resting on any point below the water table and negative pressure potential is caused due to capillarity and adsorptive forces. If the point is beneath the water table, the potential is equal and opposite to the gravitational potential that is measured from the free water surface. This is otherwise known as 'Submergence potential' or 'Piezometric potential' or 'Pneumatic Potential'. Pressure potential due to gas pressure may be measured with ordinary manometer. Pressure potential due to water weight may be measured with 'manometer' or 'Piezometer'.

Units of Soil water potential: Several units have been used to express potential in terms of differences in energy levels of soil water. A common means of expressing potential is in terms of height of water column in centimeters. Greater is the height more is the potential.

This can be expressed in terms of standard atmospheric pressure also at sea level. This is equal to 14.7 lb/in.²; 760 mm of Hg; or 1020 cm of water. The unit 'bar' which is approximately equal to one atmosphere is also used. 10 bars = Mega Pascal (M Pa)

Equivalents in energy levels of Soil Water

Height of Water Column (cm)	Potential (bars)	Potential (M Pa)
0.0	0.0	0.0
10.2	- 0.01	- 0.001
102	- 0.1	- 0.01
306	- 0.3	- 0.03
2 1020	- 1.00	- 0.1
15,300	- 15.0	- 1.5
31,700	- 31.0	- 3.1
1,02,000	- 100	- 10.0

Suctions and tensions: Both matric and osmotic potentials are negative. The negative potentials are sometimes referred to as suction or tension. These terms are advantageous over potential as they are expressed in positive units.

pF Concept:

To express the soil moisture suction or tension **Schofield 1935** has suggested to use the logarithm of this tension with a symbol pF, an exponential function of free energy difference. It is defined as the "logarithm to the base 10 of the numerical value of the negative pressure of the soil moisture expressed in centimeters".

$$pF = \log(-h)$$

pF is the logarithmic expression of the force with which water is held in soils expressed in terms of height of a water column (cm) required to produce equal tension.

P = logarithmic value

F = free energy

Height of water column (cm)	pF
1	0
100	2
346	2.53 (field capacity)
15849	4.1 (wilting point)
31623	4.5 (Hygroscopic coefficient)

Classification of soil moisture on the basis of pF:

* Water of constitution and inter layer water	pF >7.0
* Hygroscopic water	pF 7.0 – 4.5
* Capillary water	pF 4.5 – 2.5
* Gravitational water	pF 2.5 – 0.0
* Ground water	Tension free

SOIL MOISTURE CONSTANTS

Knowledge about amount of water held by the soil at various tensions is required to calculate the amount of water available to plants, the amount of water retained by the soil before percolation starts and the amount of water that is favourable for irrigation.

Soil moisture constants are expressed in terms of the energy with which the water is held at that moisture content and the relationship is a continuous function without break. For practical use and tabulate the moisture data, it is necessary to compare moisture tension with some reference points. These reference points are known as 'Moisture Constants'.

Soil moisture constant	Soil moisture potential
Oven dry soil	-10,000 bars
Air dry soil	-1,000 bars
Hygroscopic coefficient	-31 bars
Wilting coefficient	-15 bars
Field capacity	-1/3 bars
Saturation	Almost "0"

- SATURATION :

Saturation water content is the amount of moisture present, when all the pores are filled with water. A soil whose pore spaces are completely filled with water is said to be saturated soil and the water is at zero tension. Such a condition is established only in coarse textured soils but not in fine textured soils as some fine capillary pores are filled with air. So the soil normally flooded with water will not be saturated as some air is blocked. Hence it is better to define a soil as saturated when the water is at zero tension and majority of its pores are filled with water.

AERATION– POROSITY LIMIT (Non-capillary porosity): Aeration porosity of a soil is defined as that part of the pore space volume that is free of water which can be established by creating a tension of water column of 50cms. This corresponds to a pF of 1.7 or 1/20 atmospheres tension. Aeration porosity is the volume of the pores whose diameter is more than 0.06 mm.

- FIELD CAPACITY:

After heavy rain or irrigation to the soil the water drains off rapidly for the first few hours and then starts to drain slowly. After two or three days, this rapid movement becomes slow and negligible later. The soil is said to be at field capacity. At this condition water moves out of macro pores and air occupies their places. The micro pores are still filled with water, which is available to plants. Moisture movement continues but very slowly. The moisture tension corresponds to pF of 2.53. But generally 1/3 bar tension is frequently used to describe field capacity. This constant can be measured with pressure plate apparatus. (At field capacity the moisture tension is about 1.0 atmosphere. But at one atmosphere tension water column breaks. Discontinuity of water column depends on texture of the soil. Discontinuity of water column depends on texture of the soil. For loam this occurs between 1/3 to one atmospheres).

BEST TILLAGE RANGE: Tillage practices play an important role in the management of soil structure. Soil is tilled to improve its structure. If the soil is tilled, when it is wet, it will be puddled. If it is dry because of high cohesiveness of solid particles it breaks into large clods and powder. In both cases soil structure will be disturbed. It should contain enough moisture content with which it can maintain small aggregates. The pF range 2.8 to 4.4 is considered optimal for tillage operations in medium textured soils.

- WILTING POINT: (wilting coefficient or Permanent wilting percentage):

It is the soil moisture content at which plants show wilting symptoms and can't recoup or recover even though it is kept in humid chamber. It occurs at pF value 4.18. The ease of release of water to the plant roots is just barely too small to counter balance the transpiration losses. Sometimes, plants exhibit wilting symptoms but recover with the addition of water or when placed in humid chamber. The water content at this condition is called the temporary wilting point. The water remains in small capillary pores and around the soil particles.

- **HYGROSCOPIC COEFFICIENT:**

Hygroscopicity is the ability of a body to adsorb moisture from the atmosphere. It largely depends on amount and type of clay, exchangeable cations and presence of free electrolytes. Soils high in expanding type of clay minerals and organic matter have a high hygroscopic coefficient. This water is not available to plants, but available to certain microbes.

Available water : Water held by soil at potential ranging between -15 bars to -1/3 bars, is considered as plant available water.

Determination of soil moisture

Keeping in view of two basic principles, moisture in the soil is determined viz., the amount of water in the given soil and the stress or tension under which the water is held by the soil. The relationship between these two properties throughout the entire moisture range gives a good deal of insight in to the physical characteristics of a soil.

Gravimetric method : This is a standard method in which the soil sample is collected from the field (moist condition) and weighed. The weighed sample is oven dried at about 105-110°C for overnight and weighed again. The weight difference is considered as water content.

An error may result from oxidation of organic matter and also while cooling the sample after taking out the same from oven before weighing.

Several methods have been developed to simplify the determination of the amounts of soil moisture. More recently infrared radiation is utilized for drying soil samples quickly.

$$\% \text{ moisture} = \frac{\text{Weight of fresh soil} - \text{weight of oven dry soil}}{\text{Weight of oven dry soil}} \times 100$$

Electric resistance method or electrical conductivity method

In this method two platinum electrodes are embedded in gypsum block at a definite distance apart. These gypsum blocks require calibration for uniformity before use. These blocks are buried in the soil at a required depth and conductivity is measured with a modified Wheatstone bridge. The electrical resistance of the soil decreases with increase in water content. The soil water content is obtained with the help of a calibration curve, for the same block of electrical resistance against known soil water content.

This method is useful to measure the percentage of soil moisture from field capacity to wilting percentage. This is not an appropriate method in soils containing high salt concentration.

Neutron scattering method : The neutron moisture meter consists of americium and beryllium or radium and beryllium as the neutron source and boron tri fluoride (BF₃) gas as a detector.

The fast moving neutrons emitted in to the soil collide with hydrogen atoms of water molecules, lose their energy and their movement will be slowed down. The slow neutrons are caught by BF₃ gas and counted with the help of rate meter or electronic microprocessor. The more slowed down neutrons return to the probe the greater is the water content of soil.

This instrument has to be calibrated for each soil. This method is rapid, less laborious, non-destructive and repeated measurements can be made at the same depth. However, this method is not suitable for moisture determination of surface soil.

Soil moisture tension determination

Tensiometer method : Tensiometers measure the matric potential of the soil moisture. The tensiometer consists of a porous cup made of ceramic material and a mercury manometer attached to the water filled cup through a water reservoir tube. When the porous cup is placed in soil and equilibrated, water tends to move out of the cup under the suction exerted by soil.

These suction readings are thus calibrated on the gauge to a specific soil to interpret the percent of moisture.

The use of tensiometer is confined up to the minimum matric potential of -0.8 bars, but much of the available water is retained by soil between -0.8 bars and -15 bars, particularly in fine textured soils. Beyond the tensiometric range, the matric potential is usually interpolated from the water retention characteristics curve using the measured soil moisture content.

Psychrometer method : The total soil water potential is determined with the help of soil psychrometer. As the liquid water in soil is always in equilibrium with its vapour in the ambient air, the energy status of water vapour (vapor potential) must be equivalent to the energy status of soil water. At constant temperature and gravitational potential, the vapour potential is largely contributed by matric and osmotic potentials. The vapour potential of soil can be precisely estimated with the help of a thermocouple psychrometer.

Pressure plate Apparatus: It is a form of tensiometer used under laboratory conditions. A core of soil is placed firmly on a porous plate to which a suction is applied. The soil core eventually reaches an equilibrium with porous plate. The soil is weighed and relationship between tension and moisture content is determined. Suitable in 0-1 bars tension.

Pressure membrane apparatus: It is used to measure the tension values as high as 100 bars. Helpful to measure energy moisture relation of a number of samples over a wide energy range in a short time.

LECTURE 19

SOIL WATER MOVEMENT

Water is a highly dynamic component in soil system. It moves in all three phases : solid, liquid and vapour. In saturated or flooded situation, water moves in liquid phase, while in a partially dry or unsaturated soil, it moves in both liquid and vapour phases. Movement in solid phase as commonly occur in frozen soil is also believed to take place closer to clay surface.

The flow of liquid water is due to a gradient in matric potential from one soil zone to another. The direction of flow is from a zone of higher matric potential to one of lower matric

moisture potential. Saturated flow takes place when the soil pores are completely filled with water. Unsaturated flow occurs when the pores even in the wettest soil zones are only partially filled with water. In each case, moisture flow is due to energy - soil relationships.

Concept of Flow

Water movement through soil is proportional to the product of the driving force and the conductivity of soil for water.

$$Q = c DK$$

Q = Flow velocity

C = Proportional factor

D = Driving force

K = Conductivity of the medium.

This relation holds true for heat transfer and for flow of electricity as well as for water movement.

The driving force in case of water is a pressure gradient. Water moves from a position of high pressure to a position of low pressure in both saturated and unsaturated conditions, including in vapour state.

The permeability of soil for water vapour is proportional to the volume of water free pore space, regardless of size of pores. Free path plays significant role rather than size of pores.

Saturated flow : Following heavy rain or irrigation application, pores of soil are often filled entirely with water. This is said to be the saturated condition of the soil.

The flow of water under saturated condition is determined by hydraulic force driving the water through the soil (commonly gravity) and the hydraulic conductivity, or the ease with which the soil pores permit water movement.

$$V = Kf$$

V = Volume of water move per unit time. f = water moving force K = Hydraulic conductivity.

The driving force, known as hydraulic gradient, is the difference in height of water above and below the soil column.

Besides, downward flow of water in saturated condition, hydraulic force also will cause horizontal and upward flow. This flow is usually not quite rapid, because the force of gravity does not assist horizontal flow and hinders upward flow. Downward flow is more in coarse textured soils, whereas horizontal move is equally significant in fine textured soils. The law of "poiseuille" express the flow of water

$$Q = PpR^4 / SLZ$$

Where Q = Volume of flow cc/sec; P = Pressure difference dynes/cm²

R = Radius of the tube, cm ? = Length of tube

Z = Viscosity of liquid dynes – Sec/cm² (poises)

According to Poiseuille'S law, the rate of flow of a liquid through a narrow tube is proportional to the fourth power of the radius of the tube and to the pressure; and inversely proportional to the viscosity of the liquid and the length of the tube. The rate of saturated flow in soils of various texture is in the sequence :

Sand > Loam > Clay

Viscosity of water increases more than one percent with each one degree – centigrade drop in the temperature.

The law of "Darcy" states that the velocity of flow of a liquid through a porous medium is proportional to the force causing the flow and to the hydraulic conductivity of the medium.

$$Q = cKAP / L$$

Where Q = Flow velocity ($L^3 T^{-1}$)

C = Dimensionless proportionality constant

K = Hydraulic conductivity ($M^{-1}L^3T$)

A = Cross sectional area (L^2) of the porous medium

P = Pressure gradient ($ML^{-1}T^{-2}$).

Unsaturated Flow

Through large and continuous pores rapid water movement occurs under saturated condition. But in unsaturated condition, only micro pores would accommodate water and allow the water to move slowly. The relationship between matric potential and hydraulic conductivity governs the water movement under unsaturated condition.

Saturation flow occurs at or near zero potential, while most of the unsaturated flow occurs at a potential of -0.1 bar or below. Zero potential, the hydraulic conductivity is 1000 times greater, as compared to the potential that characterize the typical unsaturated flow.

Under saturated condition (high potential levels) hydraulic conductivity is higher in sand than in clay. Under unsaturated condition (less potential values) hydraulic conductivity is higher in clay than in sand.

In both saturated and unsaturated conditions, flow is majorly governed by hydraulic conductivity of the soil and the driving force. But the driving force in unsaturated condition is primarily the matric potential gradient or the difference in matric potential of the moist soil areas and the drier areas in to which the water is moving. Movement will be from a zone of thick moisture films (higher matric potential e.g. -0.001 MPa) to one of the films (lower matric potential e.g. -0.1MPa).

SATURATED FLOW	UNSATURATED FLOW
Most of the pores are filled with water	Many pores are not filled with water
Soil water will be at zero bar tension	Soil water will be at higher tension
Driving force is positive pressure potential	Driving force is negative pressure potential
Flux is in the direction & proportional to gradient $K = \frac{\Delta H}{\Delta X} \times \frac{At}{Q}$	Flux is in the direction & proportional to gradient - $K = \frac{\Delta H}{\Delta X} \times \frac{At}{Q}$
Most water is not available to plants under saturated condition	Plant will take water mostly held under unsaturated condition
Hydraulic conductivity under saturated condition is sands > loams > clay	HC in unsaturated condition is clay > loams > sands

Vapour movement in soils

Two types of water movement occur in soils, internal and external. Internal movement takes place within the soil i.e., in soil pores. External movement occurs at the land surface and the water vapour is lost by evaporation.

Water vapour moves from one point to another within the soil in response to difference in vapour pressure. Thus, water vapor moves from high vapour pressure (under saturated condition where in air is nearly 100% saturated with water vapour) zone to lower vapor pressure zone (dry soil). Similarly, if the temperature of one part of the uniformly moist soil is lowered, the vapor pressure will decrease and water vapor will tend to move toward the cooler part). Heating will have the opposite effect.

As the quantity of water vapor is small, its movement in soil is not of much practical significance. However, in drought situation, its movement may be of considerable significance especially in supplying moisture to drought resistant desert plants.

Electrolytes in soil as well as the applied fertilizers will reduce the vapour pressure, locally, thereby creates the pressure gradient, which makes water vapour to move towards the pockets of high salt concentration and fertilizers. This is useful for making nutrients available to plants.

Infiltration : Infiltration is the entry of water at the soil air interface due to sorption and vertical flow of water through the soil profile.

This process is of great practical significance, as it determines how much of rain storm or irrigation water enters the soil and how much over flows the land surface as run-off.

Irrespective of soil texture, the infiltration rate in a dry soil would be high, initially and the infiltration rate reduces exponentially with time and attains a steady rate after a long lapse of time. It is expressed as millimeters per hour. Infiltrate rate is high and constant in non-swelling clay soil i.e., laterite soils.

Percolation : The down ward movement of water through soil. Percolation occurs when the water is under pressure or when the tension is smaller than about $\frac{1}{2}$ atmosphere or when the hydraulic gradient of the order of 1.0 or less.

Percolation is very important in soil development and land management. Percolation removes some valuable nutrients away from soil i.e. nitrates and calcium.

