No Soils, No Us,

Know Soils, Know Us!

Soil, as we know, is often considered as dirt! We forget that this dirt is nothing but a mixture of minerals, liquids, gases, organic matter from life forms, and living organisms that support life on Earth. When we start exploring nature of various soils, one is always astonished to find the vast diversity in the properties and uses of soils found in India, and across the world. Sometimes, soils change over a distance of a few metres of land. This learning unit aims at getting a broad sense of the basic differences in the soils and their unique properties that contribute to any country's richest natural resource. Knowing the structural components of soils (minerals), one can start considering construction waste and decomposed matter such as sludges and composts as ways to reconstruct soils for various needs.

Rather than studying microorganisms and life forms present in the soil, this unit focus on the non-living components of soil and their significance in different usages in our lives.

Minimum time required: 4 sessions of 40 minutes

Type of Tasks: Indoor + Outdoors

Expected Learning outcomes:

At the end of this learning unit, students will be able to

1. notice that soils have diverse uses in human lives and soil uses depends on its properties.
2. realize that soils are made of different kind of particles, made of several chemical substances
3. conduct tests for some physical and chemical properties of red, lateritic, clayey and black soils viz. , carbonate, iron, content etc.
4. understand diversity in properties of their local soils through observations
5. gain local knowledge about the nearby soils through interactions with elders,
6. start rethinking different wastes (concrete debris, compost, etc) as routes to recreate soils.

Links to curriculum

NCERT Class 6 science	NCERT class 7 science	NCERT class 8 geography
Natural resources	Soil	Land, soil, water, natural vegetation and wildlife resources

Introduction

Soil is understood and used by people differently at different places. Generally when we talk about soil, we think about its fertility for growth of plants or as dirty matter lying around. However, soil (or rather different soils) play many important roles in our lives and even make our survival possible as a part of natural ecosystem. The roles different soils play in nature, in industries, and in our day-to-day lives become possible because of structures of their particles, their chemical compositions, and sometimes due to life forms that live in it.

In this Learning Unit, you will collect the types of soils that are present in your localities and study their properties. We will also try to understand which type of solid powders we call soil and which we don't.

Task 1: Soils can Change Lives and create Histories

Story 1

In year 1807, Dr. Franscis Buchmann, a surgeon in East India Company, was visiting Angadipuram in Malappuram district in Kerala. He reported a very unusual observation to the British Government. He saw a red-yellow soil about which he writes:

"What I have called the indurated (Hardened) clay..... is one of the most valuable materials for building. It is diffused in immense masses, without any appearance of stratification (layered structure or arrangement)*and is placed over the granite that forms the basis of Malayala (Kerala). It is full of cavities and pores and contains a large quantity of iron in the form of red and yellow ochres* (a clay earth pigment containing silica, aluminium and ferric oxide.)*... while excluded from air, it is so soft, that any iron instrument readily cuts it, and it is dug up in square masses with a pick-axe, and immediately cut into the shape wanted with a trowel or a large knife."*

"It, very soon after, becomes as hard as brick, and resists air and water much better than any bricks that I have seen in India..."

Image 1: Laterite blocks mined in Goa

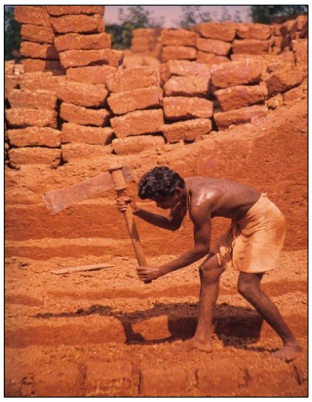

Image 2: Cutting of Laterite stones in Angadipuram, Kerala

In Kerala, this soil was known as "*chenkallu*". Dr. Buchmann called it laterite, based on the Latin Word "letritis" meaning bricks. Laterite has the peculiar property of being soft when freshly cut from below the ground level and becoming very hard as it dries. On drying, it can be used as construction material (without firing in a furnace like clay bricks) just like stones and bricks. Therefore, mining of laterite for making construction stones has been a commercial activity in such areas. Many historical building have been made using laterite blocks which have survived centuries of rains and air. On a given land, therefore, its top layers exposed to air are much harder than the wet layers below the surface.

Image 3: Pillars base made out of laterite blocks in NISER Bhubaneswar

Laterite is formed after several years of rainfall on high lands common in Karnataka, Kerala, West Maharashtra, Central Odisha and Assam and in many other parts of the world. When soluble minerals (such as sodium, calcium, and magnesium salts) dissolve in rainwater and get washed away, insoluble iron and aluminum compounds remain. The iron compounds give the soil yellow to red colour. This soil cannot hold water due to high porosity (the amount of minute spaces or holes through which liquid or air may pass). Therefore, it is not highly suitable for agriculture. Iron rich varieties of laterite are also mined as iron ore while aluminum rich varieties are mined as aluminum ore in the name of bauxite.

