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# Forensic characterization of soil from different areas of India and Bhutan

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## Abstract

*Soil is considered as one of important forensic evidence as it differs from region to region. The differences in the soil can be in terms of physical appearance such as color, texture, size of soil particle, the pH, density of soil and many more. Also the soil of a particular location has unique characters because of the vegetation of that area, used pesticides and even the soil on road sides can also varies due to presence of pollutants, blood and many others things because of road accidents and it serves as corroborative evidence is various cases specially to link primary crime scene with secondary crime scene. In present study, a research has been conducted to check the range of variations in the soil collected from different areas of India and Bhutan by physical examination, pH analysis and density gradient method.*

**Keywords:** Soil, pH, soil texture, density gradient method, stereomicroscope.

## Introduction

Forensic pedology is a branch of forensic science which involves use of geological science to solve a case[1]. Forensic soil analysis involves the examination of soil samples by various scientific methods to solve or aid in criminal investigations. It can be used as an identification marker due to its unique features or characteristics. The sediments of soil are developed due to chemical and physical alterations. For instance, the chemical alterations can be amount of pollutants such as from fuel, the amount of minerals present in soil and physical alteration can be pollens, blood etc. that varies from place to place. It can be used to obtain useful information about the nature of ground surface of the crime scene if found to be adhered to the belongings of the suspect or victim and can link the scene of crime[2]. The huge diversity of soil is due to differences in the soil formation process which in turn depends on the type of parent material, topography, climate, the flora and fauna, the watering conditions, presence of fossils, spores and pollens and even the artificial materials found there including human activities[3] which forms the basis of its uniqueness. So, organic anthropogenic substances along with plant wax which are present in soil are served as fingerprinting markers of soil of a particular location[4]. Mostly criminals are aware about DNA, finger marks and other evidences but they have very less knowledge about soil as an identifier[5]. Therefore it can serve as crucial evidence in most of cases. In a reported case soil was analyzed collected from cast of a footprint[6].

Beside physical examination of soil samples, a number of instrumental techniques like hydrometery, cation exchange capacity (CEC), X-RAY diffractometry, optical density of oxalate extract (ODOE), SEM-EDS[7] are utilized to know the various properties of soil. Density gradient technique had also been used for forensic analysis of soil[8]. However, forensic soil examination is quite difficult due to limited sample size and very less work on forensic analysis of soil samples has been reported in literature. In present study, an attempt has been made for physical examination of soil collected from different locations of India and Bhutan has been carried out by microscopic techniques and density gradient method.

## Materials and methods

**Sample collection:** Thirty six (36) samples were collected from road side using spatula and stored in airtight plastic containers separately to avoid contamination.

**Physical Examination of soil:** All the samples were observed under compound microscope at 10X and 40X. Similarly samples also had been observed under stereo-microscope at 2.5X and 4X using medium light to get bright field as well as dark field reflection so that other microscopic particles or objects present in soil can also be observed[9].

**pH testing:** 2gm of each sample was separately dissolved in 5ml of distilled water to measure pH.

**Density Gradient method:** Density gradient is the technique in which two different chemicals having opposite densities are used and different layers are made by taking different ratios of chemicals and gradients of density[10]. The particle of sample added moves through the medium of different density gradients of chemicals and get suspended at the point where density of particles becomes equal to the surrounding medium[11]. Below given formula can be applied to check the density of a particle -

$$x = \frac{D_1V_1+D_2V_2}{V_1+V_2}$$

x = Density of layers made by mixing chemicals of different densities, $D_1$= Density of chemical A, $D_2$= Density of chemical B, $V_1$= Quantity of chemical A, $V_2$= Quantity of chemical B, A and B are the chemicals having opposite densities.

