INTRODUCTION TO SOIL CHEMISTRY

Soil Chemistry is an important branch of soil science. It is fundamental to all soil processes that affect the use of soil. Soil chemistry studies the nature of chemical elements in the soil system in organic and inorganic combinations. It also studies the inter-relationship between these chemical elements and how they relate with three states of matter.

Soil chemistry is regarded as the most central of all the scientific disciplines that interact to make up of the complex web of environmental science.

Significance of soil chemistry

Understanding soil chemistry is very important to crop production in terms of

1) Improving the availability of nutrients to plants
2) To utilize soil microbial organisms to the best advantage
3) To improve the physical conditions of the soil
4) Helps to explain the basic properties of soils as they occur in nature
5) Helps to monitor and follow rapid changes that occur in the soil as a result of the introduction of intensified modern techniques in crop production

SOIL COMPOSITION

Soil may be defined as material of variable depth with a substantial solid content at the Earth's surface which is undergoing change as a consequence of chemistry, physics and biology processes.

Soil essentially consists of three phases; a solid phase, a solution phase and a gas phase.

- The solid phase usually includes an intimate mixture of mineral material, originating from rock, sediment or till, and organic material arising as a consequence of biological activity

- 2. The solution phase, this interact continuously with the solid phase. It originates infiltrating the soil or from rising water or water moving laterally.
- 3. The gas phase, or soil atmosphere composition depends upon biological activity.

SOIL COLLOIDS

- Next to photosynthesis and respiration, no process in nature is more vital to plant and animal life than the exchange of ions between soil particles and plant roots.
- These cation and anion exchanges occur mostly on the surfaces of the finer or colloidal fractions of both the inorganic and organic matter (clay and humans).
- Colloids are substances whose particle size is about 1 to 1000nm when they are mixed with another substance, usually air or water.
- Colloids are action sites for chemical reaction, microscopic, large surface area. The larger the surface area, the better they are for chemical reaction.
- Molecules of some compounds can come within the colloidal range but most colloids consist of aggregate of molecules. Colloids are so ubiquitous in nature and so distinctive that they have common names as fog, smoke, aerosol, foam, emulsion, soil and clay. All are small particles suspended in a fluid. as

General properties of soil colloids

- **Size**
- **Surface area**
- **Surface charges**
- **Adsorption of cations and water**

Types of soil colloids

There are four major types of colloids present in soil

1. Layer silicate clays
2. Iron and Aluminum oxide clays
3. Allophane and associated clays
4. Humus

(Generally 1, 2, 3 are inorganic while 4 is organic colloids)

Sources of charges on soil colloids

There are two major sources of charges on soil colloids:

1) Hydroxyls and other such functional groups on the surfaces of the colloidal particles that by releasing or accepting H^+ ions can provide either negative or positive charges.

2) The charge imbalance brought about by the isomorphous substitution in some clay structures of one cation by another of similar size but differing in charge.

Permanent charges

- **Negative charges**

A net negative charge is found in minerals where there has been an isomorphous substitution of a lower charged ion (e.g. Mg^{2+} for a higher-charged ion (e.g. Al^{3+}).

- **Positive charges**

Isomorphous substitution can also be a source of positive charges if the substituting cation has a higher charge than the ion for which it substitutes.

pH- dependent charges

- **Negative charges**

The pH-dependent charges are associated primarily with hydroxyl (OH) groups on the edges and surfaces of the inorganic and organic colloids. The OH groups are attached to iron and/or Al in the inorganic colloids (e.g. Al-OH) and to the carbon in CO groups in humus (e.g. –CO-OH). Under moderately acid conditions, there is little or no charge on these particles, but as the pH increases, the hydrogen dissociates from the colloid OH group, and negative charge result.

- **Positive charges**

Under moderate to extreme acid soil conditions, some silicate clays and Fe, Al oxides may exhibit net positive charges. The exposed OH groups are involved. In this case, however, as the soils becomes more acid, (protonation), the attachment of H^+ ion to the surface OH groups takes place.