Each soil has different names depending upon the location. In some parts of Maharashtra laterite soil is know as Chira / Jhamba , and it is known as vettukallu in some regions of Kerala. Ask your friends or elders and try to add local names of laterite soil.

Now let us try answering a few questions:

Q1. Have you found any soil in your locality having this property of being soft when wet but becoming permanently hard on drying? The soil becomes so hard that even pouring water over it cannot make it soft again.

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This students may answer based on their experience. They may also think of clay here. But it would be important to differentiate clay from laterite, because clay become soft on becoming wet whereas laterite doesn't.

Q2. Why do you think Dr.Buchmann wrote about the laterite soil to the British Government?

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There may be variety of answers here. Students may try to recollect that East India company was trying to find material resources in India that can be traded/ sold to earn money or used to develop new kind of industries. This will help students realize that many scientific discovery become public or known to the world because of their economic importance.

Q3. Do you think the kind of soil in a region can affect the lives of people living there? Is laterite soil good for the people living there or can it create problems for them?

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Here also multiple answers are possible. It is likely that economic value of the laterite soil may make people rich. It is also possible that lack of agriculture make things problematic because there is lack of food. It is also possible due to mining, peoples' houses and forests are lost. Let students think about these. For example, mining of bauxite-rich laterite has displaced many tribes in Niyamgiri hills in

Odisha, whereas in Angadipuram, mining of laterite has become a source of income for the local residents. It also affects the groundwater level and quality of water in an area. For example in calcite rich soils, groundwater has a lot of calcium and carbonate ions which makes it hard water, whereas laterite soil have less calcium and magnesium ions. Groundwater may have some iron which precipitates as it is exposed to air.

Q4. Is it easy to make a water reservoir in an area with the laterite rich soil? Will you need some other type of soil to make canal/water reservoir?

Due to high porosity, this soil cannot hold water. So unless other type of soil is brought or surface is concretized, one cannot make a canal or a reservoir in such areas. Even in the laterite rich zone, small regions may hold water in rainy season. Humus or small deposits of fine soil carried from other regions may get deposited in localized regions and hence cause water logging in rainy seasons. However, large scale water holding becomes challenging in these regions.

Task 2: Uses of Soil in Your Locality

To help you start explore the amazing properties of soils, given below are a few questions. Discuss these questions among your friends, teachers and elders around you. You can do this task in groups of 2-3 students.

Some of you may be familiar with farming/gardening or construction activities. Some of you may not be. Given below are two sets of questions. Depending on your background, you may collect answers for any one of the two sets.

SET A (for students familiar with farming/ gardening/construction)

1) Describe the soil in your locality? (think of properties like colour, texture, smell)

2) Is the soil fertile or it needs specific fertilizers to grow plants? Which plants/crops do well in this soil?

3) Some soils allow water to pass through their pores (porosity) and some soils retain water. Have you seen any water ponds/reservoirs build in your locality without cementing of the side walls or bottom? Does this soil around the pond hold water in it for a long time?

4) Some soils become soft during rainy seasons and then shrink during dry seasons. As a result of this, soils develop cracks. Have you seen any road or building floor in your locality developing cracks after rainy season? If yes, what could be the reasons for the cracks you observed?

Here students can try to recollect if soil nearby these cracks are very hard or soft or change nature during rainy season.

5) Sometimes, the nature of soil changes over few years due to various reasons like agriculture, deforestation, industrialization etc. Do you find any changes in the nature of soil in your locality over years? Is the soil known to be polluted due to any sources of pollution nearby?

Students may have observed colour of soil changing, it becoming softer, stickier, or harder. Students may also add here plastic pieces becoming a part of soil, or other kind of wastes being dumped in soil which mix up with soil. For example industrial slags, construction waste, fly ash may be alkaline and make soil harder, and lot of organic matter may make soil softer or slippery. In case if the students are not able to comment, encourage them to discuss with their elders about the changes in soil over few years.

6) At many places, colored soils called geru, khadiya, chuna, or powdered rocks are used for painting houses or pottery or making rangoli. Is the soil in your locality used for making any kind of colors or pigments?

7) At many places, soils are used to make water filters. Have you seen water filters made out of soil in your locality?

Students may have seen sand filter pots for household water filtration or may also have seen sand filters in water treatment plants for municipal water supply.

SET B (for students NOT familiar with farming/gardening/construction)

Suppose you are given different samples of soils such as clay (for example shadu mati), sand, red soil, black soil, etc. These soils have different properties such as water holding capacity, chemical nature, stickiness, particle size, porosity. Considering these properties, collect answers for following questions.