In coarser textured soils, which are porous in nature (macropores) exhibits greater percolation capacity. As evaporation and transpiration use up much of water that enters the soil, the amount of water that percolates through it decreases with depth. The greatest amount of percolation goes on in the top few centimeters.

Permeability : The ease with which water pass through a bulk mass of soil or a layer of soil is the permeability of the soil.

Soil drainage : When rainfall intensity exceeds the infiltrability of soil or the amount of rainfall exceeds the storage capacity of soil, the excess water accumulates at the soil surface and may keep the soil under saturated condition for longer time.

Drainage means removal of excess water from surface or sub-surface of soil body by means of some water conveying devices.

Excess water may be due to 1) over irrigation 2) accumulation of monsoon runoff in low lying areas for want of an outlet and 3) seepage from reservoirs, canals and ditches.

The drainage problem are two types : surface drainage problem and sub-surface drainage problems. Surface drainage problems arise in the flat areas of land that are subjected to ponded water. Uneven land, low capacity of disposal channels, above ground level water bodies are the chief causes for ponding of water in an area.

The sub-surface drainage problems may arise due to low soil permeability, humid climate and rise of ground water causing development of a shallow water table.

In case of surface drainage, water is removed directly from the land by land smoothing, land grading, bunding and ditching. Land surfaces are also reshaped to eliminate ponding and to create slopes so as to induce gravitational flow over land and channels to an outlet. The excess water can also be diverted from the land by diversion ditches, dykes etc.

Subsurface drainage refers to the outflow or artificial removal of excess water from within the soil, generally by lowering the water table or by preventing its rise, using mostly the artificial water conveying devices. An underground network can be created for facilitating sub surface drainage.

A mole drainage system: It is created by pulling through the soil at the desired depth a pointed cylindrical plug about 7-10 cm in diameter. The compressed wall channel thus formed provides a mechanism for the removal of excess water. This is an easy system to install, but is easily clogged after few years.

A perforated plastic pipe can be laid underground using special equipment. Water moves in to the plastic pipe through the perforations and can be channeled to an outlet ditch. About 90% of the underground drain systems being installed are of this type.

A clay tile system made up individual clay pipe units 30-40 cm long can be installed in an open ditch. The tiles are then covered with a thin layer of straw, manure or gravel and the ditch

is then refilled with soil. Tile drains were popular two decades ago, but high installation costs make them less competitive than the perforated plastic systems.

IMPORTANCE OF DRAINAGE

- 1 Drainage is essential, as the crop growth will be drastically affected by continuous soil saturation with water.
- 2 Soil saturation may encourage certain diseases and parasites.
- 3 Poor drainage leads to the development of salt affected soils.
- 4 High water table may limit root penetration.
- 5 Soil saturation stops the gaseous exchange causing oxygen deficiency and accumulation of CO₂ to toxic levels in root zone.
- 6 Wet soil requires more heat to warm up than dry soil, due to high specific heat of water, the growing season for winter crops is shortened in poorly drained soils.
- 7 Under poor drainage conditions / anaerobic conditions many organic and inorganic compounds will be reduced to toxic levels and inhibit crop growth.
- 8 Denitrification occurs in anaerobic conditions.
- 9 Some micronutrients will become unavailable.

LECTURE 20

SOIL TEMPERATURE

Heat is a form of energy and temperature is a measure of the heat energy. The heat energy refers to kinetic energy or random motion (vibration) of molecules of a substance. The speed of vibration is directly proportional to temperature.

Solar radiation is the source of soil heat. The flux of heat (calories or joules) into and out of the soil determines the soil thermal regime, which is characterized in terms of soil temperature (°C).

On an average only 50% of solar radiation reaches the earth, because of clouds and dust particles intercept the sun rays. This energy is primarily utilized to evaporate water from soil or

leaf surface or is radiated or reflected back to the sky. Only about 10% is absorbed by soil, which is of critical importance to soil processes and to plants growing on the soil.

The fraction of incident radiation that is reflected by the land surface is termed the "Albedo", and ranges from 0.1 to 0.2 for dark coloured, rough soil surfaces to as high as 0.5 or more for smooth, light coloured surfaces.

Heat capacity or Thermal capacity

The "heat capacity" of a soil is defined as the ratio of heat supplied to a body to the corresponding rise in its temperature.

$$C = \frac{Q}{\Delta T}$$

The heat capacity per unit mass of a body is called the "specific heat" (c) and is defined as the quantity of heat required to raise the temperature of a unit body through 1°C.

The heat capacity is expressed as quantity of heat required to raise the temperature of unit volume of soil by 1°C and is known as "Volumetric heat capacity" or simply the "heat capacity" (gram calorie) $C_v = J/m^3/^\circ C$ or $Cal/cm^3/^\circ C$

The specific heat is the heat capacity of a substance in relation to that of water.

Specific heat of water = 1.00 cal/g ; Soil forming minerals = 0.2 cal/g

OM – 0.46 cal/g ; Air – 2.4 cal/g

Dry soil – 0.233 cal/g; Soil with 50% moisture – 0.53 cal/g

Practically all substances have heat capacities lesser than that of water.

Thermal conductivity is defined as the quantity of heat passing in a unit time through a unit area of soil under a unit temperature difference between the faces and is expressed as Joules / meter / second / °C

Actual heat conductance depends on thermal conductivity and on the heat gradient. Thermal conductivity of a soil depends on its water content, texture, structure, mineralogical composition, organic matter content and compaction.

Thermal conductivity increases with increased water content, till about 50% of the soil saturation. It is observed to decrease with a reduction in particle size. Thermal conductivity of soil varies in the order : Sand > loam > clay > peat.

Thermal diffusivity ? (m^2/s) is defined as the ratio of thermal conductivity to heat capacity ? = ? / Cv . It is the measure of the rate at which changes in temperature occur in the body. The reciprocal of thermal diffusivity indicates the ability of the body to retain heat.

Thermal conductivity of water = 1.42×10^{-3}

Air = $0.062 \times 10^{-3} \text{ Cal cm}^{-1} \text{ sec}^{-1} \text{ } ^\circ\text{C}^{-1}$

Quartz = 20.0×10^{-3}

Quartz, water and air = 333 : 23 :1

$$\text{Thermal Diffusivity} = \frac{\text{Thermal conductivity}}{\text{Volumetric Heat Capacity}} = \frac{\text{Thermal conductivity}}{\text{Specific Heat} \times \text{Density}}$$

THERMAL RETENTIVITY: The ability of the body to retain heat is thermal retentivity. It is equal to the reciprocal of thermal diffusivity.

HEAT TRANSFER IN SOILS: The major physical processes responsible for the transport of heat are conduction, convection and radiation.

- a) Conduction: It may be defined as " the flow of heat through an unequally heated body from the places of high temperature to lower temperature". It is through the momentum of molecules. The molecules of the body nearer to the source absorb heat and increase their kinetic energy and begin to vibrate about their positions faster than before. They collide with other molecules and in this process they share their energies with the adjacent molecules so that other molecules increase their K.E and behave similarly to transfer heat energy from one end to another.

- b) Convection : May be defined as the motion of the hot body itself carrying its heat with it. In this process absorption of heat causes increase in volume there by decrease in density of molecules. Such a decrease in density make the hotter molecules to go up, giving their places to the cooler molecules which also behave like that after absorbing heat energy. This process occurs only in fluids.
- c) Radiation: Radiation may be defined as the process by which heat is transmitted from one place to other with out aid of intervening medium. In this process heat is transferred through the space in the form of electromagnetic waves..

Management of soil temperature

The soil temperature depends upon the heat flux in to the soil and the heat transfer processes occurring in the soil and in between the soil and atmosphere, which in turn, depend upon the thermal characteristics of the soil solids, gases and water. The soil thermal regimes greatly modify the microclimate of the area and exercise a major influence on growth and development of plants, particularly during germination and early seedling development stages.

Soil temperature can be modified by a) regulating energy balance on the soil surface b) changing the soil thermal properties and c) heating the soil through artificial means.

Temperature regulation by energy balance

The source of heat for soil is the solar radiation. The rate at which the radiant energy reaches the earth's atmosphere from the sun is called the solar constant, which has the value of about $2 \text{ cal cm}^{-2} \text{ min}^{-1}$.

The solar radiation, which reaches the soil surface, is partly reflected, partly used for heating soil, partly used as latent heat for evaporation and partly reradiated as long wave radiation.

About 90% of long wave radiation is absorbed by the water vapours present in the earth's atmosphere, which partly reradiate to the earth's surface. It implies that the energy available for heating the soil is function of the incoming and outgoing radiation. If a greater fraction of incoming radiation is absorbed by the soil than the fraction reflected or reradiated

the soil will be heated. The energy balance on the soil surface and therefore be modified through tillage and shaping of fields, mulching and vegetation; and shading and row spacing.

Tillage and shaping of fields

Since both slope and direction affect soil temperature and heat flux, soil thermal regimes can be modified by specific tillage practices such as ridges and shaping. Comparatively high temperature is recorded on ridges as compared to furrows. Besides, the slope facing west would be comparatively warmer. Soil temperature is highest in east-west oriented ridges and decreases for other ridge directions in the order.

North – south ridges > East – west ridges > N-S conventional > Listing

Mulching and vegetation

From the energy point of view, mulching is the application or creation of a soil cover that constitutes a barrier to the transfer of heat or water vapour, where as the vegetation intercepts a considerable part of the incoming radiation. Vegetation and mulching affect the soil thermal regimes by 1) interception of the incoming radiation 2) changes in albedo conditions and 3) reduction in latent heat transfer by evaporation.

The mulches commonly used include : soil, stubble, straw, weed or trash, gravel, plastic (black, transparent, opaque etc.) paper (different textures and colors) asphalt and aluminum foils.

In general, light coloured mulches will increase albedo of the surface, thereby reduces soil temperature.

Black plastic mulch – reduces out going temperature (heating)

Paper and straw mulches – increases outing temperature (cooling)

Aluminum foil mulch – sharply increases out going temperature (cooling)

Transparent plastic mulch – green house effect

Opaque mulches – thermal insulators (decreases maximum temperature and increases minimum temperature)

Shading and row spacing

Artificial shading is often practiced either to reduce the intensity of the direct radiation falling on the soil surface or to conserve the soil crop canopy heat.

Increased width in between rows, increases the temperature in rows and also shows lot of variation in temperature in between rows. In regard to row direction, east – west direction planted rows showed more variation in temperature between the rows.

Modification of soil thermal properties

Soil thermal characteristics can be modified by changing soil physical conditions through tillage practices, soil compaction, irrigation and drainage.

Tillage will loosen soil, increase the soil porosity and decrease the soil thermal conductivity and heat capacity.

Importance of soil temperature:

- Too low or too high temperatures affect the germination of seeds. Different crops have different optimum temperature for germination.
- Absorption of water and nutrients is impaired under low temperatures.
- Temperature influences nutrient availability by affecting the weathering of minerals and decomposition of organic matter.
- Low soil temperature results in white succulent roots with less branching.
- Low temperature enhances disease incidence by parasitic fungi
- Soil microbial activity and decomposition of organic matter is restricted below 10 ° C and ceases below 5°C.
- Biological nutrient transformations like nitrification, ammonification etc are affected by very high or low temperatures.

LECTURE 21

SOIL AIR

Soil is composed of solid, liquid and gaseous constituents in various proportions. The size and arrangement of soil particles or soil aggregates will determine the pore space. It is the part of the soil, not occupied by soil solids. This pore space is normally occupied by soil water and soil air in reciprocally varying amounts. An important characteristic of the pore space is its continuity. The degree of continuity of both soil water and the soil air is of great importance in determining the physical properties of soil.

Composition : The composition of soil air is not the same as that of the atmosphere. The plant life and microorganism cause the soil atmosphere to become dynamic with respect to the ratio of oxygen to carbon-di-oxide. The principal components of soil air are nitrogen, oxygen, inert gases, carbondioxide, water vapour and hydrogen. Methane, hydrogen sulfide etc., are present in negligible quantities. The proportion of nitrogen plus argon is usually found to be equal to that in the atmosphere and is 79 per cent by volume. Oxygen and carbondioxide vary in complementary proportions to make up the remaining 21 per cent.

Gases	Soil air (%)	Atmospheric air (%)
Nitrogen	79.20	79.00
Oxygen	20.60	20.97
Carbondioxide	0.50(variable)	0.033
Other gases	traces	

CO₂ content vary from 10-10000 times to that of atmospheric air

Since soil air is located in the net work of soil pores separated by soil solids, it varies in composition from place to place in the soil. In local pockets, reactions involving gases can greatly modify the composition of the soil air. The composition of soil air at the surface and atmospheric air are mostly similar, because of rapid gas exchange at surface, but this similarity decreases with increase in the depth of soil.

The composition of air is the resultant of two sets of processes that function simultaneously viz : chemical and biological reactions that result in the production of CO₂ at the

use of O₂; and physical processes that affect the interchange of gaseous constituents between the soil voids and the atmosphere. First process accentuates the differences, whereas the second one minimizes the differences.

Gaseous exchange in soil

The exchange of gases in between soil air and atmospheric air is referred to as soil aeration. This is very important for growth of plants and soil microorganisms and thin biological activities. Two mechanisms have been identified in the interchange of gases between soil voids and the atmosphere i.e. mass flow and diffusive flow.

Mass flow : Mass flow of gases in to and out of the soil occurs whenever there is a difference in total pressure between the soil air and atmosphere. This difference is mainly due to expansion and contraction of soil gases due to changes in temperature and barometric pressure, air replacement through rainfall, irrigation and drainage.

Diffusion : Diffusion is the random movement of molecules (molecular motion) of a gas or of a liquid. Net movement of gases by diffusion occurs when the partial pressures of individual gases in two neighbouring systems are different, but the total pressure is the same in both. Diffusion accounts for >90% of gaseous exchange.

In soils, due to biological activity, there is a continuous production of CO₂ at the exhaustion of oxygen. This results in the increased partial pressure of CO₂ and reduced partial pressure of oxygen. It leads to continuous interchange of CO₂ and O₂ in between soil and atmosphere.

According to Fick's law, diffusion is a function of the concentration gradient, the diffusion co-efficient of the medium, and the cross sectional area.

$$dQ = DA \quad (dc/dx)dt$$

where dQ is the mass flow (moles) during the time at across area A (sq.cm), dc/dx the concentration gradient [moles/cc (cm)], and D the proportionally constant or diffusion coefficient (sq.cm/sec).

Characterization of soil aeration

There are various parameters that can be used for characterizing soil aeration.

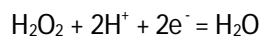
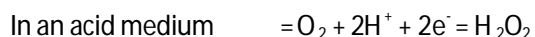
- The volume percentage of soil air or air capacity: Indicates the part of pore space filled with air. Minimum of 10-12 % is required.
- Gaseous composition.
- The oxygen diffusion rate: Determines the rate at which oxygen can be replenished if it is used by respiring plant roots or microbes.
- Oxidation reduction potential: Indicates whether the soil is in oxidized or reduced state. It is a measure of tendency of a system to reduce or oxidize expressed as negative and positive potentials, respectively.
- Composition of soil for its reduced components.

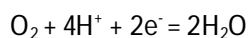
Measurement of ODR

The equipment for the measurement of oxygen diffusion rate consists of the platinum microelectrode, the reference electrode, the voltmeter, the ammeter, the variable resistor and the battery.

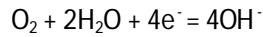
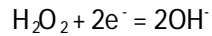
When a certain electrical potential is applied between a reference electrode and a platinum electrode inserted in the soil, oxygen gets reduced at a platinum surface resulting in a current flowing in between the electrodes. This current is proportional to the rate of oxygen reduction, that is, the current is governed by the rate of oxygen diffusion to the electrode.

Each molecule of oxygen which diffuses to the surface of the electrode takes up four electrons and reacts with hydrogen ions to form water in an acid solution, or, reacts with water to form a hydroxyl ion in an alkaline solution.