**Table-1:** Sample description collected from different locations including temperature of location during collection.

| County | State | District | Sample No. | Locations | Temperature ($^0$C) |
|---|---|---|---|---|---|
| India | Punjab | Kapurthala | 1 | Chaheru | 16 |
| | | | 2 | Kapurthala main city | 19 |
| | | | 3 | Jagjeetpur | 14 |
| | | | 4 | Phagwara | 17 |
| | | | 5 | Darvesh Pind | 14 |
| | | Jalandhar | 6 | Rama Mandi | 18 |
| | | | 7 | Jalandhar main city | 18 |
| | | | 8 | Goraya | 18 |
| | | | 9 | Phillaur | 16 |
| | | | 10 | Ashahoor | 7 |
| | Haryana | Gurugram | 11 | Gurugram | 21 |
| | | New Delhi | 12 | New Delhi | 20 |
| | Rajasthan | Bundi | 13 | Bundi | 23 |
| | | Sawai Madupur | 14 | SawaiMadupur | 25 |
| | | | 15 | Ranthambore | 23 |
| | | Kota | 16 | Landmark city | 24 |
| | | | 17 | Aerodram Circle | 23 |
| | | | 18 | Dadabari | 23 |
| | | | 19 | Gumanpur | 22 |
| | West Bengal | Kolkata | 20 | Victoria memorial | 25 |
| | | | 21 | Ecopark Kolkata | 23 |
| | Meghalaya | East Khasi Hills | 22 | Mylliem | 23 |
| | | | 23 | Umtyngar | 21 |
| | | | 24 | Laimer | 18 |
| | | | 25 | Langkyrding | 28 |
| | | | 26 | Lumshyiap | 28 |
| | Nagaland | Wokha | 27 | Dimapur | 23 |
| | | | 28 | Kohima | 27 |
| | | | 29 | Mesephema | 29 |
| | | | 30 | Chumukedima | 29 |
| Bhutan | -- | Dzongkhag | 31 | Thimphu | 5 |
| | | | 32 | Kinga | 12 |
| | | | 33 | Motithang | 14 |
| | | Punakha | 34 | Kabisa | 12 |
| | | Paro | 35 | Paro | 15 |
| | | Chukha | 36 | Chukha | 8 |

Bromoform (more denser) and Bromobenzene (less denser) chemicals were used to make gradients in borosilicate glass measuring tube (25ml). Following ratio of solvents have been used for layer formation:

**Table-2:** Ratio of Solvents Used to Form Layers

| Layers | Bromoform (ml) | Bromobenzene (ml) |
|---|---|---|
| 1. | 4 | 1 |
| 2. | 3 | 2 |
| 3. | 2 | 3 |
| 4. | 1 | 4 |

So the densities of different layers were calculated by applying above mentioned formula as follow-

$$\text{Density of layers}(x) = \frac{D_1V_1+D_2V_2}{V_1+V_2}$$

Density of Bromoform ($D_1$) = 2.89g/cm$^3$

Density of Bromobenzene ($D_2$) = 1.52g/cm$^3$

Density of Layer 1:
Density of Bromoform ($V_1$) = 4ml
Density of Bromobenzene ($V_2$) = 1ml
$x_1$ = (2.89X4)+(1.52X1)
4+1
$x_1$ =2.616g/cm$^3$

Density of Layer 2:
Density of Bromoform ($V_1$) = 3ml
Density of Bromobenzene ($V_2$) = 2ml
$x_2$ = (2.89X3)+(1.52X2)
3+2
$x_2$ = 2.342g/cm$^3$

Density of Layer 3:
Density of Bromoform ($V_1$) = 2ml
Density of Bromobenzene ($V_2$) = 3ml
$x_3$ = (2.89X2)+(1.52X3)
2+3
$x_3$ = 2.08g/cm$^3$

Density of Layer 4:
Density of Bromoform ($V_1$) = 1ml
Density of Bromobenzene ($V_2$) = 4ml
$x_4$ = (2.89X1)+(1.52X4)
1+4
$x_4$= 1.794g/cm$^3$

So x1, x2, x3 and x4 were the densities of layers made by using different ratios of Bromoform and Bromobenzene and the soil particle were separated according to their densities. The density of these layer, is maximum in the lowest layer or layer1 i.e. 2.616g/cm$^3$ and minimum in the layer 4 or the uppermost layer i.e. 1.794g/cm$^3$.

## Result and discussion

**Physical examination of soil:** Indian soil is alluvial in nature and of light brown in color whereas Bhutan soil is mostly dark brown and it is a dry soil made by landslide. When soil was compared intra state wise of India it has been found that there is big differences in soil color like blackish brown brownish red brown respectively collected from Punjab Meghalaya and Rajasthan. When soil collected from various regions of India and Bhutan was compared then Indian soil has been found to be alluvial in nature and of light brown color whereas soil samples collected from different areas of Bhutan found to be dark brownish color and dry soil made by landslide. The soil color varies due to the color of rocks from which these are made, due to pollutants and so on.