1) If you want to set up a large garden for growing fruits and vegetables, what type of soil will you prefer? What different properties of soil will you consider?

2) You have to make a *diya* or small pot using any of these soils. Which soil will you use and why?

For making clay lamps and pots, one needs clay, which has very fine particles, is sticky, had no hard stones while wet, and on drying can retain shape given when it was wet. For example there are silts found near river banks which have very small particles, are very soft when wet, but on drying it again becomes very powdery. Thus silts cannot be used for making lamps or pots.

3) We sometimes hear of structures like tunnels collapsing down, occurrences of landslides due to multiple reasons such as heavy rainfall, deforestation in the nearby places, etc. Do you think nature of soil underneath and around also plays a role in it? In what ways?

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Soils such as clays or black soil softer or swell when wet. Such soils swell during monsoon and contract during non-monsoon. This expansion and contraction of soils often causes a lot of damage to civil structures.

4) At many places, sand and clay are mined for construction industries, or soils are dug out for extracting metals or other elements such as silicon. Is any soil in your vicinity used for extracting any metals or materials for industry?

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Common examples seen in India could be clay mining for bricks, or mining of minerals such as bauxite (aluminium ore) or haematite (iron ore) for metal extraction or silica mining for electronics.

5) Are there borewells or handpumps in your home or neighborhood? Is the water from these borewells or handpumps potable (drinkable)? If yes, what makes this water so clean?

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Usually water in borewells or handpumps is potable because it is filtered through thick beds of underground soil. In some places, however, students may report bad quality water coming from handpumps or borewells, because of contamination in soils or aquifers.

Task 3: Collecting soil samples

Materials required: 4 paper bags/beakers/ any other containers, thermometer, shovel or soil digging tool

Collect soil samples from 2 sites in the school campus. Soil from garden, roadside, open ground, banks of a pond, etc, can be collected.

From each site, collect two samples of soil.

- One just from the surface. Label it as surface soil.
- Other one by digging a pit of 1-2 ft deep (using a small shovel). Label it as sub-surface soil.

Using a thermometer, check the temperature difference in surface and subsurface soil at the same spot.

It may be discussed that the thermometer would normally show the temperature of the room air or of the object that is in contact with its bulb and thus will not reach a reading of 0°C, unless you put it in ice. You may also need to show students how to read temperature in a thermometer.

Soil		Temperature
S1	Surface soil	
	Sub-surface soil	
S2	Surface soil	
	Sub-surface soil	

Q1. Did you find any difference in temperature of soils at surface and sub-surface, and at different locations? Explain your observation.

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Depending upon the time of temperature measurement whether it is in early day time, afternoon or evening, the temperature of the surface and sub-surface soil can change.

Q2. Did you find any other difference in the surface and sub-surface soil?

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Difference in colour variation and presence of organisms in surface and sub-surface soil can be discussed here.

Task 4: Let us observe the collected soils

Let's try to understand that there is variation in soil at different locations and with also with depths.

Material needed: Scale, hand lens, and if available a compound microscope with glass slides.
First try to observe and understand the physical characteristics of soil particles. Fill your observations in the observation table below.
I. Soil colour (with naked eye): Colour of the soil depends on how much organic matter is present and the kind of minerals it contains. Look at the soil samples and see if it is red, black, or grey. Is it same colour in both dry and wet forms?

Soil Colour	**What it may be telling**
Red	Presence of iron
White	Presence of calcium carbonate
Black/grey (Dry)	Presence of Humus
Black Wet	Saturated with water

II. Soil Texture (with dry soil): Take some dry soil in your hand and rub the particles between your

fingers. Do you feel soil particles hard/ soft and if they are breaking easily? Are there pebbles in soil?

III. Observation under lens: Take a pinch of dry soil on a piece of paper, observe under a hand lens. Note colours of soil particles, presence of biological matter (decaying plants, leaves, insects), and anything else that you see. Even transparent glass marbles can be used as a lens to observe the soil particles.

IV. Soil Texture (with wet soil): Take a handful of wetted soil on your hand. Rub the particles between your fingers. Do you feel particles as hard, slippery but non-sticky, or very soft and sticky?

Observation Table

Soil	Visual Characteristics (colour, texture, presence of plants/insects matter)					
		Color (with naked eye)	Presence of plants/insects	Texture of dry soil (hard/ soft, sticky/non-sticky, presence of pebbles ...)	Texture of wet soil (hard, slippery but non-sticky / very soft and sticky..)	Particles seen under lens (transparent / coloured)
S1	Surface soil					
	Sub-surface soil					
S2	Surface soil					
	Sub-surface soil					
S3	Surface soil					
	Sub-surface soil					

Note: Use the same soil samples in the same sequence for Task 5.