In neutral or alkaline soils = $O_2 + 2H_2O + 2e^- = H_2O_2 + 2OH^-$



It is found that root growth ceased when the ODR dropped to about **20 x 10⁸ g/cm²/min.**

Effect of soil air on plant growth, soil properties and nutrient availability

Soil air with its constituents plays a vital role in modifying the physical, chemical and biological properties of the soils, there by governs the nutrient and water availability and ultimately the plant growth.

- Under poor aerated conditions development of plant roots will be restricted or inhibited.
- Absorption of water and nutrients will be decreased.
- Toxic substances will be formed.
- Soil aeration influences the activity of soil micro organism and also affects the rate of decomposition of organic matter.
- BNF and many nutrient transformations will be carried out by microbes under will aerated conditions. Many nutrients like Fe and Mn will be at their toxic levels under poorly aerated conditions.
- Many toxic organic acids like lactic, butyric and citric acid etc., will be found under anaerobic conditions and cause injury to plant roots thereby minimize the ability of roots to absorb nutrients and water.

- Zn and Mn availability will be reduced under poor aeration conditions.
- Incidence and virulence of diseases largely controlled by soil aeration.

Management of soil aeration

- ODR should be at least $30 \times 10^{-8} \text{ g/cm}^2/\text{min}$.
- Oxygen concentration in the soil air should be at least 10%.

Measures to improve soil aeration

- Since diffusion is the main agent for air renewal, a more open structure, a lower moisture content and a higher temperature will be helpful in increasing diffusion rate of air.
- Tillage, incorporation of organic matter and mulching are the standard methods to create porosity in the soil system.
- Providing drainage facilities is a remedy to improve air capacity of soil.

LECTURE 22

SOIL COLLOIDS

Thomas Graham (1861) coined the term 'colloid' (Greek Kolla = glue eidos = like) In a true solution as sugar or salt in water the solute particles are dispersed in the solvent as single molecules or ions. In this case the diameter of dispersed particles ranges from 1A^0 to 10A^0 (0.00001 to 0.001μ).

In a suspension as sand stirred in water, the solute particles are aggregates of millions of molecules. The diameter of these particles is of the order of 2000A^0 or more.

When the diameter of the particle of a substance dispersed in a solvent ranges from about 10A^0 to 2000A^0 the system is termed a colloidal solution, colloidal dispersion or simply a colloid (0.001 to 0.2μ)

Some of the soil particles are of colloidal size and exhibit colloidal properties in soil system. Soil colloids are broadly classified as inorganic and organic colloids. Inorganic colloids based on the shape are divided into crystalline and amorphous colloids.

General Properties of Colloids

- 1 Shape
- 2 Size
- 3 Surface area
- 4 Electrical charge
- 5 Adsorption
- 6 Plasticity
- 7 Cohesion
- 8 Swelling & Shrinkage
- 9 Flocculation & Deflocculation
- 10 Brownian movement
- 11 Tyndal effect

Shape : The mineral colloids are laminated, made up of layers of plates or flakes or even rods. The different units or flakes of clay minerals are held together with varying degrees of force depending upon the nature of the clay mineral.

The edges of clay minerals are of clean cut or frayed or fluffy. In all cases clay minerals are developed more in the horizontal axis than of vertical axis.

- 1 Kaolinite ----- Hexagonal crystals
- 2 Montmorillonite -- Flakes
- 3 Humus-----Variable
- 4 Halloysite-----Rod shaped

Size and Surface Area : Colloids are extremely small in size. The upper limit in diameter for the colloidal state is generally considered to be about one micron. Some with upper limit of 2μ exhibit colloidal properties but they are not technically colloids.

The colloids expose a large surface area per unit mass. The external surface area of one gram of clay colloid is at least 1000 times that of one gram of sand. Certain silicate clays with

expanding plate like makeup offer internal surfaces besides external surface area. The total surface area of soil colloids ranges from $10\text{m}^2/\text{g}$ for clays with only external surfaces to more than $800\text{m}^2/\text{g}$ for clays with extensive internal surfaces. The colloidal surface area in the upper 15 cm of a hectare of a clay soil could be as high as 7,00,000 sq. kms.

Electrical Charge: The colloidal surfaces, both external and internal characteristically carry negative and / or positive charges. For most colloids electronegative charges predominate, although some mineral colloids in very acid soils have a net positive charge.

Adsorption : Adsorption of cations / anions and water is the important consequence of the charges on colloids. The negatively charged colloids are of practical significance, as they attract hundreds of thousands of positively charged ions (cations). This gives rise to an ionic double layer.

The adsorption of ions is governed by the type and nature of ion, ion concentration and the type of colloidal particle.

- Higher is valency, higher the adsorption (excepting H^+)
- With same valency, the ion with more atomic weight is preferred.
- Concentration of the ion in the solution also determines the adsorption rate.

Plasticity: Soil containing more than about 15% clay exhibits plasticity that is pliability and the capability of being molded. This property is due to the plate like nature of the clay particles and the combined lubricating and binding influence of the adsorbed water. Thus the particles of plastic soils easily slide over each other, much like panes of glass with films of water between them.

Plasticity is of practical importance because of its influence on tillage operations. The clayey soils with smectite type clay minerals present a significant problem, by not allowing to obtain a stable granular structure.

Montmorillonite > Illite > Kaolinite

Swelling and shrinkage: Some clays swell when wet and shrink when dry. After prolonged dry period, soils rich in smectite minerals often are criss-crossed by wide deep cracks that, at first, allow rain water to penetrate rapidly. Later, because of swelling, such a soil is likely to close up and become much impervious than one dominated by kaolinite or illite.

Inter crystal expansion; adsorbed ions for water and air entrapped are primarily responsible for swelling.

Cohesion : It indicates the tendency of clay particles to stick together. This tendency is due primarily to the attraction of the clay particles for the water molecules held between them. Hydrogen bonding between the clay surfaces and water and also among water molecules is the attractive force responsible for cohesion. It results in the formation of some resistant hard clods. Smectites and fine grained micas exhibit a noticeable degree of cohesion. In contrast, humus reduces the attraction of individual clay particles for each other.

Brownian Movement: The continuous rapid zigzag movement executed by a colloidal particle in the dispersion medium is called Brownian movement or Motion (Robert Brown, 1927).

In a colloid suspension, the colloidal particles are under constant rapid motion. They move in a short straight line path in the medium and change their path abruptly due to collision with other colloidal particles or molecules of dispersion medium.

The smaller the particle, the more rapid is its movement and more often does it collide. The Brownian movement is mainly responsible for the coagulation or flocculation of colloidal particles.

Tyndal Effect : Dust particles float in air form a colloidal suspension. If a strong beam of light is passed through such suspension the particles appear bigger than original size. This is due to the diffusion of light by the colloidal sized particles, which is called "Tyndal Effect".

Flocculation : Aggregation or clumping together of individual, tiny soil particles is called flocculation.

Clay particles by virtue of carrying negative charge on its surface repel each other and disperse in the medium. When the negative charge is satisfied by cations, which are tightly held on clay surface, the repulsive forces would be very minimum. It leads to coagulation or flocculation of soil particles.

From the stand point of agriculture, flocculation is generally beneficial because it is the first step in the formation of stable aggregates or granules. The ability of common cations to flocculate soil colloids is in the general order of $Al^{3+} > H^+ > Ca^{2+}, Mg^{2+} > K^+ > Na^+$. Incidentally the colloidal complexes of humid and sub-humid region soils are dominated by aluminum, hydrogen, calcium and magnesium and those of semi-arid regions are high in Calcium and magnesium ions.

Deflocculation : It is the dispersion of colloidal particles, due to the repulsion of negatively charged particles. Under deflocculated condition particles move away from each other, and act independently.

Dispersion is encouraged by the large number of water molecules associated with each micelle and with the adsorbed cations. Highly hydrated monovalent cations like Na^+ do not effectively reduce the electro negativity of the micelle and are loosely held. It makes the individual micelles to repel each other continuously and stay in dispersion.

Dispersion can be reduced by (i) decreasing the pH of the medium (ii) replacing the sodium with H^+ , Ca^{2+} , Mg^{2+} and Al^{3+} like cations and (iii) increasing the salt concentration in the soil solution.

LECTURE 23

Secondary silicate clay minerals

Inorganic soil colloids or clay minerals or secondary silicate minerals, which are mostly newly formed crystals from the soluble products of the primary minerals. Some clay minerals are formed by slight alteration of some primary minerals i.e., illite from Muscovite or Biotite.

Secondary minerals

- Layer silicate clays
- Fe and Al oxide clays
- Allophone and associated amorphous clays

Formation

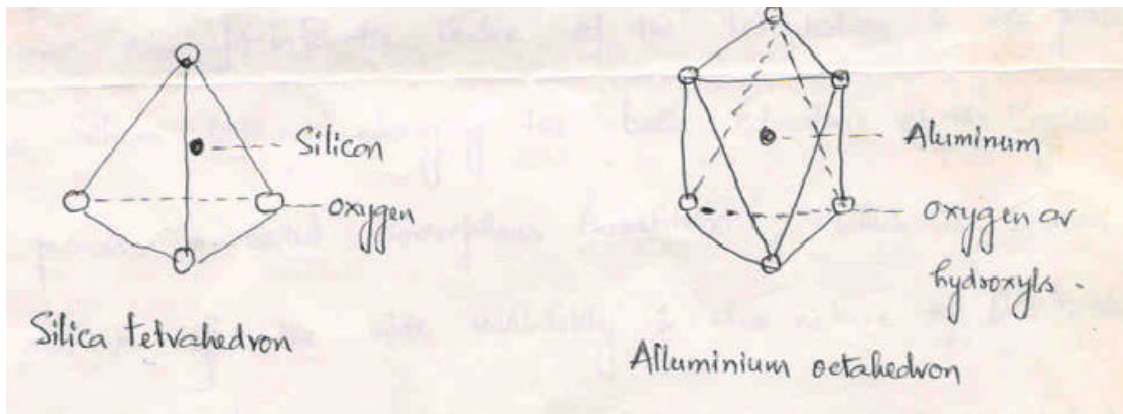
1. A slight physical and chemical alteration of certain primary minerals
2. A decomposition of primary minerals with subsequent recrystallization of certain of their products.

Layer Silicate Clays : These are crystalline, layer like structures. The layers comprise primarily horizontally oriented sheets of Si, Al, Mg and/or Fe atoms, surrounded and held together by oxygen and hydroxyl groups e.g. kaolinite, montmorillonite and illite etc.

The basic building block for the silica dominated sheet is a unit composed of one silicon atom surrounded by four oxygen atoms. It is called "silica tetrahedron" because of its four sided configuration. An interlocking array of a series of these silica tetrahedra tied together horizontally by shared oxygen anions gives a "Tetrahedral sheet".

The basic building block for the aluminum and /or Magnesium (some times iron) dominated sheet is a unit composed of an aluminum ion surrounded by six oxygen atoms or hydroxyl groups gives an eight sided building block termed "Octahedron". Numerous octahedra linked together horizontally comprise the "Octahedral sheet".

In aluminum dominated sheet, two Al^{3+} ions satisfy the negative charge from surrounding oxygen and hydroxyl ions and so this sheet is known as "di-octahedral sheet". In Magnesium dominated sheet, three Mg^{2+} ions satisfy the negative charge and so this sheet is known as tri-octahedral sheet.



The tetrahedral and octahedral sheets are bound together with in crystals by shared oxygen atoms in to different layers. The specific nature and combination of sheets is these layers vary from one type of clay to another and largely control the physical and chemical properties of each clay mineral.

Classification of silicate clay minerals (Layer silicates)

Based on the number and arrangement (sequence) of tetrahedral and octahedral sheets in each crystal unit of silicate clays, they are classified.

- 1:1 type : Kaolinite, Halloysite
- 2:1 type : Montmorillonite, illite, vermiculite (limited expansion, 2:1 type), Talc
- 2:2 type : Chlorite

Layer silicate minerals are also classified based on layer charge per unit cell of structure, the type of inter layer bond and interlayer cations, type of cations in octahedral sheet etc.

Kaolinite

It is 1:1 type clay mineral made up of one silica tetrahedral sheet combined with one aluminum octahedral sheet. The tetrahedral and octahedral sheets in a layer of kaolinite crystal are held together tightly by oxygen atoms, which are mutually shared by silicon and aluminum cations in their respective sheets. The crystal units in turn are held together by “**hydrogen bonding**”, which results in “fixed” structure, giving no scope for cations or water to enter between the structural layers. Other minerals of this group are halloysite, anauxite, dickite.

Montmorillonite

This is a 2:1 type mineral comes under smectite group. Other minerals of this group are beidellite, nontronite, saponite etc. It is an expanding type of clay mineral.

Fig Layer Structure of montmorillonite

Each layer is made up of an octahedral sheet sandwiched between two tetrahedral sheets. Two units are linked together by weak oxygen bonding, which results in ready and variable space between layers, for occupation by water and exchangeable cations. Isomorphous substitution occurred in both tetra and octahedral sheets (Si by Al) (Al by Mg), giving rise to net negative charge (high CEC)

Illite : It is a 2:1 non-expanding type clay mineral. It is also called as hydrous mica.

In a given layer, the tetrahedral and octahedral sheets are oriented as that of montmorillonite. In tetrahedral sheet 20% silicon is substituted by aluminum. The resultant negative charge is satisfied largely by potassium and keeps

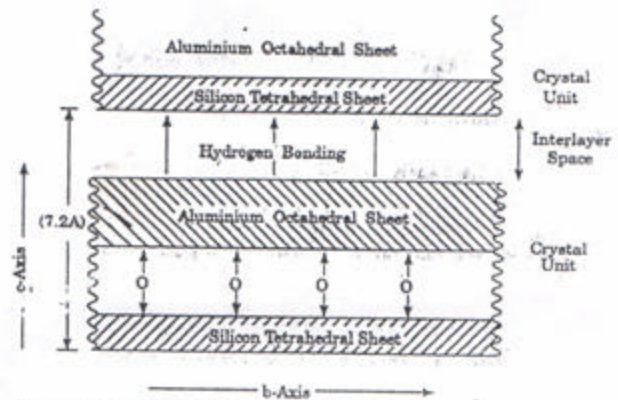


Fig. 3.5 Schematic sketch of crystal structure of kaolinite

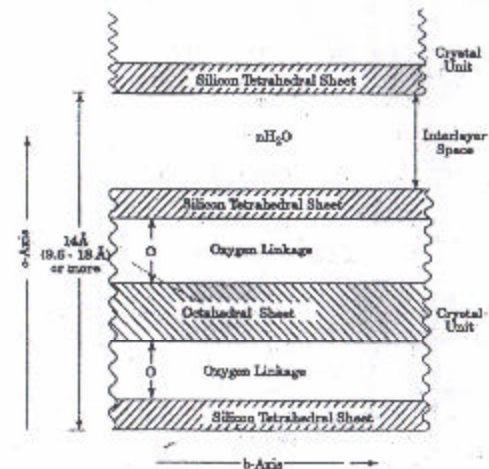


Fig. 3.6 Schematic sketch of crystal structure of montmorillonite

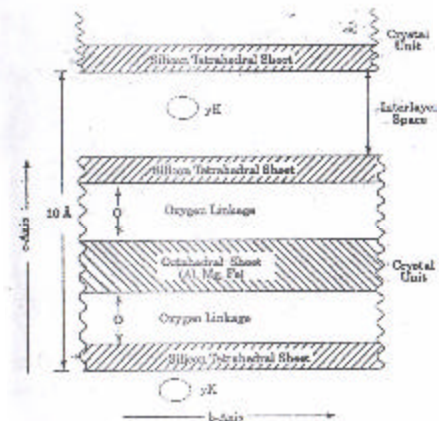


Fig. 3.7 Schematic sketch of crystal structure of Illite

the lattice structure nonexpanding. The properties of illite, lie in between those of Kaolinite and montmorillonite.

Distinguishing Properties of Important Clay Minerals.