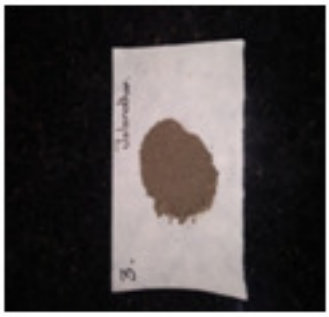

**Figure-1:** Sample 7.

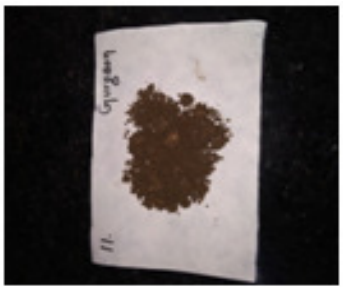

**Figure-2:** Sample 11.

**Figure-3:** Sample 27.

**Figure-4:** Sample 22.

**Figure-5:** Sample 31.

**Figure-6:** Sample 13.

**Figure-7:** Sample 20.

**Table-3:** Physical Examination (colour and soil Type) of collected samples

| Sample No. | Location | Colour | Type of Soil |
|---|---|---|---|
| 1 | Chaheru | Dark Brown | Loamy |
| 2 | Kapurthala | Dark Brown | Loamy |
| 3 | Jagjeetpur | Brown | Sandy loamy |
| 4 | Phagwara | Dark Brown | loamy |
| 5 | Darvesh Pind | Light Brown | Loamy |
| 6 | Rama Mandi | Light brown | Loamy |
| 7 | Jalandhar | Brown | Sandy Loamy |
| 8 | Goraya | Brown | Sandy Loamy |
| 9 | Phillaur | Brown | Loamy |
| 10 | Ashahoor | Brown | Loamy |
| 11 | Gurugram | Black | Sandy Loamy |
| 12 | New Delhi | brown | Sandy Loamy |
| 13 | Bundi | Brown | Clay Loam |
| 14 | Sawai Madupur | Blackish Brown | Sandy Clay loamy |
| 15 | Ranthambore | Deep Brown | Clay Loam |
| 16 | Landmark city | Deep Blackish Brown | Sandy Loamy |
| 17 | Aerodram Circle | Light Brown | Sandy Clay Loamy |
| 18 | Dadabari | Brownish | Sandy Loamy |
| 19 | Gumanpur | Brown | Loamy |
| 20 | Victoria memorial | Light Brown | Alluvial |
| 21 | Ecopark Kolkata | Light Brown | Alluvial |
| 22 | Mylliem | Light Brown | Sandy Loamy |
| 23 | Umtyngar | Deep Reddish Brown | Sandy Loamy |
| 24 | Laimer | Reddish Brown | Sandy Clay |
| 25 | Langkyrding | Deep Reddish | Loamy Silt |
| 26 | Lumshyiap | Deep Brownish | Sandy Loamy |

| | | | |
|---|---|---|---|
| 27 | Dimapur | Reddish Brown | Clay Loamy |
| 28 | Kohima | Deep Reddish Brown | Sandy Clay Loam |
| 29 | Mesephema | Brownish Red | Sandy Loamy |
| 30 | Chumukedima | Deep Reddish Brown | Sandy Loamy |
| 31 | Thimphu | Dark Blackish Brown | Loamy |
| 32 | Kinga | Brownish Red | Clay loam |
| 33 | Motithang | Balckish | Sandy Loamy |
| 34 | Kabisa | Reddish brown | Clay Loam |
| 35 | Paro | brown | Red Loamy |
| 36 | Chukha | Dark Brown | loamy |

**Microscopic Analysis: Analysis by Compound Microscopy:** All the samples were analyzed at 10X and 40X and huge differences were found in microscopic feature. Such as the formation like clouds, the appearance like globe, stones are also seen and many more differences like microscopic animals were seen in the microscopic examination of soil.

Stereomicroscopic analysis of soil has also been performed and difference in soil was analysed. Present study also indicates that Indian soil is mostly alluvial soil and Bhutan soil is mostly Dry soil, which is made by several landslides in foothills and many other regions.