SILICATE MINERAL CHEMISTRY

The silicate minerals are responsible for the important, physical and chemical properties of most soils. Silicate minerals characteristically contain Si, O_2 and Al.

Silicon

It makes up of 27.6% of the Earth crust, second to O_2. Si compound make up of the framework for most soils except tropical soils. It is amphoteric and usually slightly acidic, forming weak acid.

Definition of clays

Clays are the active mineral portion of soils dominantly colloidal and crystalline. The crystalline nature of clays is such that they have definite repeating arrangement of atoms which they are composed of. Majority are made of planes of O_2 atoms with Si and Al atoms holding the O_2 together by ionic bonding.

Classification of clays

Clays are usually given group names based on their structure or on purely chemical composition. There are 3 groups.

1) Silicate clays: - These are crystalline clays e.g. Montmorillonite, illite, vermiculite, kaolinite, chlorite. Each crystalline clay is like a particular deck of cards. Each card represent a layer each of which is an exact replication of each other layer.

2) Amorphous clays:- These are non-crystalline, which have silica, they are mixtures of Si and Al that have not formed well oriented crystals but sometimes have high cation or anion exchangeable capacity.

3) Sesquioxides:- These consists of groups of Fe, Al and Ti oxides clays. They are present in condition where there is excessive leaching caused by rainfall and sometimes intensive weathering of minerals in humid warm climate. They can be crystalline or armorphous.

Structures of layer silicate clay

This implies the basic building blocks of clays. All soil clays are formed from the same 2 basic structural units. It is the way these 2 basic building units are put together that gives the soil clay distinctly different properties. They are:

1) **Silica tetrahedron:-** This is a silica dominated sheet is a unit composed of one silicon atom surrounded by four oxygen atoms.

O

Si SiO_4

O O O

2) **Aluminum and/or Mg octahedron:-** In this unit, an Al or Mg is surrounded by 6 oxygen atoms or hydroxyl groups, the center of which define the apices of an 8-sided solid. .

O O O

Al or Mg Al_2O_6 or Mg_3O_6

O **O** **O**

MINERALOGICAL ORGANIZATION OF SILICATE CLAYS

On the basis of the number and arrangement of tetrahedral (silica) and octahedral (Al-Mg) sheets contained in the crystal units or layers, silicate clays are classified into two different groups, 1:1 – type minerals and 2:1 – type minerals.

1:1 type minerals

The layer of the 1:1 type minerals are made up of one tetrahedral (silica) sheet and one octahedral (alumina) sheet hence the terminology 1:1 type crystal. Kaolinite is the most prominent member of this group, others are halloysite, nacrite and dickite.

Characteristics of kaolinite

1) It has strong H-bonding

2) It does not allow water to penetrate between the layers and have almost no swelling

3) It has low cation exchangeable capacity.

4) Kaolinite exhibits less plasticity (capacity to be molded), stickiness, cohesion, shrinkage or swelling.

5) Kaolinite containing soils make good bases for road beds and building foundations.

2:1 type minerals

The crystal unit (layers) of these minerals are characterised by an octahedral sheet sandwiched between two tetrahedral sheets. Four general groups have this basic crystal structure. Two of them, smectite and vermiculite (expanding – type) and the other two fine-grained (illite) and chlorite (non expending).

Expanding minerals

- **The smectite group**

Characteristics of smectites

1) High plasticity and cohesion
2) Their marked swelling when wet and shrinkage on drying
3) Has high CEC
4) Permeability to water is low.

- **Vermiculites**, these are also 2:1 type minerals, an octahedral sheet being found between two

tetrahedral sheets. In most soil verticulites, the octahedral sheet is aluminum dominated (dioctahedral), although Mg-dominated (trioctahedral) vermiculites are also found.

- **Non-expanding minerals**

Micas and chlorites are the types of minerals in this group.

- **Muscorite and biotite** are examples of unweathered micas often found in sand and silt

separates.

Soil chlorites are basically Fe-Mg silicates with some Al present.