S.No.	Property	Kaolinite	Montmorillonite	Illite
1.	Type	1:1	2:1 expanding	2:1 nonexpanding
2	Size (μm)	0.5-5.0	0.01 to 1.0	0.2 to 2.0
3	Shape	Hexagonal crystals	Flakes	Flakes
4	Surface area Internal surface area (m^2/g) External surface area (m^2/g)	– 10-30	550-650 70-120	-- 70-100
5	Inter layer spacing (nm)	0.7 (7.2\AA)	1.0-2.0 (9.6 to 18.0\AA)	1.0 (10\AA)
6	Isomorphous substitution	-No- (pH dependant charge)	Octahedral sheet (0.6)	Tetrahedral sheet (1.0)
7	CEC (cmol (p+) kg^{-1})	2 to 5	80 to 120	15-40
8	Inter layer bonding	Hydrogen bonding	0-0 bonding	0-0 bonding
9	Cohesion, plasticity swelling and shrinkage	Low	High	Medium

Chlorite

It is a 2:2 or 2:1:1 type of clay mineral. Chlorites is basically iron – magnesium silicates with some aluminum present. It has 2:1 layers, like others, alternate with a magnesium dominated trioctahedral sheet giving a 2:1:1 ratio. Magnesium also dominates the octahedral sheet in 2:1 layer. Thus the crystal unit contains two silica tetrahedral sheets and two magnesium dominated trioctahedral sheets.

It is a nonexpansive type, with size and negative charge similar to that of illite. Chlorites are mostly found mixed with montmorillonite and vermiculite.

ALLOPHONE AND OTHER AMORPHOUS MINERALS

The colloidal matter without an ordered three dimensional crystalline structure are referred to as short range minerals.

Allophone is a general name for amorphous aluminosilicate gels. It is a poorly defined aluminosilicate with a general composition approximating $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot \text{H}_2\text{O}$.

These clays occur where large amounts of weathered products existed but have not had the conditions or time for good crystal formation. Allophone is most prevalent in soil developed from volcanic ash. Their properties are quite unusual. These clays have a variable charge, which is totally governed by soil pH. Allophone has high CEC (150 cmol kg^{-1}) in neutral to mildly alkaline conditions and even exhibits high AEC in acidic environment.

Zeolite and TiO_2 (Rutile) are the other important amorphous minerals. Imogolite $\text{SiO}_2 \cdot \text{Al}_2\text{O}_3 \cdot 2.5\text{H}_2\text{O}$ (135 cmol kg^{-1}) found in weathered volcanic ash on pumice beds (Imogo).

Sesquioxide clays : *Sesqui* means one and one half times. These clays are commonly dominant in the highly weathered soils of tropics and semi tropics (humid-hot-well drained conditions)



These clays tend to occur as amorphous coatings on soil particles imparting characteristic colors (Pink, red, brown etc.). The crystallization of amorphous iron compounds is responsible for the irreversible hardening, upon drying, of "plinthite" (laterite) from tropical regions in to some stone like materials.

Sesquioxide clays are non-sticky and non-plastic. They carry positive and negative charges (variable charges) depending on pH of the medium. Soils rich in sesquioxide clays pose a problem of phosphorus availability.

ORGANIC COLLOIDS : Most of the colloidal properties of soil organic matter are due to humus. Humus is highly colloidal and amorphous in nature. Organic colloids are composed basically of carbon, hydrogen and oxygen rather than Si, Al, Fe, O and OH groups in mineral colloids. Organic colloids vary in size. The specific surface area of well developed humus may be as high as $900 \text{ m}^2/\text{g}$ and its exchange capacity ranges from 150 to 300 Cmol.kg^{-1} .

The charge on organic colloids is strongly pH dependant. The negative charge of humus is generally agreed to be due to dissociation of H^+ from functional groups and positive charge is due to protonation of functional groups.

The important functional groups are carboxylic (COOH) phenolic (C₆H₄OH), enolic (OH) and imide (=NH) etc.

Differences between organic and inorganic colloids

PROPERTY	ORGANIC COLLOIDS	INORGANIC COLLOIDS
Origin	Decomposition of organic matter	Weathering of rocks and minerals
Composition	C, H, O (N, P, S)	Si, Al, Fe, Mg, O, OH
Shape	Amorphous	Crystalline except allophone and sesquioxide clays
Stability	Unstable in nature	Stable
Origin of charge	pH dependant	Mostly due to isomorphous substitution and partly by soil reaction
CEC	150-400 cmol kg ⁻¹	3-150 cmol kg ⁻¹
Water and nutrient holding capacity	High	Low
Plasticity	Low	High
Surface area m ² /g	Around 900	Variable (10 to >700)

LECTURE 24

ORIGIN OF CHARGE ON SOIL COLLOIDS

The two properties that mostly account for the reactivity of soils are surface area and surface charge. Surface area is the direct result of particle size and shape. Charge development in soils is intimately associated with clay sized particles and humus.

Two types of charge arises on inorganic colloids i.e., permanent charge or constant charge, temporary charge or variable charge.

Permanent charge

Isomorphous substitution

Substitution of one ion with another ion of comparable size (within 15 %) and charge variation of one unit without disturbing the crystal lattice.

The weathering of wide variety of rocks and minerals permits cations of comparable size to substitute for silicon, aluminum and magnesium ions in the respective tetrahedral and octahedral sheets. Aluminum (0.051 nm) is only slightly larger than silicon (0.042 nm). Consequently the aluminum can fit in to the centre of the tetrahedron in the place of the silicon without changing the basic structure of the crystal. This process is called "Isomorphous substitution", which is common and accounts for the wide variability in the nature of silicate clays. It is of vital importance because it is the primary source of both negative and positive charges of silicate clays.

Isomorphous substitution also occurs in the octahedral sheet. Iron (Fe^{3+} -0.064 nm) and zinc (0.074 nm (Fe^{2+} 0.070 nm) can fit in to the position of either aluminum or magnesium (0.06), as a central ion in the octahedral sheet.

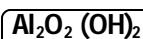
Isomorphous substitution is responsible for development of permanent charge on inorganic colloids. The isomorphous substitutions have taken place slowly through past weathering cycles, and are not subject to easy modification. Consequently, these charges are termed constant or permanent charges, because they are related to the chemical composition of silicate clays.

In the process of substitution, the substituting ion may have a greater, equal or lower charge and size than the ion for which it substitutes. The difference in dimensions of substituted ions was reported to be no more than 15% and the valency difference between the substituting ions should not be more than one unit (Paton, 1978).

Tetrahedral sheet



Octahedral sheet

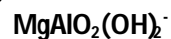


No substitution

Al substituted for Si

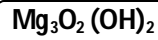


Mg substituted for Al

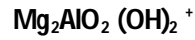


substitution resulted in negative charge

Isomorphous substitution can also be a source of positive charge. If Al^{3+} ion substitutes for Mg^{2+} ion, a net positive charge results. Such positive charges are characteristic of the trioctahedral sheet in some vermiculites and chlorites.



Trioctahedral sheet



net positive charge because

Al^{3+} substituted for Mg^{2+}

Though there is a scope for development of both positive and negative charges on silicate clays, the net charge is always negative because most of the substitutions lead to the development of negative charges, which far outweigh the positive charges.

TEMPORARY CHARGE ON COLLOIDS

It is the second source of charge on some silicate clays (kaolinite) and on humus, allophone and Fe, Al hydroxides. Because these charges are "pH dependant", they are termed "variable, temporary and pH dependant" charges.

The positive charge developed at low pH and the excess negative charge developed at high pH, are collectively known as pH dependant charges. The soil's total charge is the algebraic sum of its positive and negative charges.

The zero point charge (ZPC) has been used as an index of the positive and negative charges on soil colloids. The ZPC is the pH at which negative and positive charges of a colloid are equal.

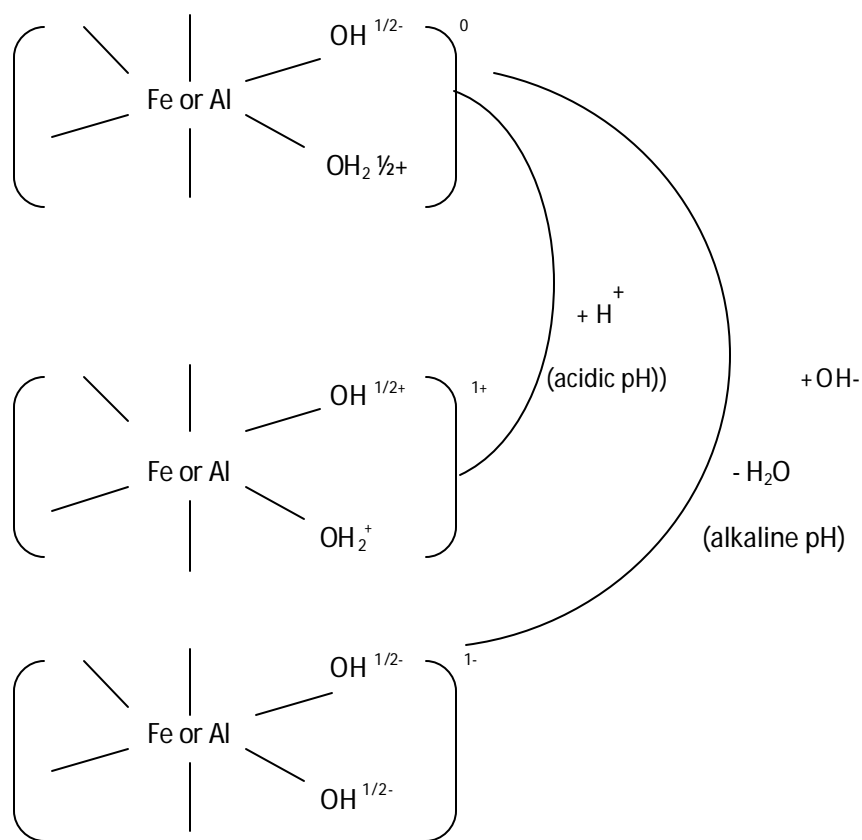
The contribution of edge OH groups on crystal edges or on exposed planes gives rise to charge on certain colloids. At high pH, hydrogen of OH^- on crystal lattice dissociates and combines with hydroxyl ions to form water molecules. This leaves negative charge on colloidal surface. At low pH protonation of exposed hydroxyl groups results in positive charge development. dependant charge is related both to the acidity of the edge groups and to the area of the edge surface. In 2:1 type minerals, edge surface is small relative to the basal plane. Kaolinites tend to stack in C-dimension, increasing the relative area of edges in relation to basal plane area. For these reasons, pH dependency of charge is more important for kaolinite than for smectites or vermiculite.

2:1 type minerals 5-10% pH dependant charge

1:1 type mineral 50%



Development of positive and negative charges on crystal edges:



Organic colloids: The primary source of charge on organic colloids is considered to be the gain or loss of H⁺ from functional groups on the surface of colloids. The functional groups include hydroxyl (-OH), carboxyl (COOH), phenolic (-C₆H₄OH) and amine (-NH₂). The charge that develops from such groups depends largely on the pH of the ambient solution, which regulates the degree of protonation or deprotonation of the group.



The soil colloids that are capable of developing pH dependant charge include layer silicates, oxides and hydroxides of Fe and Al and organic matter.

	Negative charge			
	Total	Constant%	Variable%	
Organic	200	10	90	0
Montmorillonite	100	95	5%	0
Illite	30	80	20	0
Kaolinite	8	5	95	2
Gibbsite	4	0	100	5
Goethite	4	0	100	5

LECTURE 25

ION EXCHANGE IN SOILS

Ion exchange is defined as a reversible process by which cations and anions are exchanged between solid and liquid phases and between solid phases, if in close contact with each other.

Adsorption is defined as a phenomenon by which an increase in concentration or an accumulation of an ion on a solid occurs due to ion exchange or other reactions. Desorption is a phenomenon by which the replacement or release of an adsorbed ion species occurs.

Ion exchange property is almost entirely to the clay and silt fractions and the organic matter. The soil particles are amphoteric in nature and soil particles have the power to hold both cations and anions. The charge density and potential are higher on edges and corners and in furrows and cavities as compared to flat (plane) surfaces and consequently in exchange phenomena are probably concentrated more in those sites.

The exchangeable ions are held to the surface by coulomb forces and van-der-waal's forces. In most of the soils the exchangeable cations are Ca^{2+} , Mg^{2+} , H^+ , K^+ , Na^+ and NH_4^+ , of which Ca^{2+} is the dominant exchangeable ion. In strong acid soils $\text{Al}(\text{OH})_2^+$ may act as a dominant exchangeable ion. In alkali soil Na^+ becomes dominant and the most common anion SO_4^{2-} , Cl^- and HCO_3^- etc

Cation Exchange

The process of replacement of cations adsorbed on exchange complex by other cations is called cation exchange. The reaction of cation exchange takes place rapidly and the interchange is chemically equivalent. The exchange of cations in the soil takes place between.

- 1 Cations in the soil solution and those on the exchange complexes of soil (clay crystal and humus)
- 2 Cations released by plant roots and those on the exchange complexes of soil.
- 3 Cation on the surface of either two clay crystals, two organic colloids; or a clay and humus particle.

All the cations are not adsorbed with equal tenacity, and the exchange complex does not possess same strength of negative charge at all points. The cation with less size and higher charge per unit size are held more strongly than other cations.

Power or replacement of cation; $H^+ = Al^{3+} > Ca^{2+} > Mg^{2+} > K^+ = NH_4^+ > Na^+$

Cation Exchange capacity of soils (Thomas Way, 1850)

The sum total of the exchangeable cations that a soil can absorb is known as "Cation Exchange Capacity" of that soil. It is the amount of exchangeable cations per unit weight of dry soil. It is measured in mill equivalents of cations per 100 grams of soil (Recently $cmol(p^+) kg^{-1}$)

The mill equivalent is used because the number of negative charge sites in a given sample does not change, but the weights of cations, that may be adsorbed to those sites at one time do change because they have different weights.

Base Saturation : The percentage of total CEC satisfied with basic cations is termed base saturation. It is defined as the extent to which the exchange complex of a soil is saturated with exchangeable cations other than hydrogen and aluminum and it is expressed as a percentage of the total cation exchange capacity.

$$\% \text{Base Saturation} = \frac{\text{m.eq. of basic cations per 100 g soil}}{\text{Total CEC in m.eq. per 100 g soil}} \times 100$$

The degree of base saturation is an important property of soil which usually reflects the extent of leaching and weathering of soils. It is an indication of soil fertility. The ease with which adsorbed cations are released to plants depends on the degree of base saturation.

>80%	-	Highly fertile soils
50-80%	-	Medium fertile
<50%	-	Low fertile

Liming is the common means by which the percent base saturation of soils is increased. As a general rule, the degree of base saturation of normal cultivated soils is higher for arid than humid region soils. Also, the degree of base saturation of soils formed from lime stones or basic igneous rocks is greater than that of soils formed from sand stones or acid igneous rocks.

Soils with larger amounts of organic colloids or 1:1 type clay colloids can supply the nutrient cations to plants at a much lower degree of base saturation than soils high in 2:1 type clay colloids.

The percent base saturation does provide numerical values of the amount of exchangeable hydrogen and aluminum ion species and this helps in predicting the amount of lime needed to neutralize soil activity.

Kind of adsorbed cations also affects the soil pH. With same base saturation percentage, the soil dominated by Na^+ cation presents higher pH values than the soil dominated by Ca^{2+} and Mg^{2+} cations.

Factors affecting CEC

- 1 More fine the soil more is the CEC
- 2 More humus content more is the CEC
- 3 2:1 clay minerals have more CEC than 1:1 type minerals
- 4 In alkaline pH range, CEC would be more
- 5 Liming & Fertilization increases the CEC

Importance of CEC

- 6 The most important reaction in nature after photosynthesis.
- 7 It is an important reaction in correcting soil acidity and basicity
- 8 It alters soil physical properties
- 9 Through cation exchange mechanism (large cation exchanger), the percolating waters will be purified or altered (Ground water pollution is checked)

- 10 Plants absorb exchangeable cations by interchange or contact between the root hairs and colloidal complex
- 11 The amounts of cations in the soil solution are intimately related to the exchangeable cations.
- 12 Offers buffering capacity to soils.

ANION EXCHANGE

Anion exchange occurs on positively charged sites exist on the edges of layer silicate minerals (1:1 type in particular) and surfaces of oxides (with low specific surface area), mainly under acidic conditions.