Whereas stereomicroscopic examination soil collected from different regions of Bhutan showed crystal like appearance due to presence of big chunks in it

**pH:** The soil samples collected from different location showed variation in pH.

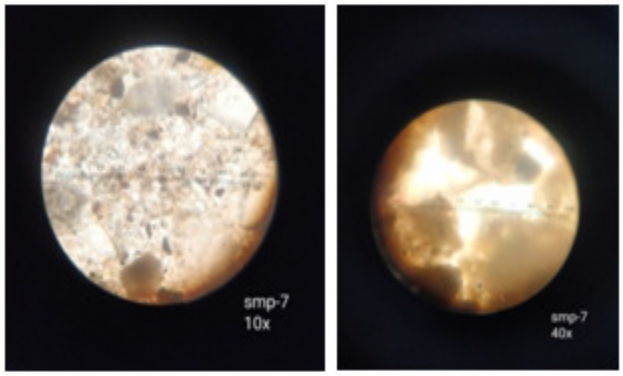


**Figure-8:** Sample 7.

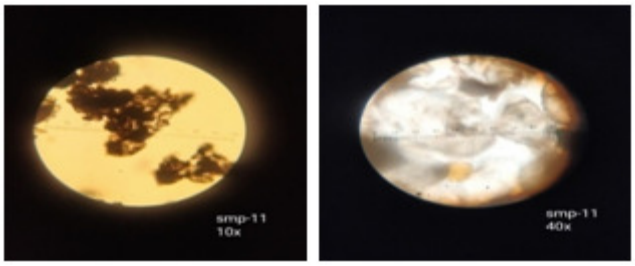


**Figure-9:** Sample 11.

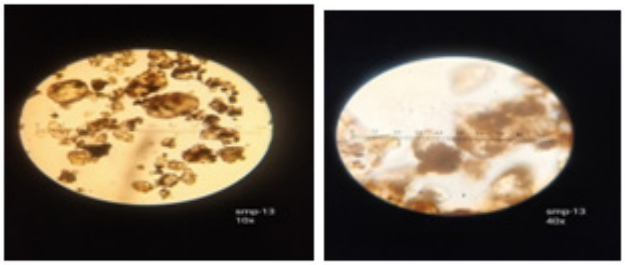

**Figure-10:** Sample 13.

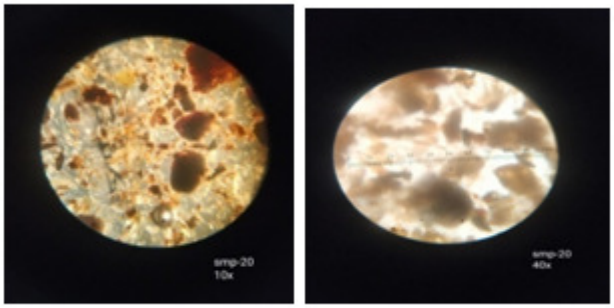


**Figure-11:** Sample 20.

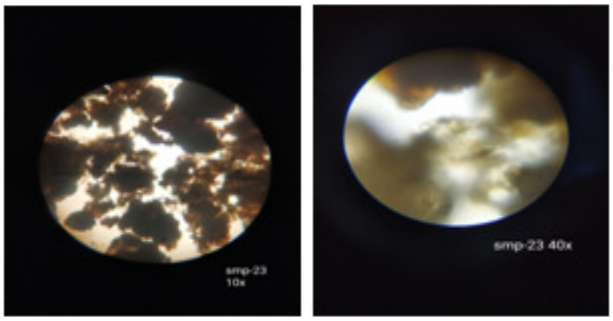


**Figure-12:** Sample 23.

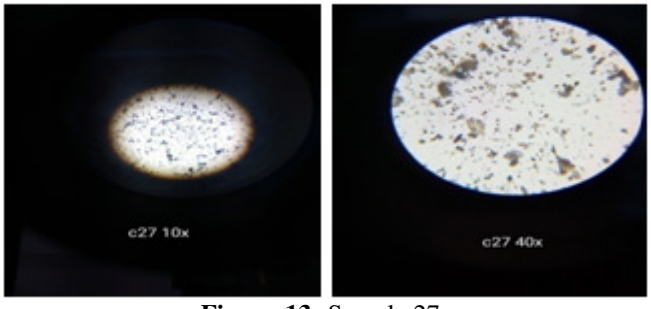


**Figure-13:** Sample 27.

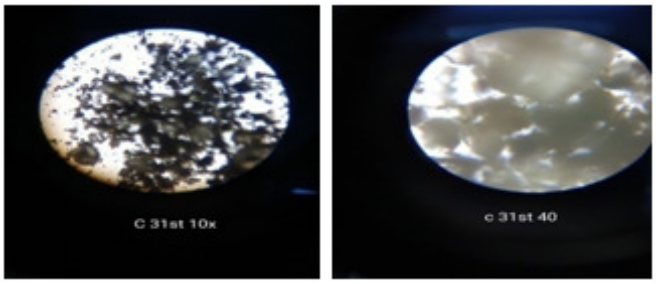


**Figure-14:** Sample 31.

**Table-4:** Shows pH of collected soil samples

| Location | pH |
|---|---|
| Chaheru | 7.96 |
| Rama Mandi | 7.80 |
| Jalandhar Bus Stand | 7.81 |
| Kapurthala Bus Stand | 7.89 |
| DarveshPind | 7.85 |
| Jagjeetpur | 7.86 |
| Phagwara | 7.77 |
| Guraya | 7.63 |
| Phillaur | 7.72 |
| Ashahoor | 7.99 |
| Gurgaon | 6.69 |
| New Delhi | 6.76 |
| Bundi | 7.11 |
| SawaiMadupur | 6.87 |
| Ranthambore | 6.88 |
| Landmark City | 7.76 |
| Aerodram Circle | 7.71 |
| Dadabari | 7.65 |
| Gumanpur | 7.50 |
| Victoria Memorial | 8.13 |
| Ecopark Kolkata | 8.05 |
| Mylleim | 6.80 |
| Umtyngar | 6.40 |
| laimer | 6.69 |
| Langkyrding | 8.00 |
| Lumshyiap | 7.74 |
| Dimapur | 6.22 |
| Kohima | 7.40 |
| Mesephema | 6.49 |
| Chumukidema | 6.86 |
| Timphu | 6.54 |
| Kinga | 7.92 |
| Motithang | 7.90 |
| Kabisa | 7.28 |
| Paro | 6.65 |
| Chukha | 6.72 |

**Table-5:** Shows the general location wise comparison of pH of soil from India and Bhutan

| Location | Sum of pH | Mean |
|---|---|---|
| Punjab | 7.96+7.80+7.77+7.85+7.87+7.89+7.63+ 7.72+7.99 | 7.048 |
| Haryana | 6.69+6.76 | 6.725 |
| Rajasthan | 7.11+6.87+6.88+7.76+7.71+7.65+7.50 | 7.354 |
| West Bengal | 8.13+8.05 | 8.09 |
| Meghalaya | 6.80+6.40+6.69+8.00+7.74 | 7.126 |
| Nagaland | 6.22+7.40+6.49+6.86 | 6.742 |
| Bhutan | 6.54+7.92+7.90+6.65+7.28+6.72 | 7.163 |