Based on size, soil particles are classified as gravels, sand, silt and clay. This particle size distribution affects the physical characteristics of soils.

Sr. No	Soil Texture	Presence of Sand, Silt, Clay	Particle size
1	Rough to touch	Soil is sandy	Larger particle (visible to naked eye)
2	Smooth or floury	Silt is present	Medium particle size (particle visible to naked eye on keen observation)
3	Feels sticky	Clay is present	Smaller particle size (particles not visible by naked eye)

At many places which have undergone construction, soils are transported from some other place and added to that place. It may be true for most schools. Thus the soil student observe may have mixed characteristics of local soil and soil brought from other place.

V. Microscopic observation: If possible, observe soil particles under a microscope. For this take a pinch of wet soil and smear it on glass slide, cover with cover slip and put it under a 10X lens. What do you observe? Do you see particle of same colour as you saw with naked eye or of different colours? and size or do you also see transparent or crystalline particles?

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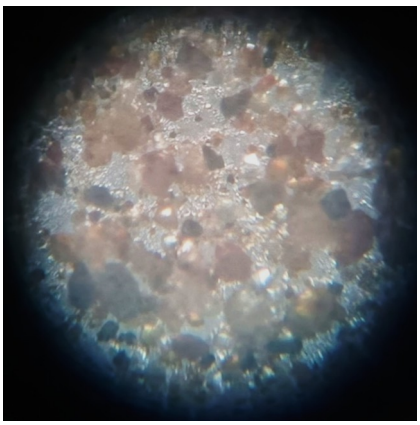

Image 4: Photo of a soil sample observed under an compound microscope (under 10X objective; 100X magnification)

If looked under high resolution micrsocopes such as Scanning Electron microscopes, the particles of soils show diverse structures. Some types of soil particles also are further made up of very fine crystals.

VI. Soil Shrinkage: Wet the soil and make a ball or ped out of it .Measure its width using a scale. Allow it to dry for one day. Next day measure if the width is same on drying or has decreased or increased.

Record the observations for different samples in the table below. You can check the samples collected by your friends and add it in S2 and S3.

Soil		Ball, block /Ped size initially	Ball, block/Ped size after 1 day
S1	Surface soil		
	Sub-surface soil		
S2	Surface soil		
	Sub-surface soil		
S3	Surface soil		
	Sub-surface soil		

Q1. Does the ball or ped change in size? For road or building which are build on this soil, do you see any effects during or after rain.

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Clogging in soils (as optional task)

Materials needed: Funnel, filter paper, tap water, spatula or spoon

1.Prepare soil slurry by adding 20 ml of water in 10 g of soil sample. Set a filter paper in a funnel kept over a beaker/test tube. Pour soil slurry into the funnel. Is water passing easily through the soil? Determine how many ml of water passes through the funnel per minute. Here, let students find relative drainage rates. No need to actually calculate the rate of percolation using formula.

2.Add more water gently over the funnel and measure the rate again. Does it decrease? Is there any difference in the rate with change in soil samples? Does percolation stop after some time? This will indicate clogging properties of soil. Does addition of small plastic pieces in soil lead to faster clogging or lower percolation rates.

(Generally, if puddles form very fast, that means water does not pass through very easily. Hence the porosity of soil is very low. If puddles don't form even after a lot of rain, then the porosity of soils is high).

Q2. Have you seen such a soil or pictures of dry land with big cracks in it? Where?

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Image 5: Dry land with cracks

Students may have seen such picture in TV, newspaper, internet or in real life. Let them write whatever they want. You can try to recollect if any road or building cracked or sunk with the cycles of summers and winter. The soils which are highly rich in carbonates, such as those found in the foothills of Himalayas also, show shrinkage over years due to dissolution of carbonate minerals. This phenomenon is different from swelling and shrinkage of black soils.

Now a memory game... Try to remember:
In summers, does the soil in your school area crack? Yes ☐ No ☐
In monsoon, do puddles form within few minutes of rain or after a lot of rain?
Does it tell anything about soil porosity?

Task 5: Some chemical properties of soil

Materials required: litmus paper or turmeric paper, bar magnet, lemon juice or vinegar, few beakers (100 mL), watch glass, dilute HCl and dil NaOH solutions (for optional tasks)

I. Soil Acidity/Basicity: Take 10 g (or two spoonful) of soil in a beaker and add about 20 mL (or one test tube) of water. Stirring it will produce a soil slurry. Use a litmus paper to check if it is acidic or basic.

II. Iron content in the soil: Take a handful of dry soil and stir a bar magnet in it. Do you find particles sticking to the bar magnet? Particles being attracted to magnet are indication of iron or iron oxides being present in the soil.