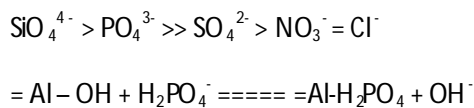
The total amount of exchangeable anions held by a unit mass of soil, is termed as its anion exchange capacity.

Anion exchange capacities are generally low and increases as the pH decreases or acidity increases.

As the ratio of CEC/AEC of a layer silicate mineral increase, the adsorption of anions decreases. (Monmorillonite 6.7, Illite 2.3 and Koolinite 0.5).

Acid soils in tropical and sub tropical regions containing hydrous oxides of Al and Fe exhibit much higher AEC than alkaline and calcareous young soils of arid and semi-arid regions.

Preference of anions for the positive sites



Like cation exchange, anion exchange largely determines the ability of soils to provide nutrient anions to plants properly.

Calculation of Base Exchange Capacity and Exchangeable Acidity

Problem: The CEC of a soil is 20m.eq./100g soil. The estimated amount of Ca is 0.160g/100g; Mg is 0.048g/100g; Na is 0.046g/100g and K is 0.117g/100g soil. Calculate the percent base saturation and base unsaturation or exchangeable acidity.

$$\text{Exchangeable Calcium} = \frac{0.160}{20} \times 1000 = 8.0 \text{ m.eq. / 100g}$$

$$\text{Exchangeable Magnesium} = \frac{0.048}{12} \times 1000 = 4.0 \text{ me. / 100g}$$

$$\text{Exchangeable Sodium} = \frac{0.046}{23} \times 1000 = 2.0 \text{ me. / 100g}$$

$$\text{Exchangeable Potassium} = \frac{0.117}{39} \times 1000 = 3.0 \text{ me. / 100g}$$

$$\text{Total Exchangeable bases} = 17 \text{ m.eq. / 100g}$$

$$\text{Percent Base Saturation} = \frac{17}{20} \times 100 = 85$$

$$\text{Exchangeable acidity or Base saturation} = 100 - 85 = 15 \%$$

LECTURE 26

SOIL BIOLOGY

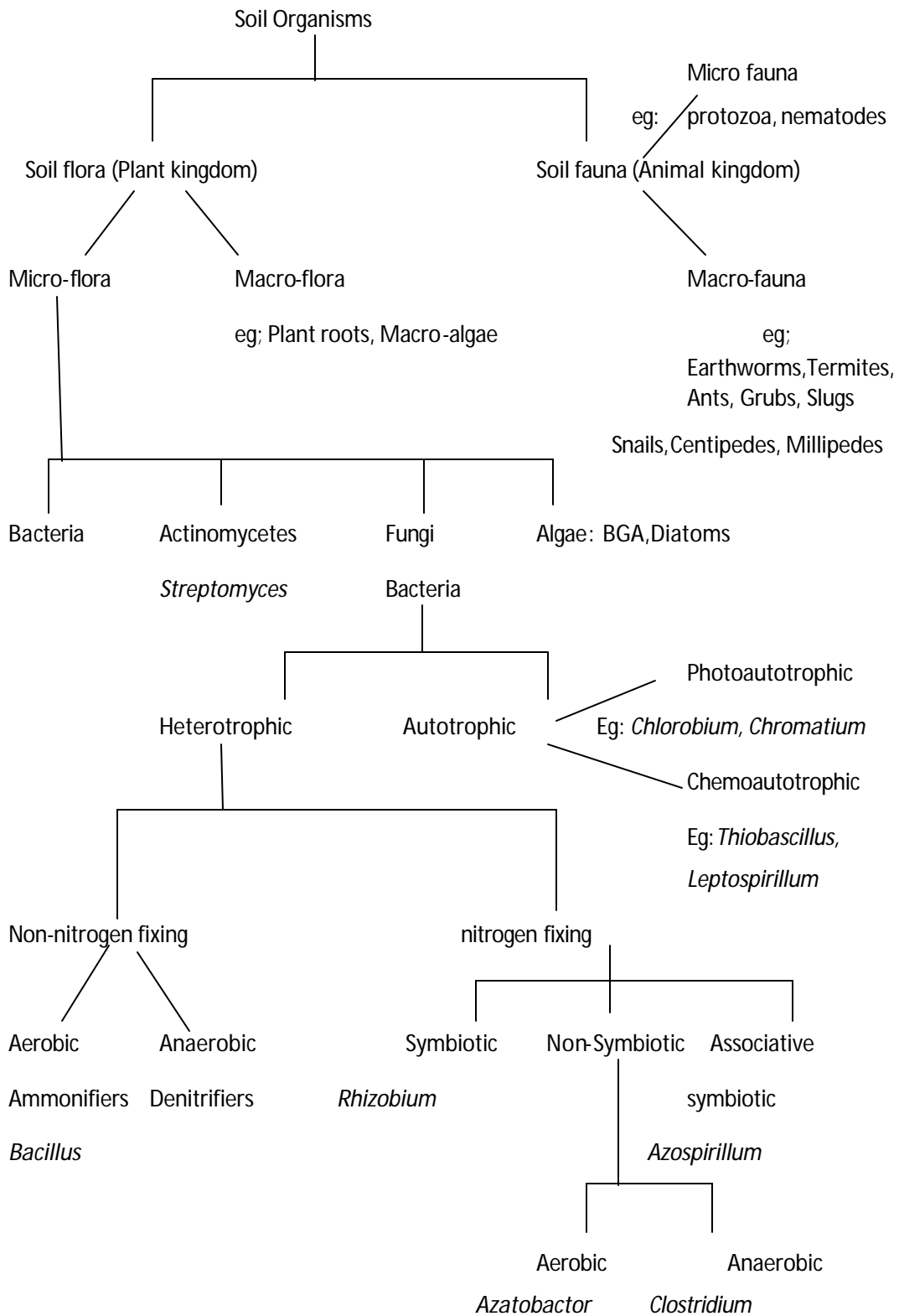
The soil is teeming with millions of living organisms which make it a living and a dynamic system. Under microscope it reveals a complex arrangement of soil particles and pore spaces filled with air and water. It is in these pore spaces that plant roots and millions of organisms develop, ranging from microscopic to macroscopic in size.

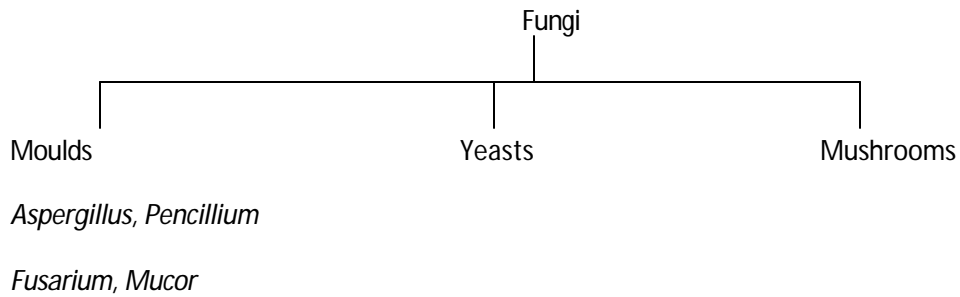
The organisms in the soil, not only help in development of soils but carryout a number of transformations facilitating the availability of nutrients to the plants. In the absence of the activities of these organisms, in soil, life on earth would have come to a halt, as all available nutrients would have ended up locked in the organic, disrupting the nutrient cycles.

Greek word Bios= life, logos=study

The study of living organisms in soil is called Soil biology.

Classification of soil organisms:





Organisms number, Biomass and Metabolic activity

Biomass: weight of organisms per unit volume of soil is called biomass. Soil organisms' number is influenced by many factors like climate, vegetation, and the physical and chemical characteristics of soils. The species composition in an arid desert will certainly be different from that in a humid forest area, which in turn would be quite different from that in a cultivated soil. Acid soils are populated by quite different species from those in alkaline soils. Similar differences are expected from tropical forest areas to cool temperate regions.

Forested areas support more diverse fauna than do grasslands, but the activity of flora and fauna is higher in grass lands. Cultivated fields are generally lower than undisturbed native lands in numbers and biomass of soil organisms especially the fauna.

Organisms	Number (Per gram) ODS	Biomass (kg/HFS)
Bacteria	10^8 - 10^9	450-4500
Actinomycetes	10^7 - 10^8	450-4500
Fungi	10^5 - 10^6	1120-11200
Algae	10^4 - 10^5	56-560

Micro organisms are numerous in number with monopolized biological activity in soils (60-80% of total biological activity)

Some Autotrophic Bacteria: Nitrifying bacteria, Iron bacteria, Hydrogen bacteria, Sulphur bacteria, Manganese bacteria, Methane bacteria, Carbommonoxide bacteria

Autotrophs : An organism capable of utilizing CO_2 or carbonates as the sole source of carbon and obtaining energy for life processes from the oxidation of inorganic elements or compounds such as iron, sulphur, hydrogen, ammonium and nitrites (chemoautotrophic) or from radiant energy (photoautotrophic)

Heterotrophs : An organism capable of deriving energy for life processes only from the decomposition of organic compounds and incapable of using inorganic compounds as sole sources of energy or for organic synthesis.

Bacteria : Bacteria are single cell organisms. They are known for rapid proliferation. They adjust quickly to changes in environment. Size will seldom exceed 4-5 μm (length). Shape may be round, rod like or spiral. In the soil, the rod shaped ones seem to predominate

Bacterial population vary from few billion to three trillion in each kilogram of soil.

Psychrophiles - $<10^\circ\text{C}$

Mesophiles - $20^\circ\text{C}-40^\circ\text{C}$

Thermophiles - $>40^\circ\text{C}$

Acidophiles - Thrive well in acid medium

Alkaliphiles - Thrive well in alkaline medium

Fungi : Like bacteria and actinomycetes, fungi contain no chlorophyll. They are longer than bacteria and heterotrophic in nature (Saprophytic in nature). Fungi are broadly grouped in to yeasts, molds and mushrooms, out of which molds and mushrooms are important in soils.

Important molds in soils are Penicillium, Mucor, Fusarium and Aspergillus. Prefer acid medium (4.5-6.5). Some fungi can tolerate even pH 9.0. Mushroom fungi are found in forests and grasslands. Mushroom fungi are not widely distributed like molds, but are of much significance especially in breaking down of woody tissue.

A mutually beneficial (symbiotic) association between numerous fungi and the roots of higher plants is called 'Mycorrhizae' (fungus root), is useful in adsorption of nutrients.

Actinomycetes : Thread / Filamentous bacteria. Next to bacteria in abundance. A common genus is streptomyces.

Algae : Chlorophyll containing organism. Aerobic. Photoautotrophic Ex:- Blue green algae (Anabaena, Nostoc, Oscillatoria, Tolypothrix etc)

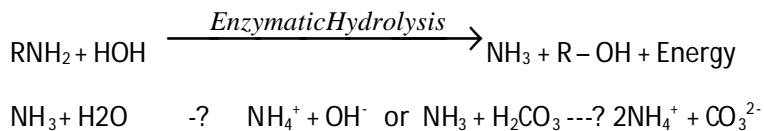
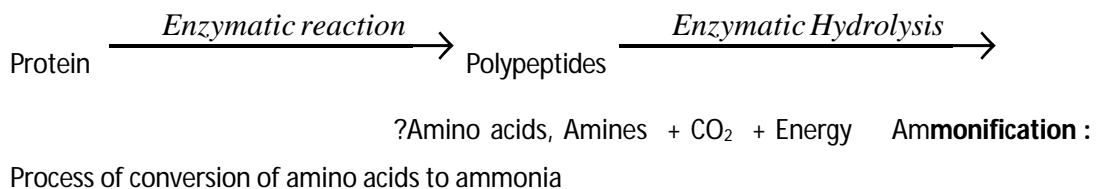
Benefits of soil organisms

- 1 Organic matter decomposition O.M ? humus
- 2 Inorganic Transformations NH_4^+ ---- ? NO_3^- and S? SO_4^{2-}
- 3 Nitrogen fixation
- 4 Solubilisation of insoluble phosphorous compounds
- 5 Solubilisation of insoluble Sulphur compounds(S oxidizing and reducing organisms)
- 6 Formation and development of soil
- 7 Production of soil enzymes, growth promoting substances and antibiotics
- 8 Detoxification of soil pollutants

9. Protect plant roots from invasion by soil parasites and pathogens.

MINERALIZATION: Mineralization is the conversion of an element from an organic form to an inorganic as a result of microbial decomposition.

The heterogeneous group of heterotrophic soil microorganisms takes part in mineralization of organic nitrogen and converts it to inorganic nitrogen. The reactions go uninterrupted, as long as carbon source is available for microbes.



IMMOBILIZATION: The conversion of the element from the inorganic to the organic form in microbial tissues or in plant tissues, thus rendering the element not readily available to other organisms or to plants, is called immobilization. **Harmful**

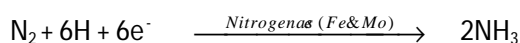
LECTURE 27

Nitrogen Fixation

Biological nitrogen fixation is the bio-chemical process by which elemental nitrogen is combined in to organic forms. It is carried out by a number of organisms including several species of bacteria, a few actinomycetes and blue green algae.

The quantity of nitrogen fixed globally each year is enormous (175 million Mg), which is more than the nitrogen applied through chemical fertilizers.

Although nitrogen is fixed by a number of different organisms a common mechanism appears to be involved in all the cases.

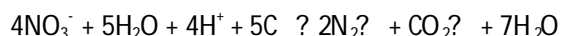


The site of nitrogen reduction is the enzyme nitrogenase, a two-protein complex consisting of a large ion, a molybdenum containing member, and a smaller companion containing iron.

Nitrogen fixing systems

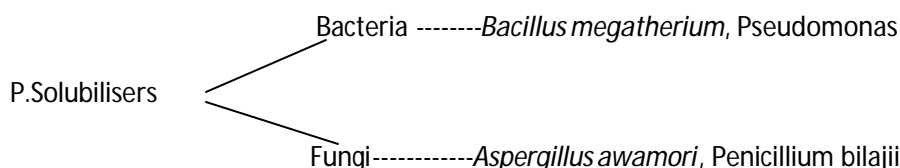
N- Fixing System	Organism Involved	Plant Involved	Site of fixation	Nitrogen kg N/ha/year
Symbiotic				
Legumes	Rhizobium bacteria	Legumes	Nodules	50-100
Non-legumes	Frankia (Actinomycetes)	Alnus	Nodules	50-150
	BGA(Anabaena)	Casuarinas Azolla(Fern)	Leaf	100-150
<u>Associative</u>	Azospirillum	Non -legumes	Rhizosphere	5-30
<u>Non-Symbiotic</u>	BGA (Oscillatoria)	Not involved with plants	Soil & Water	10-50
	Azotobacter, (aerobic)	Beijerinckia,		5-30
	(anaerobic)	Clostridium		5-20

DENITRIFICATION : In flooded soils the oxygen supply to soil is virtually cut - off because very less diffusion rate. Under such conditions, the facultative anaerobes Viz: Thiobacillus denitrificans, Thiobacillus thioparus (autotrophic) , Pseudomonas, Micrococcus, Achromobacter and Bacillus, during respiration, utilize the NO_3^- as terminal acceptor and reduce it to NO, N_2O and finally to N_2 . In this fashion the nitrate leached from oxidized layer and the nitrate nitrified at the root rhizosphere will be denitrified.



The losses due to denitrification may range from 10 to 40 percent of the applied nitrogen. Of the denitrified gas, about 90 % is in the form of N_2 . N_2O is lost at pH below 7.0 and causes atmospheric pollution. Denitrification is influenced by high organic matter content, moisture regime, soil type, Eh of soil, high temperature, supply of nitrate and cropping.

Phosphorous Solubilisation : The phosphorous element which is released during mineralization is likely to be converted to an insoluble inorganic compound. Some of the bacteria and other micro organisms are known to solubilise these compounds and make the phosphorous available to plants.



P-Absorber -----VAM fungi (Versicular arbuscular mycorrhizae

Glomus fasciculatum and *Gigaspora margarita*.

Among different phosphorus solubilisers fungi is more efficient, but not exploited commercially, as they do cause some diseases to crop plants also.