pH of Indian soil varies from 6.725-8.09 whereas in Bhutan it is 7.163s.

**Density Gradient Method:** The soil samples have been separated according to the density of surrounding i.e. gradients of Bromoform and Bromobenzene.

**Table-6:** Shows the layers of soil in density gradient method.

| Location | Layer 1 (ml) | Layer 2 (ml) | Layer 3 (ml) | Layer 4 (ml) |
|---|---|---|---|---|
| Chaheru | 0-1 | 2-15 smudging | 15-17 | 19-19.5 |
| Rama Mandi | 0-0.5 | 10-14 | 19-20 | - |
| Jalandhar Bus Stand | 0-0.5 | 2-10 smudging | 12-17 | 18-19 |
| Kapurthala Bus Stand | 0-1.5 | 19-20 | - | - |
| Darvesh Pind | 0-0.5 | 1-2 smudging | Floating above 20 | - |
| Jagjeetpur | 0-0.5 | 16-20 | - | - |
| Phagwara | 0-1 | 17-20 | - | - |
| Guraya | 0-1 | 17-19 | - | - |
| Phillaur | 0-2 | 17-20 | - | - |
| Ashahoor | 0-2 | 10-12 soil clot | 17.5-20 | - |
| Gurgaon | 16-19.5 | - | - | - |
| New Delhi | 0-0.5 | 6-7 soil clot | 8-9 soil clot | 16.5-20 |
| Bundi | 7-12 | 13-14.5 | 15-19 | - |
| Sawai Madupur | 6-9 | 13.5-20 | - | - |
| Ranthambore | 11-20 | - | - | - |
| Landmark City | 6-14 | 15-20 | - | - |
| Aerodram Circle | 0-10 | 10-15 smudging | 19.5-20 | - |
| Dadabari | 0-8 | 8-11 smudging | 11-13 | 13-19 |
| Gumanpur | 0-5 | 5-12.5 | 12.5-19 smudging | 19-20 |
| Victoria Memorial | 2-8 | 8-15 smudging | 15-20 | - |
| Ecopark Kolkata | 2-6.5 | 6.5-12 smudging | 16.5-20 | - |
| Mylleim | 0-1 | 17.5-20 | - | - |
| Umtyngar | 0-1.5 | 5-12 | 17-20 | - |
| laimer | 0-1 | 15.5-20 | - | - |
| Langkyrding | 0-4 smudging | 11-20 | - | - |
| Lumshyiap | 0-3 smudging | 5-15 | 17-20 | - |
| Dimapur | 7.5-11 | 17-20 | - | - |
| Kohima | 0-5 smudging | 5-9.5 | 18-20 | - |
| Mesephema | 0-5 | 5.5-10 | 18.5-20 | - |
| Chumukidema | 2-6.5 | 15-17 | 17.5-20 | - |
| Timphu | 16-20 | - | - | - |
| Kinga | 0-5 | 10-14 | 19-20 | - |
| Motithang | 5-8 smudging | 8-11.5 | 15-20 | - |
| Kabisa | 0-6 smudging | 7-14 | 14-19.5 smudging | 19.5-20 |
| Paro | 0-2 | 3-11 smudging | 17-20 | - |
| Chukha | 0-11 smudging | 17-20 | - | - |