III. Carbonate content: Now take a spoonful of soil in a watch glass or beaker and add few drops of lemon juice or vinegar. Is there any effervescence (evolution of a gas in form of tiny bubbles)? In most cases, effervescence indicates presence of carbonate minerals in the soil and the gas evolved is carbon dioxide.

Soil + Vinegar $\longrightarrow$ Carbon dioxide (effervescence)

The purpose of above tests is only qualitiative identification (presence/absence) of come common species in soil. It may help students to recognize soil containing (or composed of) mineral salts. Quantitative determination is not expected here.

If possible, following tests may also be conducted by students under supervision of teachers.

Aluminium in soil**:** Take 10 g of soil in a beaker. Add 25 mL of commercial vinegar, and let it soak for a day. Next day decant the supernatant in another beaker and add few mL of dilute solution of sodium hydroxide. Formation of gelatinous precipitate which dissolves in excess NaOH indicates the presence of aluminium and/or zinc in the soil, which is soluble in acetic acid/vinegar. To compare, take 25 mL of commercial vinegar, and add sodium hydroxide and see if similar turbidity is observed here also.

Iron in soil: Take 10 g of soil in a beaker. Add 25 mL of dilute hydrochloric acid, and let it soak for 10-15 min. Decant off the supernatant and add solution of sodium hydroxide. Formation of red-brown precipitate indicates the presence of iron in soil, which dissolves in the hydrochloric acid. To compare, take 25 mL of dilute HCl, and add sodium hydroxide. In this, no red precipitate would be seen.

Soil		Acidic/Basic	Carbonates (present/ absent)	Iron (present/ absent)
S1	Surface soil			
	Sub-surface soil			
S2	Surface soil			
	Sub-surface soil			
S3	Surface soil			
	Sub-surface soil			

Q1. When we throw acidic substances in soil, what all changes these may make to the soil?

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About your soil samples:

Since now you have observed the colour, texture, porosity, and recollected its behaviour in rains/summers, can you find from your teachers/parents/elder living in your area in your school is:

a. Laterite b. Red Soil c. Black Soil d. Alluvial soil e. Any other type_____

Soil deposited by the rivers during the 2018 floods in Kerala was acidic in nature and it needed to be treated with laterite or loamy soil before agriculture use.

Revisit task 2 to prompt students to think about the connection between soil properties **(**water holding capacity, chemical nature, stickiness, particle size, porosity) and the application of soil in different areas.

Task 6: Story 2: Diversity in natural soils over short distances.

In the year 2014, Dr. Pradeep Sarkar, an earth scientist from Pune and his friends were walking in the small hills of *Belhe* and *Alkuti* villages of Ahmednagar- Pune region (Maharashtra). They noticed huge black rocks (called Basalt rocks formed from cooled volcanic lava in past) which had crystals in them. Some of the large crystals were white to cream colored, and some of the smaller crystals were brownish in color. The brown colouration they thought could be caused by action of water, soil

minerals or living organisms on the white crystals. Surrounding rocks had a different cluster of green coloured minerals. Some of the green minerals were opaque and some beautifully crystallized, in the cavities of the main rocks.

Within ~5 km of that area, they also found layers of red and green colored clayey rocks showing angular and blocky structures (common in black basalt rocks). This was surprising because that region is made of igneous rocks (black basalt). Such layer of red and green soil could not come from physical breaking of the basalt rocks. One of the fellows told *"This red patch (known as Red bole) could be because of chemical weathering of the basalt rocks leaving behind iron and magnesium rich minerals (Fe_2O_3 and MgO)"*. Dr. Sarkar further explained that these layers of red boles (boles are weathered rocks formed from basalts) have commonly been seen in the Deccan Plateau of southern India.

Image 6: Photo showing layer of red bole marking the base of basalt

		
Quartz crystals (Amethyst) found in the cavities of basalt	*Zeolite mineral found in the cavities of basalt*	*Banded agate found as nodules in volcanic rocks*

Image 7 : Different types of crystals

Q1. Do you find such color variations and crystals in the rocks and soils in your surroundings?

Q2. How the colour of crystals affects the color of the soil and its properties in the area?

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The mineral crystals are formed under high temperatures and pressures thus giving them the form. When these minerals undergo weathering, there is a change in the chemical content of the minerals, further leading to change in the rock color.

Task 7: Gold standards for Soil

While looking around, we also observe the following substances which sometime look like soil.

a. Dust (which settles from air or wind and is collected after brooming home or roads)

b. Compost (decomposed food or biological waste which is brown in colour)

c. Construction waste (broken concrete, bricks, mortar, as powder or as big chunks)

d. Sludges (black brown solid that are removed from drains, ponds, sewers, or industrial plants and are heaped by roadside to dry)

Q1. Which of the above substance you can call soil?