VAM is useful to explore more area and utilize phosphorus like immobile elements.

Harmful Activities of Soil Organisms

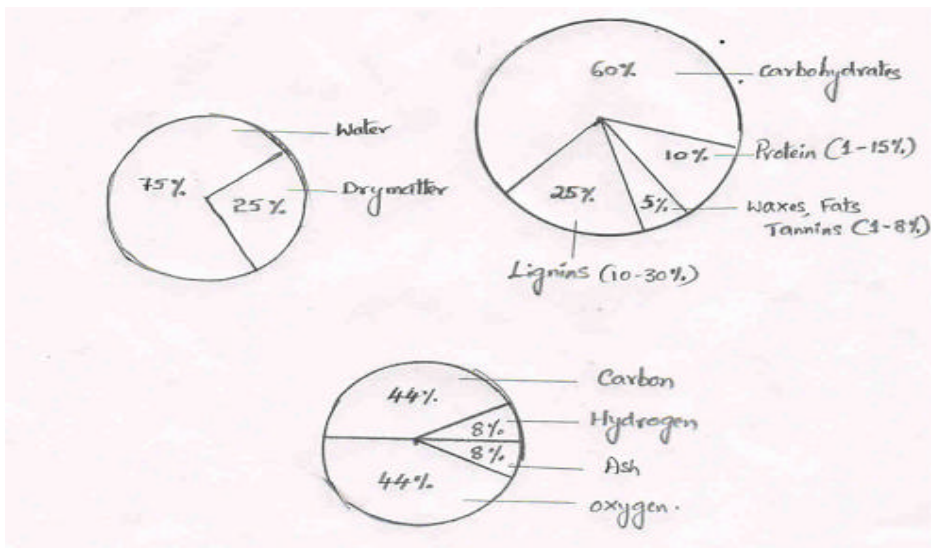
- Rodents, snails, slugs, termites, insect larvae and nematodes cause great
- damage to plants
- Mainly fungi, but bacteria and actinomycetes ,also, are responsible for
 - many soil borne diseases of crop plants.

- Offer lot of competition to higher plants in utilizing the soil available nutrients, particularly in the presence of carbon sources in the soil.
- Under conditions of poor drainage, depletes the available oxygen and hampers the normal growth of plants.
- Under anaerobic conditions, bacteria transform some of the nutrients to unavailable form (k & Zn etc.) and some nutrients to be available in toxic levels (Fe & Mn etc.)

LECTURE 28

Soil Organic Matter

Sources of soil organic matter:- The original source of soil organic matter is plant tissue (leaves, roots and left outs of harvested crops). Animals are the secondary sources of organic matter (their bodies when their life cycles are consummated)

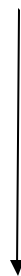


DECOMPOSABILITY OF PLANT RESIDUES

* Sugars, Starches and simple proteins

- 1 Crude proteins
- 2 Hemicelluloses
- 3 Cellulose
- 4 Fats, Waxes etc.,
- 5 Lignins

Rapid decomposition



Very slow decomposition

ORGANIC MATTER DECOMPOSITION

When organic tissue is added to soil three general reactions take place.

- 1 The bulk of the material undergoes enzymatic oxidation with CO_2 , H_2O and energy and heat as the major products.
- 2 The essential elements such as nitrogen, phosphorous and sulphur are released and / or immobilized by a series of specific reactions relatively unique for each element.
- 3 Compounds very resistant to microbial actions are formed either through modification of compounds in the original plant tissue or by microbial synthesis.

The native flora of soil i.e. bacteria, fungi and actinomycetes are involved in the decomposition of organic matter. Different soil enzymes (protein substances) produced by these microorganisms are directly responsible for the decomposition by reducing the activation energy, necessary to breakdown the bonds of different organic materials.

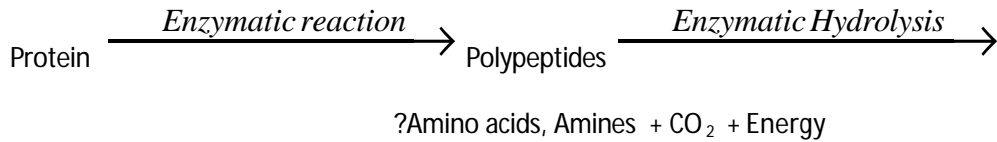
An enzyme is a substance, composed of proteins that are capable of lowering the activation energy of other selective compounds enough to allow the breaking of a particular bond under a particular environment.

The action of enzyme to make a split easier does not use up the enzyme. An activator that is not consumed or changed by such a process is called catalyst. Many different enzymes are produced by a single organism and many organisms produce the same enzyme.

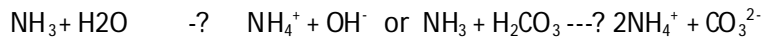
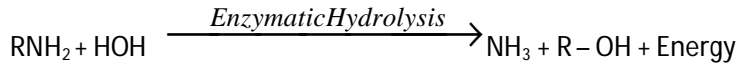
The simple end products of decomposition of organic matter under aerobic soil situations are CO_2 , NH_4^+ , NO_3^- , H_2PO_4^- , SO_4^{2-} , H_2O , resistant residues and various other essential plant nutrients like Ca^{2+} , Mg^{2+} , Fe^{2+} , Mn^{2+} , Zn^{2+} , Cu^{2+} etc.,. Under anaerobic conditions the end products are CH_4 (swamp gas), some organic acids (R-COOH) eg. lactic, propionic and butyric acid etc., NH_4^+ , various amine residues (R-NH₂), toxic gas H_2S and ethylene ($\text{H}_2\text{C}=\text{CH}_2$) and the resistant humus substance.

MINERALIZATION Mineralization is the conversion of an element from an organic form to an inorganic as a result of microbial decomposition.

The heterogeneous group of heterotrophic soil microorganisms takes part in mineralization of organic nitrogen and converts it to inorganic nitrogen. The reactions go uninterrupted, as long as carbon source is available for microbes.



Ammonification : Process of conversion of amino acids to ammonia

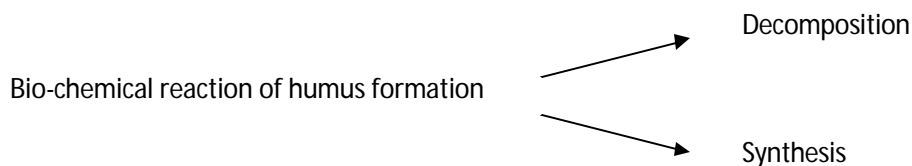


IMMOBILIZATION: The conversion of the element from the inorganic to the organic form in microbial tissues or in plant tissues, thus rendering the element not readily available to other organisms or to plants, is called immobilization.

SOIL HUMUS

Humus is a complex and rather resistant mixture of brown or dark brown amorphous and colloidal organic substances that results from microbial decomposition and synthesis and has chemical and physical properties of great significance to soils and plants

Synthesis of Humus : The formation of humus is strictly a bio-chemical process and rather complicated one. The compounds that make up humus have been synthesized by microorganisms in the soil from the products of the break down or alteration of the original tissue.



The simpler compounds resulted from break down of organic matter may take part immediately in human forming processes, a bio-chemical synthesis. These simpler compounds are metabolized in to new compounds in the body tissue of the soil organisms. The new compounds are subjected to further modification and synthesis as the microbial tissue is subsequently attacked by other soil micr oorganisms.

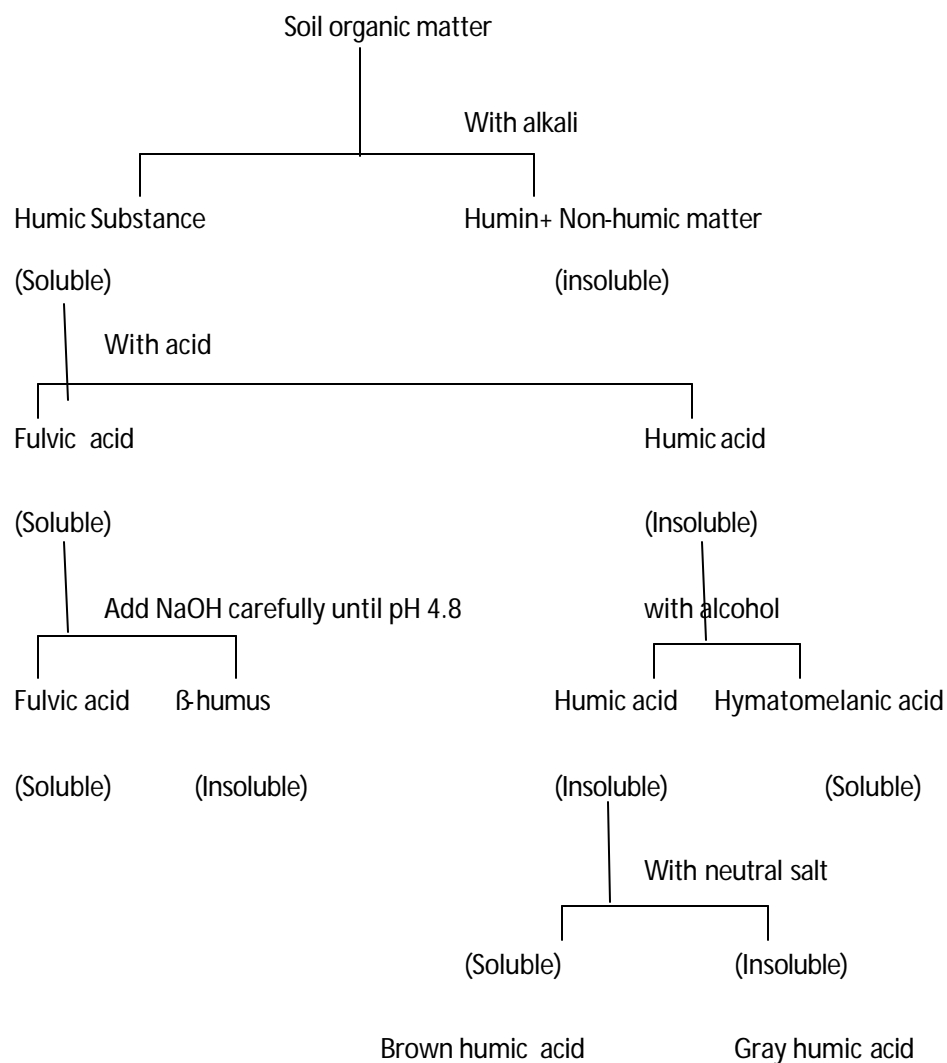
Additional synthesis reactions involve break down products of lignin as the phenols and quinones. These decomposition products, present initially as separate molecules called 'monomers' are enzymatically stimulated to join together in to polymers. By this process of polymerization (linkage) polyphenols and polyquinones are formed. These high molecular weight

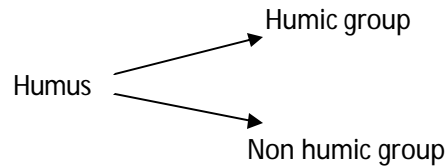
compounds interact with nitrogen containing amino compounds and give rise to a significant component of resistant 'Humus'.

Fractionation of Humus or Soil organic matter

Soil humus, the complex array of substances left after extensive chemical and biological break down of fresh plant and animal residues, makes up 60-70% of the total organic carbon in soil. Because of the complexity, humus is often divided through solubility separations.

Extraction and fractionation of organic matter or humus





Humic group : The humic substances makes up about 60-80% of soil organic matter and comprised of the most complex materials (Aromatic, ring type structures that include polyphenols and polyquinones) with no sharply defined physical and chemical properties. They are resistant to microbial attack. They are amorphous, dark in color and have high to very high molecular weights from a few hundred to several thousand.

On the basis of resistance to degradation and of solubility in acids and alkalis, humic substances are classified in to three chemical groupings.

- 1 Fulvic acid: - lowest molecular weight, lightest in color, soluble in both acid and alkali and most susceptible to microbial attack.
- 2 Humic acid: - Medium in molecular weight and color, soluble in alkali but insoluble in acid and intermediate in resistance to degradation.
- 3 Humin:- Highest in molecular weight, darkest in color, insoluble in both acid and alkali and most resistant to microbial attack.

Non-Humic Group : Comprises 20-30% of the organic matter in soils. These are less complex and less resistant to microbial attack. They are comprised of specific organic compounds with definite physical and chemical properties. These include polysaccharides (polymers that have sugar like structures with general formula of $C_n(H_2O)_n$, sugar amines, nucleic acids, phospholipids, vitamins & sulfolipids. Polysaccharides in particular are helpful in cementing soil aggregates together.

LECTURE 29

IMPORTANCE OF SOIL ORGANIC MATTER / HUMUS

Influence of Humus / Organic matter on soil physical, biological and chemical properties.

- 1 Imparts dark color to soils
- 2 Supplies polysaccharides for binding soil particles for formation of aggregates (genesis of good soil structure)
- 3 Increases infiltration rate of water and provides better drainage

- 4 Increases water holding capacity
- 5 Reduces plasticity, cohesion, stickiness etc in clay soils
- 6 Reduces bulk density, there by influence porosity favorably
- 7 Through granulation, reduces wind erosion losses
- 8 Provides mulching (raw organic matter) and lowers soil temperature during summer. Acts as an insulator and retards heat movement between atmosphere and soil
- 9 Reduces alkalinity in soils by releasing organic acids and CO₂
- 10 With high adsorption capacity, it accounts for 30-90% of the adsorbing power of mineral soils (Carboxylic group – 54% ; phenolic & enolic groups – 36%; imide group – 10%)
- 11 Acts as a buffering agent and reduces the likelihood damage from acids and alkalis.
- 12 With its solubilising effect, increses the availability of nutrients
- 13 Acts as a store house for nutrients. Organic matter is the source of 90-95% of nitrogen in unfertilized soils. Also supplies available 'P', 'S' and micro nutrients like Fe, Mn, Cu and Zn etc.,
- 14 Adsorbs temporarily the heavy metal pollutants and cleans the contaminated waters.
- 15 Serves as a source of energy for macro and micro organisms in soils and helps in performing various beneficial functions in soils (N- fixation, mineralisation etc.)
- 16 Acts as a chelate and increases the availability of micro nutrients
- 17 Various organic substances like vitamins, antibiotics and growth promoting substances namely auxins are produced by different micro organisms during decomposition of organic matter. Also some fungi-toxins are produced to control diseases.

Carbon : Nitrogen Ratio

Both mineralization and immobilization are accomplished by microbes under the influence of temperature, moisture and pH etc.,

These processes are more influenced by C/N, C/P and C/S ratios of decomposing plant residues.

An average proportion of C/N/P/S in soil humus is appropriately 140:10:1.3:1.3. The ratios recorded for C and P are some what more variable than for C and N, or C and S.

C:N Ratio	C:P Ratio	C:S Ratio	N.M	N.I
<20:1	<200:1	<200:1	Yes	No
>30:1	>300:1	>400:1	No	Yes
20-30:1	200-300:1	200-400:1		Neither gain nor loss

C:N ratios of some organic materials

<u>Material</u>	<u>C:N ratio or C/N</u>
Microbial tissues	6-12
Sewage, Sludge	5-14
Soil Humus	10-12
Annual Manures	13-25
Legume residues and green manures	13-25
Cereal residues and straws	60-80
Forest Wastes	150-500

The quantity of carbon declines with the advancement of decomposition process. Similarly, the inorganic element released during mineralization process is also lost, by several means i.e. plant utilization, leaching, volatilization, conversion to insoluble compounds etc.. It results in a stabilized C:N ratio to the soil i.e. 10:1 or 12:1

Significance of C : N ratio in Soil Fertility :

- 4 C : N ratio determines the microbial activity and their proliferation
- 5 C:N ratio of organic residues determines the rate of decomposition of organic residues.

- 6 C : N ratio determines the net availability of nutrients to plants
- 7 The supply of nitrogen, phosphorus and sulphur are largely determined by C:N ratio of organic residues.

LECTURE 30

SOIL CLASSIFICATION

Classification is the grouping of objects in some orderly and logical manner into compartments. Classification of soils is the grouping of soils in orderly manner into different classes.