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Q2. If you need to test if the given material is a soil which tests will you conduct with the soil sample? Explain your reason for choosing those tests

- test its texture, porosity and shrinkage
- Chemically tests for iron, carbonates, or acidity/basicity.
- Taking the sample on a glass slide and observe it under microscope
- other tests_____

Q3. If you want to use the above as soils (or mixtures for soils) for following uses, what kind of modifications/processing is needed in the soil?

(a) gardening

(b) construction materials

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For construction, usually hardness and binding ability is desired. If the materials is soft (like compost or sludge), then hard material such as concrete mortar, or grits can be added. Addition of lime or clay as binding agent also helps.

For agricultural purpose, compost and sludges have nutrients but sometimes don't have sufficient hardness to support plants. These can be mixed with construction waste after powdering or sieving to prepare soils for cultivation. Also, sludges and composts if not stabilized can be acidic. Concrete is usually alkaline in nature. Thus, mixing these may also change their acid-base properties.

Land and soil reclamation is a challenge and need for many places which are left abandoned from a mine or industry, which closed down in a region. It is also likely to be a growing area in future for sustainable growth.

Q4. Based on learning from tasks above, describe soil in your locality and for what purposes you can use soil in your locality.

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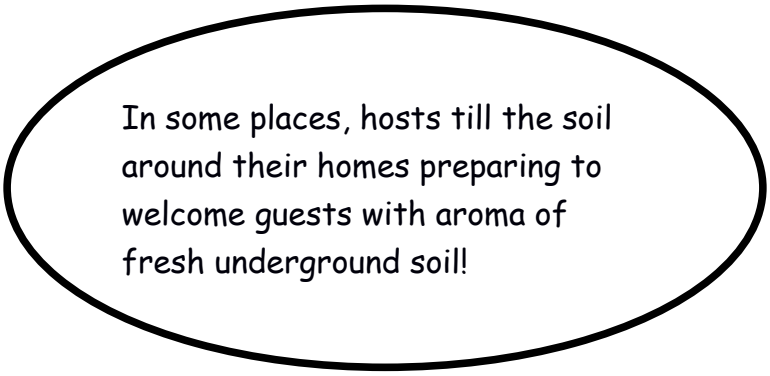

Task 8: Soil of a different place (Optional)

As we have seen above, soils have different properties and affect the local environment in different manners:

1) Water holding capacity affects the nature of plants and animal that can stay around.
2) Porosity affects how water flows over and through it (important during rains and other times for drainage).
3) Hardness and swelling behavior affects the strength of building and structures over it.
4) Soil type of a locality may change drastically over very short distances as well as with depth.

With this background, try exploring the soils in and around your school.

Repeat Task 1 (part 2 and 3) with soil around your home or another area about 1-2 km away from your school.

Try to find out if any location nearby has been dug or there is an exposed profile of soil (near roadside construction it may be easier to find). Do you see different layers of soil? Collect samples of soils from the different layers and repeat the above. if there is a hilly area near your school, try comparing soils at the top and bottom of hills.

Q1. Do you see variations in soils? What kind of differences did you observed in different soils in your surrounding?

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(In general, variation in soils are observed over few kilometer or sometimes on two sides of road. The idea of variation in soil may be linked to diversity of vegetation/ plants or animals or other organisms

or human activities like construction of buildings or roads)

Also try to find if the soil is natural soil of that area or has been brought and added to that region from somewhere else (For example, old broken construction material is dumped at many sites and in some places fertile soil is brought and added for growing some plants (transported top soil).

Suggested Extention: Make a Chart

Students can make a chart highlighting their findings about the soil in and around your school as discovered in this learning unit.

References:

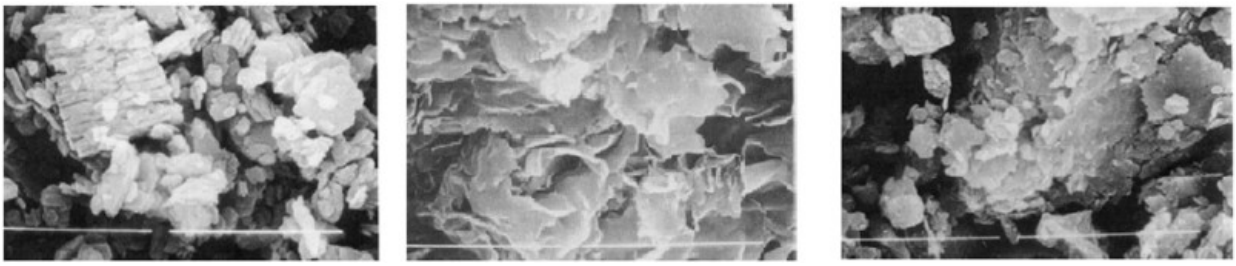
1. Buchannan F (1807). A journey from Madras through the countries of Mysore, Canara, and Malabar. East India Co., London, 2, pp. 440-441.
2. Sarkar P. et al (2016). Petrography of Megaporphyritic Lava Flow from Belhe-Alkuti area, Ahmednagar district, Maharahtra, India, JGSR vol. 1,no2, pp.105-110.

Image sources :

1. Image 1- Directorate of Mines and Geology, Goa, www.dmggoa.goa.gov.in/laterite.php)
2. Image 2 -https://in.pinterest.com/pin/552535448038143916/
3. Image 4- Courtesy: C G Sathish (HBCSE)

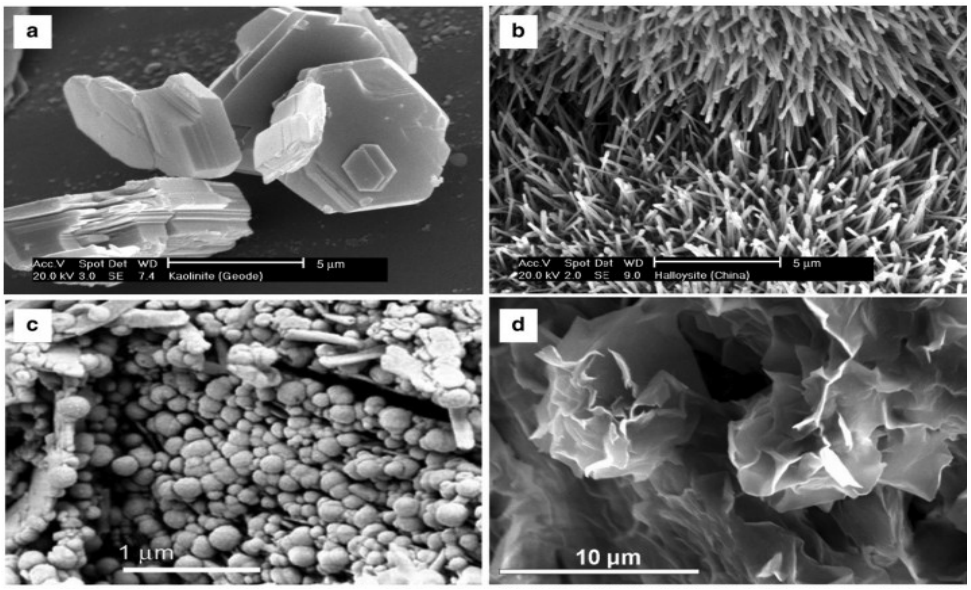
APPENDIX A

When clays are observed at 1 µm scale, we can see that all particles have platy structures. Depended upon how the clay formed in a particular region, the clay particles or plates may look like very straight sheets, irregular flakes, folded sheets, flattened wires, fibers or even tubes. However, in all these structures, the particles have large surface areas, which make clay minerals their unique properties like high retention capacity of water or other molecules.