Early systems of classification: They are quite simple and practicable.

Economic classification: This system is adopted by the revenue department for grouping soils according to their productivity for the purpose of taxation.

Physical classification: It is based on the physical properties like soil texture. The soils are termed as sandy, loamy, clay etc. Based on soil structure, soils are classified as single grained soils, aggregated soils etc.

Chemical classification: It is based on the chemical properties of the soils. Calcareous soils, gypsiferous soils, alkaline soils, acidic soils etc.

Geological classification: Two broad groups are recognized.

i) Residual/sedentary soils – soils developed in-situ from the underlying rocks.

ii) Transported soils – soils developed from transported & deposited sediments.

Physiographic classification: In this system, the characteristics of the landscape were considered. The soils are termed as levee soils, terrace soils, mountain soils, hilly soils, upland soils, lowland soils etc.

Other types of classifications:

Based on organic matter content: Organic soils and inorganic soils.

Based on climate: Arid soils, humid soils, subhumid soils etc.

Based on vegetation: Prairie soils, grassland soils, forest soils, etc.

DIAGNOSTIC HORIZONS

A diagnostic horizon is one, which is formed as a result of pedogenic processes and having distinct properties or features that can be measured in terms of measurable soil properties. Based on the location in the soil profiles, these are divided into two categories.

Diagnostic surface horizons (epipedons)

Diagnostic sub-surface horizons (endopedons)

Epipedons: Gr. *epi*, over, and *pedon*, soil

Nine epipedons are recognized.

Mollic (L. *mollis*, soft) Epipedon

Umbric (L. *umbra*, shade) Epipedon

Anthropic (Gr. *Anthropos*, man made) Epipedon

Plaggen (Ger. *Plaggen*, sod) Epipedon

Ochric (Gr. *ochros*, pale) Epipedon

Histic (Gr. *histos*, tissue) Epipedon

Melanic (Gr. *melanas*, black) Epipedon

Folistic (L. *folia*, leaf) Epipedon

Grossarenic Epipedon (L. *grossus*, thick, aren, sand)

I. Mollic Epipedon: It is soft, thick, moist, dark coloured, humus rich horizon

1. The structure is not hard even under dry condition.
2. Rock structure is less than one – half of the volume
3. Colour with a value of 3 or less (moist), and of 5 or less (dry)
4. A base saturation (by NH_4OAc) of 50 percent or more;
5. An organic carbon content of 0.6 percent or more
6. 18 cm or more depth
7. Phosphate content of less than 1,500 ppm soluble in 1% citric acid
8. Some part of the epipedon is moist for 90 days or more.
9. The *n* value is less than 0.7

II. Umbric Epipedon: It has all properties of mollic epipedon except base saturation (BS is < 50%)

III. Anthropic Epipedon:

It shows some evidence of disturbance by human activity and meets all the requirements for a mollic epipedon, except for *one or both* of the following

1. 1500 mg/kg soil or more of P₂O₅ or
2. Dry for 9 months or more.

IV. Plaggen Epipedon: The plaggen epipedon is a human made surface layer 50 cm or more thick that has been produced by long continued manuring

V. Ochric Epipedon: all the properties are opposite to that of mollic epipedon.

Colour: Value 5.5 or more (dry), 3.5 or more (moist)

Organic matter : <1% (0.6%O.C)

Structure: Hard or very hard and massive when dry

Moist period: Dry for more than 3 months in a year

VI. Histic Epipedon: It is saturated for 30 days or more. Consists of organic carbon of 8 – 16% or more depending upon the clay content Of 0-60%.

VII. Melanic Epipedon: This horizon is commonly formed on volcanic ash deposits. It has andic soil properties in top 30cm, a colour value (moist) 2 or less, a melanic index of 1.7 or less and 6 % or more organic carbon

VIII. Folistic (L. *folia*, leaf) Epipedon: Saturated for < 30 days & consists of organic carbon of 8 – 16% or more depending upon the clay content Of 0-60%.

IX. Grossarenic Epipedon: It has sandy texture of thickness 100cm or more over an argilling horizon.

DIAGNOSTIC SUB-SURFACE HORIZONS (ENDOPEDONS)

Gr. *endon*, endo, within and *pedon*, soil). Formed below the surface of soil. Some of these are regarded as 'B' horizons and others as part of 'A' horizon.

19 endopedons are recognized. Important endopedons are

Albic horizon: (L. *albus*, white) Eluvial horizon 'E' formed below 'A' horizon

Light colored bleached horizon (value 4 or more), >85% by volume of albic materials, >1cm thick,

Argillic horizon: (L. *argilla*, white clay). Bt (textural 'B' horizon), subsurface horizon with a significantly higher percentage of clay than overlying horizon due to illuviation.

Calcic horizon: (L. *calcis*, lime). Illuvial horizon, Bk, Ck, 15cm or more thick, not hard and has 15 percent or more CaCO₃

Cambic horizon: (L. *cambiare*, to exchange). It is the result of physical alteration, chemical transformation of parent material. Hence, called altered B/ Brown B/ Structural B horizon (Bw).

Duripan : (L. *durus*, hard). Silica cemented hard sub-surface horizon. Bqm.

Gypsic horizon: L. *gypsum*, By, Cy. Illuvial horizon. 5% or more gypsum accumulated to 15 cm or more thick,.

Natric horizon: Nl. *Natrium*, sodium.

Argillic horizon +; (Btn). The argillic horizon has ESP >15,

Oxic horizon: Fr. *Oxide*, oxide, Bo. Intensively weathered horizon. Oxides are dominant.

Petrocalcic horizon: Gr. *petra*, rock.

Hard cemented calcic horizon. Ckm, Bkm

Petrogypsic horizon: Cemented/indurated gypsic horizon. Cym, Bym

Spodic horizon: Gr. *spodos*, wood ash. Bhs, Bh, Bs. =85% spodic materials. The horizon accumulates illuvial humus and / or sesquioxides.

LECTURE 31

SOIL TAXONOMY

In 1951 a decision was taken in US to develop a new system of classification because of the following defects in the genetic system:

Zonal, intra-zonal and azonal soils were not clearly defined

Classification is based on assumed soil genesis

Definition of certain taxa was based on virgin soils

Too much emphasis on soil colour

Taxa of lower category were defined in terms of comparative and subjective definitions

No suitable classes were provided at some of the category levels

Some families were not clearly defined

Nomenclature was a collection from several sources

Guy D smith was the leader of the New Comprehensive System. Series of approximations from 1953 to 1960 were made and were circulated to criticism for precision and revision. Each successive approximation was made more precise and more complete than one before and was evaluated by more people. Finally it was published as 7th approximation in 1960. It was supplemented in 1964 and 1967. It was released as Soil Taxonomy (USDA Hand Book No. 436) by the USDA Soil Survey Staff in 1975. Since that time it has undergone 9 revisions. Now second edition (1999) of Soil Taxonomy and 11th edition (2010) of Keys to Soil Taxonomy are being followed.

V V Dokuchaev (1846 – 1903) – Founder of Modern Pedology

C F Marbut (1920 – 1940) – Founder of American Pedology

Salient features of soil taxonomy:

- It is based on measurable soil properties
- It considers all such properties which affect soil genesis
- The nomenclature is most logical & helps in relating the place of taxon
- It is truly multi -categorical system with 6 categories
- It is an orderly scheme without prejudice and facilitate easy remembering of objects.

Advantages of soil taxonomy over other systems:

- It permits the classification of soils rather than soil forming processes
- It focuses on soils rather than related sciences such as geology and climatology
- It permits the classification of soils of unknown genesis
- It permits the greater uniformity of classification
- The soil with a different genesis but having identical properties are classified within the same unit

- There is no particular order for strictly hydromorphic and halomorphoc soils as in the other systems.

NOMENCLATURE

The unique feature of *soil taxonomy* is the unusual – sounding nomenclature used to identify different soil classes. Although unfamiliar at first sight, the nomenclature system has a very logical construction and conveys a great deal of information about the nature of the soils named. The system is to learn after a bit of study. In an attempt to make the nomenclature more uniform, understandable and adaptable, new names/words were coined from many roots in Latin, Greek, with a few others from English, German, and Japanese languages.

The words selected were self explanatory, easily remembered, suggest properties of the object, suggest the place of taxon in the system, as short as possible, euphonic (easily pronounceable), and fit in as many languages as possible.

1. The names of the orders are coined words and have a common ending, sol (L. solum, soil). The names of orders are combination of two parts – 1. word containing the formative element and sol connected by vowel 'I' or 'O' for Latin and Greek words respectively.

Mollisol, Alfisol, Ultisol, Entisol, Histosol. Spodosol etc.

The formative elements of the order is carried out in the names of other categories of that order and used as an ending.

Udoll, Haplustert, Typic Haplustept

2. Each suborder name consists of two syllables. The first is the suggestive of a property of that suborder and the second the name of the order as reflected by the formative element of the order.

Udoll, Cryept, Ustalf etc.

3. Likewise, the name of the great group is coined by prefixing one additional word (distinguishing character of the great group) to the suborder name.

Durustalf, Hapludoll, Calciustert etc.

4. Subgroup name consists of the name of the great group modified by one or more adjectives (binomial nomenclature)

Vertic Haplustept, Typic Calciustert

5. Family names meet the need for making practical prediction for land use planning. It indicates particle size class, mineralogy class, and STR class.

Fine silty, kaolinitic, isohyperthermic, Typic Hapludoll

Hence it is a polynomial nomenclature.

6. The name of the soil series has no pedogenic significance but represent a prominent geographic name of a river, town, area or person where the series has been first recognized.

Patancheru series – red soils Kasireddipalli series – black soils.

LECTURE 32

SOILS OF INDIA

Geographic location: Asian continent, North of Equator,

Between $8^{\circ}4'$ & $37^{\circ}6'$ N latitude and $68^{\circ}7'$ & $97^{\circ}25'$ E longitude

Extent: 329mha or 329×10^4 sq.km (3.29 msq.km)

ALLUVIAL SOILS

Extent: 75 mha

Soil formation: Parent material: River alluviums from erosion products of rivers, coastal alluviums from coastal sands; and deltaic alluviums from Heterogeneous sediments

Salient features:

Texture is variable. Coarser near source & finer in proximity to the sea (delta)

Fluvial in nature, stratified which is reflected in their texture and OM distribution.

Colour depends on parent material

Depth depends on geographic position,

Calcium carbonate content is variable

Mostly alkaline (aridic & ustic SMR) or acidic (udic SMR only) in reaction.

Profile development is variable A – C to A-B-C profiles

Inherently rich in plant nutrients – fairly sufficient in P and K but deficient in N and OM.

Potentialities: River alluviums and deltaic alluviums are best agricultural soils. Wheat, rice, sugarcane and other crops can be grown well

Constraints:

Stratification restricts leaching and drainage

Extreme sandy nature that promotes excessive leaching of water and plant nutrients

Hydromorphic condition that promotes reduction and results in poor aeration for plant growth.

They can be rendered saline where evaporation exceeds rainfall (aridic).

The river alluviums and deltaic alluviums are becoming waterlogged and salt affected due to injudicious use of irrigation water.

Due to intensive use for cultivation, secondary problems are arising like deficiency of S and Zn.

Receding ground water and rising ground level in some areas.

Management:

Judicious use of I.W & fertilizers. Providing drainage facilities

BLACK SOILS

Extent: 74Mha

Soil formation:

Parent material: Generally basic parent material like basalt rich in lime, soda feldspars and clay. Semiarid-subhumid climate, Lower/ plain topography

Soil Properties:

Black colour - clay humus complex / titaniferous magnetite,

30-80%clay (highly argillaceous), clay - clay loam, smectite clay,

Extremely hard on drying and very sticky and very plastic on wetting

Because of swell-shrink nature, they develop deep wide cracks, gilgai relief, slickensides in lower depths due to churning / argillopedoturbation.

$\text{SiO}_2/\text{R}_2\text{O}_3$ 3 – 3.5, high B.D (1.5 – 1.8 Mg m^{-3}) due to compaction in lower layers, high total pore space, pH (7.8 - 8.7/9.5), CEC (35 – 55 cmol/kg), BS up to 100%, CaCO_3 (up to 40%), WHC (150 - 250 mm/m)

Generally low OM. High nutrient holding capacity.

Low HC and permeability. Hence ill drained and more runoff.

Constraints:

Deep black soils: Narrow workable moisture, poor trafficability, high draft power (heavy soils), low permeability, poor drainage, low HC,

High EC and salinity in sub-soil.

Micronutrient deficiency in calcareous soils.

Potentialities & Land Use:

Inherently fertile, suitable for dry farming, under rainfed conditions cotton and millets, under irrigation rice, sugarcane etc., can be grown

Management: ICRIASAT – Dry season / pre-monsoon sowing, BBF

RED SOILS

Extent: 25 to 30% of GPA of the country. 70Mha

Extent in AP: Geographical area of the state 27.4Mha (2,74,000sq.km, 100sq.km = 1 ha).

Red soils 65, laterite soils 1, black soils 25, alluvial 5 and coastal sands 3% in AP.

Present in all the districts of the state.

Other names: Morphologically they are red loams, red earths, red & yellow soils. Brown soils are called parwa while red soils are called rakar.

Soil formation:

The name red is given to soils rich in **sesquioxides** that have developed of archean origin (granites, gneisses).

Generally red soils are formed on well drained, **stable higher landforms** (higher topography).

Under hot, semi-arid to humid sub-tropical climate,

The weathering is **moderately intense** and leads to enhanced decalcification.

Some weathering products are **leached out** leaving behind the less mobile elements (Si, Fe, Al). The Fe and Al under **oxidized** conditions, form sesquioxides imparting **red colour**.

Salient features:

Red to yellow (hydration & coatings of Fe and Al oxides 30 – 40%),

Is to c texture, Shallow to deep,

Low to high clay, kaolinitic / illitic, low WHC & NHC

Well to excessively drained as evident from their colour,

CN ratio 10:1, pH 6 - 7.5,

CEC low (25 – 40 cmol/kg of clay) and BS is low to medium,

SiO₂/R₂O₃ 2.5 – 3.0, Low nutrient status (O.C, N, P, K, lime)

Constraints: Shallow depth if formed on elevations, soil erosion, sub-surface hardening, sub-surface ahrd pans, surface crusting, rapid drying, excessive drainage or some times runoff, high surface soil temperature in dry areas, deficient in OM, N, P Ca. High in Fe₂O₃ & Al₂O₃, kaolikinite, allophanes - P fixation, though K is sufficient - fast depletion due to continuous cropping.

Crusting and hardening of red sandy soils (chalkas): Reasons:

Proportion of clay to sand +silt ratio (3:7) – strength 36kg/cm² on drying

Presence of free iron oxides which form irreversible bonds with clay fraction

Sealing pores by rain drops force– dispersion of soil particles.

Management: tillage with spike roller, pulling thorny bush to break the crust.

Mulching of seed lines Sowing on the sides of the ridges

Incorporation of slowly decomposable organic residues– paddy husk, grounut pod shells, coir pith etc.

Potentialities & Land use:

Under good mangement practices, these soils are good for agricultural, horticultural and plantation crops.

Management: Application of organic materials and proper fertilization.

LATERITE SOILS

Extent: 25 Mha

Other names: The term 'laterite' was coined by Buchanan in 1807 for highly ferruginous, vesicular, unstratified deposits of Malabar hills.

Soil formation: Basic parent material, sub-tropical to tropical climate,

higher topography under rain forest vegetation. The siliceous matter is leached during weathering and sesquioxides are left behind.

Lateritic soils are formed under same climatic conditions but alternate wet and dry conditions are not required.

Soil Properties: Red colour (5YR or redder), highly weathered hence very deep soils, high clay % (not due to migration but due to *in situ* alteration), open texture, massive structure, narrow $\text{SiO}_2/\text{R}_2\text{O}_3$ (<2) ratio, strongly acidic,

LAC (<16cmol/kg clay), BS = 40% (low), kaolinite dominant, low OM

Constraints: High permeability, low AWC, highly leached,

Chemically degraded, low nutrient reserve, deficiency of P, K, Ca, Zn, B etc.,

Strongly acidic, high P fixation, Al & Mn toxicity.

Land Use: Generally used for plantation crops & shifting cultivation (should be 20 years or more), In low level areas - rice, banana coconut & high level areas - coffee, cocoa, rubber, tea are grown

Management: Liming and fertilization (rock phosphates and silicates)

COASTAL SANDS

Occur all along coast 3 to 12 km away on both east and west coast.

They are derived from marine sediments

Properties: Deep to very deep, Ground water at as depth of 2 to 5 mts. Brackish ground water, Occasionally saline with neutral pH. Sandy texture with negligible clay content, Single grain structure. Loose consistence, Light soils. Rapid permeability, excessively drained. Low WHC and NHC. Low OM, low fertility, low CEC and BS

Land use: Owing to extreme sandy nature, these soils are able to withstand irrigation with high saline water – Doruvu technology can be followed

Constraints: During cyclone periods – these soils are inundated due to tidal over – flow

Appendix

The information given in Appendix is only to gain more knowledge about the course

GENESIS OR DEVELOPMENT OF SOIL STRUCTURE: It refers to the causes and methods of formation of the structural units or aggregates. There are two steps in origin of soil structure.

a. Flocculation

b. Cementation

Flocculation: In soils with an appreciable content of clay, the primary particles, under favourable circumstances, tend to group themselves into structural units, known as secondary particles or aggregates. Initially clay particles will be flocculated under favourable conditions, to trigger the mechanism of particle grouping leading to formation of clay domains. This flocculation, which is an electro-kinetic phenomenon, cannot guarantee the stable aggregate formation. Flocculation is of two types:

Salt type: When electrokinetic (zeta potential) is reduced sufficiently, a collision between the particles results in mutual attraction and flocculation takes place. It takes place in the presence of divalent and trivalent cations and is less stable.

Edge-to-face type: Flocculation occurs as a result of electrokinetic attraction between the positive edges and negative faces of clay minerals. This is more stable.

Cementation: Stable aggregate formation requires a cementing agent to bind the flocculated particles, together. Organic matter, calcium carbonate and sesquioxides are the common cementing agents.

Factors responsible for aggregate formation:

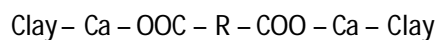
Number of mechanisms or factors work together and be responsible for aggregate formation, which can be grouped together as biological, chemical and physical in nature.

Biological factors: Biological agents sustain the aggregation in soils, directly and indirectly through supply of organic substances. These organic binding substances are transitory in nature,

because of their susceptibility to microbial decomposition. These, organic matter must be replenished and supplied continually, if aggregate stability is to be maintained in the long run.

- Extensive network of roots pushing through the soil, compress soil particularly into small aggregates. The dehydration of soil in the vicinity of root system causes local shrinkage with the formation of surfaces of fracture.
- Root exudations and continual death of roots, particularly root hairs, promote microbial activity, which results in production of humic cements.
- The fungi and actinomycetes cause mechanical binding of the aggregates by the mycelia they produce.
- Microorganisms, particularly bacteria help in binding aggregates by excreting mucilaginous products viz: polysaccharides, hemicelluloses or uronides, levans as well as numerous other natural polymers. Especially, the polysaccharides are the flexible molecules capable of forming multiple bonds with several particles at once.
- The products of microbially decomposed organic materials such as humic acids, colloidal proteins and cellulose materials also produce stabilizing effect.
- Organic products also promote aggregate stability by reducing wettability and swelling.
- Earth worm casts are well known for their stability (7-18t/acre).

Clay organic interaction: Clay-clay interaction, particularly under dry condition takes place due to electrostatic and vander waal's forces, which leads to formation of secondary particles. Polyvalent cations (Ca^{2+} , Mg^{2+} , Al^{3+} etc) adsorbed on the surface of the clay serve as bridges to form clay organic complexes and leads to the formation of stable aggregates.



Soluble sesquioxides are deposited on the surface of the clay particles and form complexes with humus. Colloidal hydrated iron oxides become almost completely irreversible upon dehydration, which is an important factor in the production of highly stable aggregates in laterite soils.

The bonding of organic polymers to clay surfaces by cationic bridges H-bonding, vander-wall's forces and sesquioxide humus complexes are the important mechanisms by which organic collids stabilize the soil structure.

Chemical: The chemical mechanisms responsible for aggregation include exchangeable cation interactions and cementing action of inorganic colloidal substances etc.

Cation effects: When polyvalent cation like Ca^{2+} , Mg^{2+} , Al^{3+} and H^+ are adsorbed on negatively charged clay colloids, clay particles flocculate, and in the presence of organic cementing agents these floccules get aggregated. So the soils dominated by calcium are better aggregated than soils with Na as dominate cation.

Sesquioxide colloids: In laterite soils high degree of aggregation is due to the cementing action of irreversible colloidal iron-hydroxide. The trivalent iron serves as flocculating agent while gelatinous iron hydroxide acts as cementing agent. The iron hydroxide is precipitated as hydrated gel which on dehydration acts as a good cementing agent for soil particles due to its irreversible character.

Physical : The major physical mechanisms responsible for aggregate formation are shrinkage and swelling, freezing and thawing and colloidal clay effects.

Alternate wetting and drying, which is common in nature, is very conducive for aggregation in soil. Due to unequal stresses and strains that are created by the swelling and shrinkage, disruptive action of occluded air in the clods, during wetting, and cementation of particles due to dehydration during drying, lead to aggregate formation. Repeated cycles of these mechanisms lead to development of a well defined network of cracks, which act as natural cleavages for well developed structure.

Freezing and thawing, just like swelling and shrinkage causes aggregated formation.

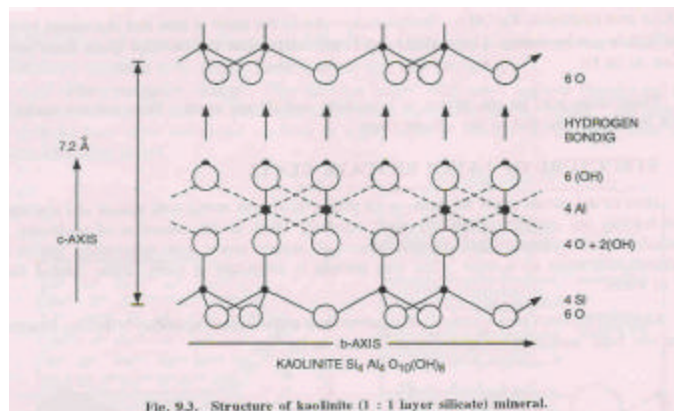
Synthetic organic amendments: Synthetic polyelectrolytes have been used for promoting aggregation and stabilizing soil structure. These include polycations, polyanions (hydrolyzed polyacrylonitrile) and non-ionic polymers (polyvinylalcohol) and are also known as soil conditioners. As these conditioners are similar to soil polysaccharides, their binding action on soil aggregates is also similar.

Polycations like other cations, are adsorbed on clays through cation exchange and exhibit high flocculating power. In this process also calcium will act as a bridge between clay and organic polymer (polycation).

Polyanions form peripheral complexes linking clay lattices together in an edge-to-edge arrangement by a series of H bonds. They do not flocculate but stabilize the flocculated clays. These polyanions are adsorbed on the surface of dispersed particles and bind particles by forming bridges between the particles. Eg. VAMA: Vinyl acetate maleic anhydride. Also known as Krillium. Non-ionic conditioners may form inter-micellar complexes with layer silicate clays

Each soil has distinct problems and requires specific soil and crop management practices for soil structure management.

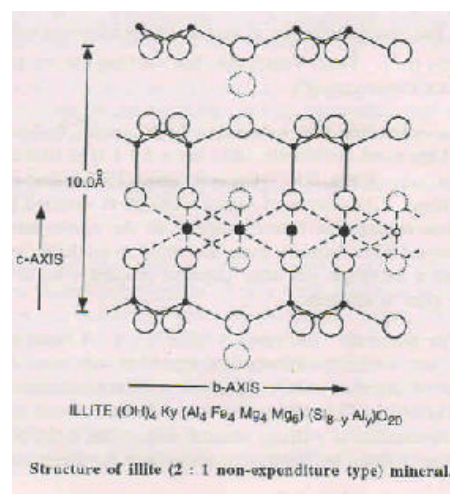
Detailed Structures of clay minerals:



KAOLINITE

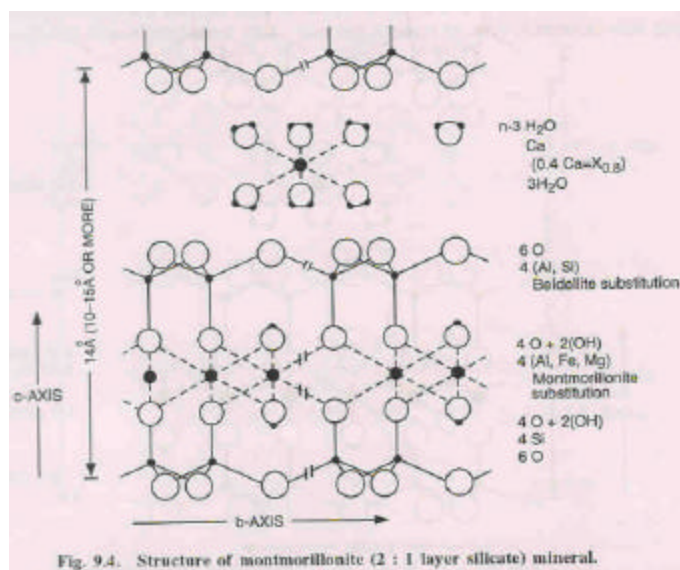
Fig. 9.3. Structure of kaolinite (1 : 1 layer silicate) mineral.

ILLITE



Structure of illite (2 : 1 non-expansion type) mineral.

MONTMORILLONITE



Category	No. Of taxa	Differentiating characteristics
Orders	12	Presence or absence of major diagnostic horizons / properties.
Suborders	65	Presence or absence of properties related to wetness, moisture regime, climate, parent material and vegetation.
Great Groups	319	Based on base status, STR, SMR, presence or absence of plinthite, fragipan, duripan etc.
Subgroups	2400+	Typic, Intergrades. Extrgrades
Families	4500+	Properties which meet the practical predictions for land use planning – Particles size class, mineralogical class, STR class
Series	19000+	Kind, arrangement, and features of horizons in a pedon.

Table 1 Differentiating Characteristics of Categories in Soil Taxonomy

Table 2 SOIL ORDER NAMES AND THEIR FORMATIVE ELEMENTS

S. No.	Order	Formative Element	Derivation of formative element	Mnemonic (memory device)
1	Alfisol	alf	Nonsense syllable	Pedalfer
2	Andisol	and	J. <i>an</i> – <i>ando</i> , black soil	Ando
3	Aridisol	id	L. <i>aridus</i> , dry	Arid
4	Entisol	ent	Nonsense syllable	Recent
5	Gelisol	el	Gr. <i>gelid</i> , very cold L. <i>gelare</i> , to freeze	Gelid Jell
6	Histosol	ist	Gr. <i>histos</i> , tissue	Histology
7	Inceptisol	ept	L. <i>inception</i> , beginning	Inception
8	Mollisol	oll	L. <i>mollis</i> , soft	Mollify
9	Oxisol	ox	Fr. <i>Oxide</i> , oxide	Oxide
10	Spodosol	od	Gr. <i>spodos</i> , wood ash	Podzolized (odd)
11	Ultisol	ult	L. <i>ultimus</i> , last	Ultimate
12	Vertisol	ert	L. <i>verto</i> , turn	Invert

EXTENT OF DIFFERENT SOIL ORDERS

S.No	Order	In world		In India		
		M.Sq.miles	Rank	M ha	% total	Rank
1	Entisol	12.50	4	80.10	24.37	2
2	Vertisol	02.10	9	26.30	08.02	4
3	Inceptisol	15.80	2	95.80	29.13	1
4	Aridisol	19.20	1	14.60	04.47	5
5	Mollisol	09.00	6	08.00	02.43	6
6	Spodosol	05.40	8	Absent		
7	Alfisol	14.70	3	79.10	24.25	3
8	Ultisol	08.50	7	00.80	00.26	7
9	Oxisol	09.20	5	00.10	00.03	8
10	Histosol	00.80	10	Very small extent		9
11	Andisol	00.80	11	Absent		
12	Gelisol	---	12	Absent		

In India the extent of Inceptisols, Entisols, and Alfisols is more than 75%

If Vertisols are also included the extent is more than 80% of the total.

SIMPLIFIED KEY TO SOIL ORDERS (A flow diagram)

Permafrost within 100/200 cm of the soil surface	?	Yes ?	Gelisol
		? No	
More than 30% organic matter to a depth of 40cm	?	Yes ?	Histosol
		? No	
Spodic horizon within 2m from the surface	?	Yes ?	Spodosol
		? No	
Andic soil properties of > 35cm thickness soil		? Yes ?	Andisol
		? No	
Oxic horizon within 1.5m but no kandic horizon	?	Yes ?	Oxisol
		? No	
30% or more clay up to 50cm, cracks, slickensides	?	Yes ?	Vertisol
		? No	
Dry for more than 50% of the year		? Yes ?	Aridisol
		? No	
Argillic/kandic horizon with < 35% BS		? Yes ?	Ultisol
		? No	
Mollic Epipedon / dark coloured soil of grasslands	?	Yes ?	Mollisol
		? No	
Argillic / kandic horizon with 35% or more BS		? Yes ?	Alfisol
		? No	
Cambic horizon		? Yes ?	
Inceptisol		? No	
No diagnostic horizon other than ochric/anthropic horizon ?		Yes ?	Entisol

TRADITIONAL SOILS OF INDIA & THEIR TAXONOMIC UNITS

S.No	Genetic name	Distribution	Taxonomic Units (up to suborder)
1	Alluvial Soils	Punjab, Haryana, U.P, Bihar, Bengal, Assam, Orissa, coastal Gujarat, TN and Kerala	Fluvents, Psammets, Aquepts Aquepts, Ustepts Ustalfs Calcids, Cambids, Salids, Gypsids
2	Black Soils	Maharastra, Gujarat, A.P, Karnataka	Orthents Ustepts Usterts
3	Red Soils	AP, TN, Karnataka, Kerala, MP, Orissa	Orthents, Ustepts Ustalfs, Ustults
4	Lateritic Soils & Laterites	Orissa, Goa, Assam, TN, Kerala, Karnataka, AP, Maharashtra	Aqupts, Udults, Ustults Ustox
5	Desert Soils	Rajasthan, West Punjab	Orthents, Psammets Cryepts Cambids, Cryids Torrerts
6	Forest & Hill Soils	Kashmir, Bihar, West Bengal	Udalfs, Udults, Ustults
7	Terai Soils	U.P	Cryolls
8	Peaty Soils	Kerala & NE region	Sulfaquents Sulfaquepts
9	Marshy Soils	Orissa, Sunderbans (W.B), Mangoove forest of TN	Hydraquents, Fluaquepts

Agro-Ecological Regions: According to Sehgal et al. (1992) India is divided into 20 (1-20) AERs and 60 AESRs based on landform (physiography), soils, bioclimate, and LGP.

Bioclimate is the climate prevailing a few meters above and a few meters below the soil surface where biological activity prevails.

Traditional types of red soils in AP:

1. Red sandy loams	2.2Mha	8% of GPA
2. Red earths with loamy subsoil	8.2	30
3. Red earths with cclayey subsoil	0.82	3
4. Red loams of shallow to medium depth	2.5	9
5. Red loams (deep)	0.82	3
6. Red soils with clay base	3.29	12%
Total	17.84Mha	65%

Sulphur oxidising bacteria

Obligate Chemo lithotrophs:	Thiobacillus
Facultative :	Beggiotoa, Thiothrix (Oxidise H ₂ S & Deposits 'S')
Heterotrophic bacteria :	Bacillus, Pseudomonas, Anthrobacter
Heterotrophic Fungus :	Aspergillus, Penicillium
Photo-lithotrophs :	Rhizospirillum, Rhodopseudomonas

Sulphur reducing bacteria : Desulphovibrio, Desulfotomaaculum