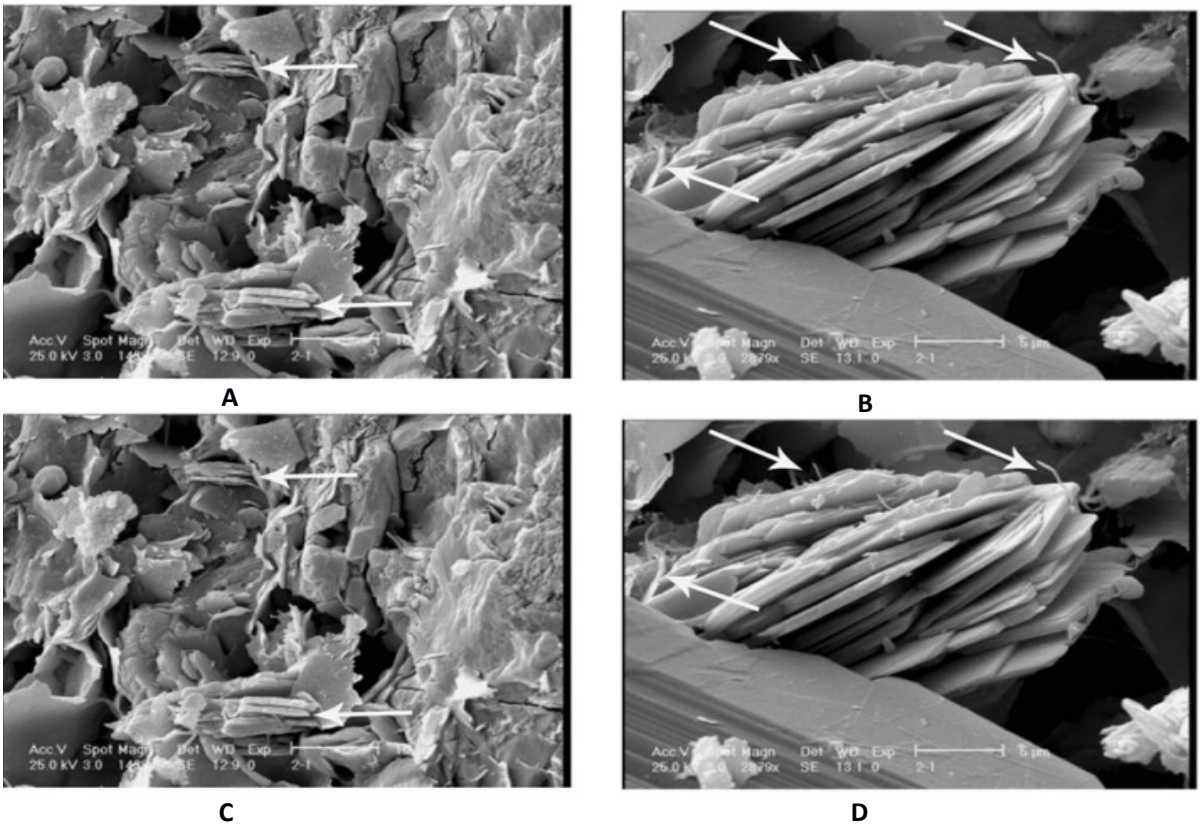


(a) (b) (c)

1. Electron microscope image of different types of clays. (a) Kaolinite, (b) montmorillonite, (c) Illite (length of the distance between the white lines 0.5 µm)



2. Electron microscope images of clay minerals: (a) pseudohexagonal crystals of kaolinite; (b) tubular crystals of halloysite; (c) spheroidal crystals of halloysite; (d) wavy subhedral montmorillonite crystals (from Fesharaki et al., 2007)



3. SEM images showing: (A) Altered feldspar among quartz grains, (B) Growth of vermicular kaolinite (the arrows)within an altered feldspar (Q: quartz), (C) incipient growth of dickite crystals (arrows), (D) incipient growth of illite crystals (arrows) on kaolinite.

References:

1. Ural, Nazile (2021). "The significance of scanning electron microscopy (SEM) analysis on the microstructure of improved clay: An overview" Open Geosciences, vol. 13, no. 1 p. 197-218.

2. Christidis, G.E. (2011).Industrial clays, European Mineralogical Union Notes in Mineralogy, Volume 9, Chapter 9, p. 341–414.

3. Zamanzadeh, Mohammad,Amini, Abdolhossein, Ghavidel-syooki, Mohammad(2009). Sequence stratigraphic controls on early-diagenetic carbonate cementation of shallow marine clastic sediments (the Devonian Zakeen Formation, southern Zagros, Iran), Geosciences Journal Vol. 13, No. 1, p. 31 − 57.

APPENDIX B: Images used in the Learning Unit

Image 1 : Laterite blocks mined in Goa

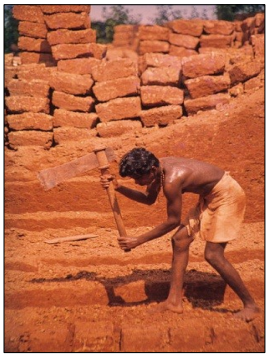


Image 2: Cutting of Laterite stones in Angadipuram, Kerala

Image 3: Pillar base made out of laterite blocks in NISER Bhubaneswar

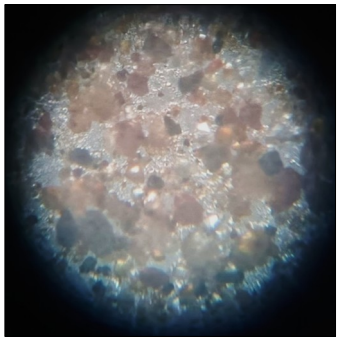
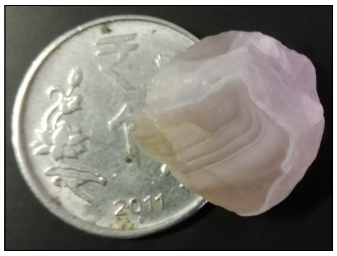


Image 4: Photo of a soil sample observed under an compound microscope (under 10X objective; 100X magnification)

Image 5: Dry land with cracks



Quartz crystals (Amethyst) found in the cavities of basalt

Zeolite mineral found in the cavities of basalt

Image 6: Photo showing layer of red bole marking the base of basalt

Banded agate found as nodules in volcanic rocks

Image 7: Different type of crystals