These are the density gradients of soil samples made in the different gradients of chemicals Bromoform and Bromobenzene which varies from place to place.

As shown in Table-3, in soil collected from Punjab, mostly two and three layers of soil density gradient are seen. The samples from Haryana showed, more variation in density as only one layer of density gradient is seen in soil collected from Gurgaon and four layers are seen in soil collected from New Delhi. In The sample which has been collected from Kolkata i.e. sample 21, 20 only three layers of density gradient have been seen. Density Variation in Rajasthan samples have been also seen as sample 18 and sample 19 showed four layers, three layers have been seen in 13 and 17 sample, two layers are seen in 14 and 16 sample ,and one layer of soil density gradient is seen in sample 15. In the soil samples collected from Nagaland mostly two layers of soil density gradient are seen except sample 23 which showed three layers. In the soil samples collected from Meghalaya three layers of soil are mostly seen but sample 27 showed two layers of soil density gradient. Density variation in soil collected from Bhutan is also seen as sample 32, 33 and 35 showed three layers, sample 34 showed two layers and sample 31 showed one layer of soil density gradient.

In the soil samples collected from India mostly two and three layers of soil density gradient are seen and three layers of soil have been common in Bhutan soil.

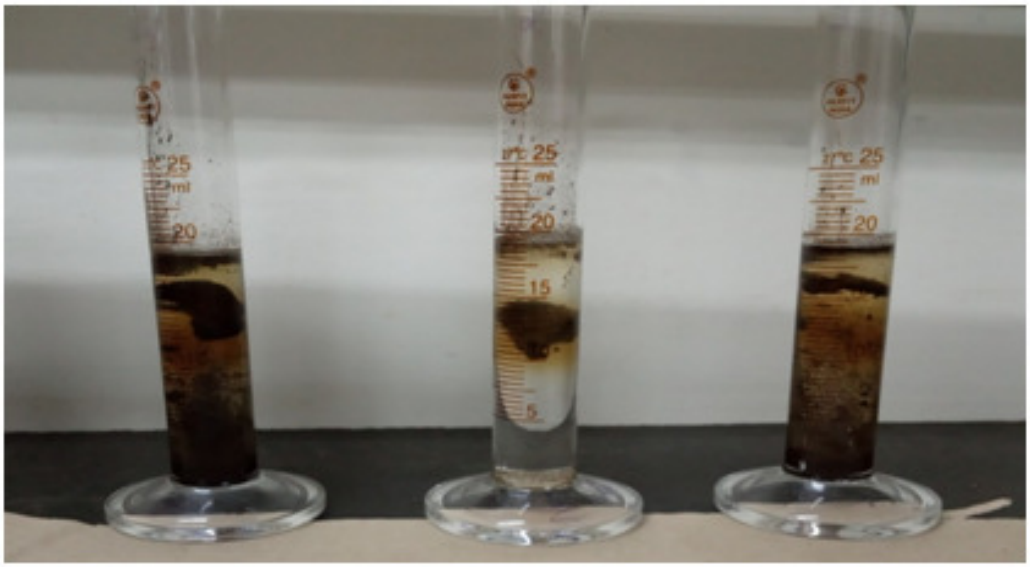

**Figure-15:** Sample 1, Sample 2, Sample 3.

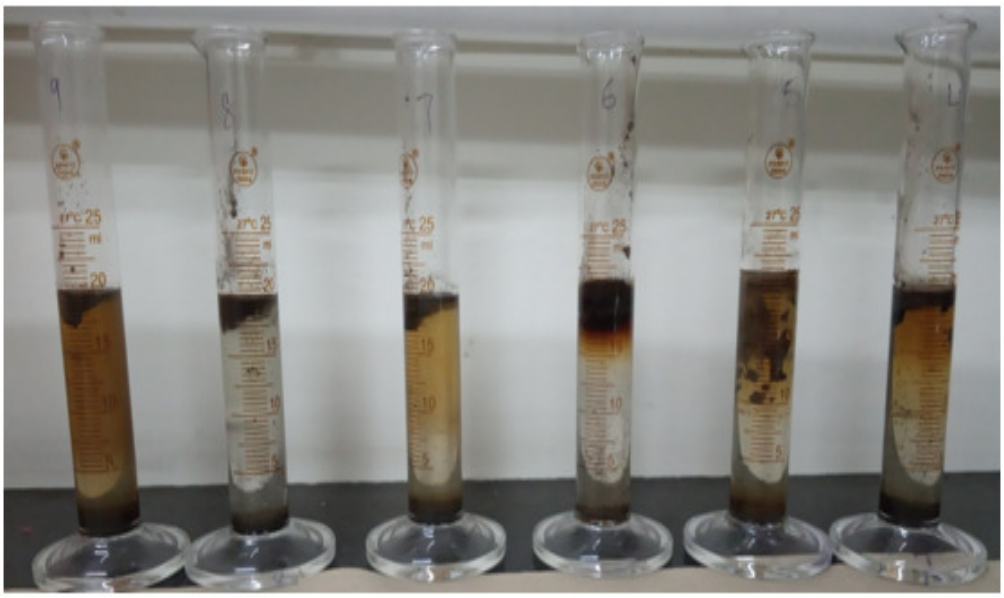

**Figure-16:** Sample 9, Sample 8, Sample 7, Sample 6, Sample 5, Sample 4.

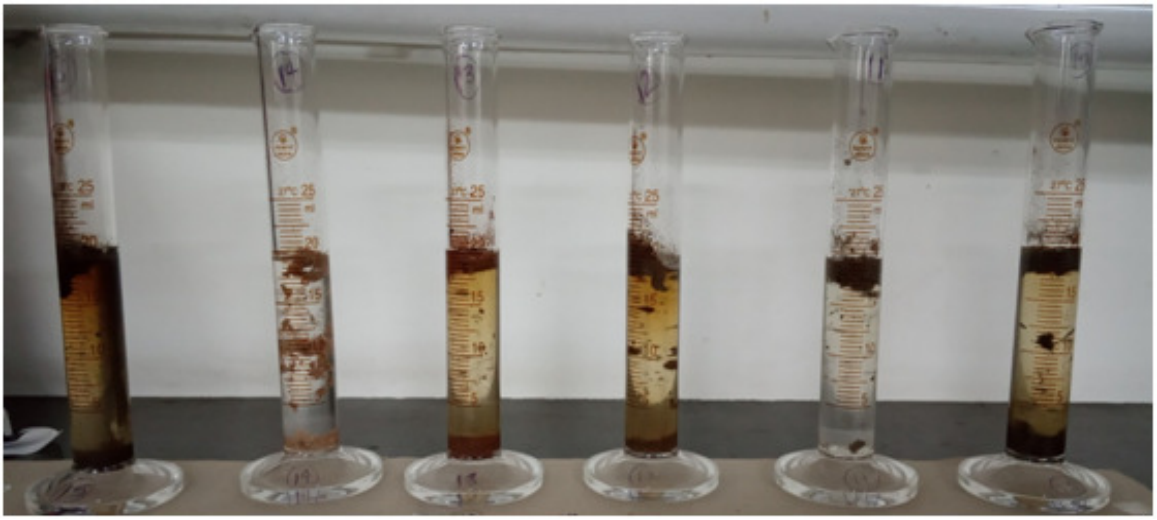

**Figure-17:** Sample 15, Sample 14, Sample 13, Sample 12, Sample 11, Sample 10.

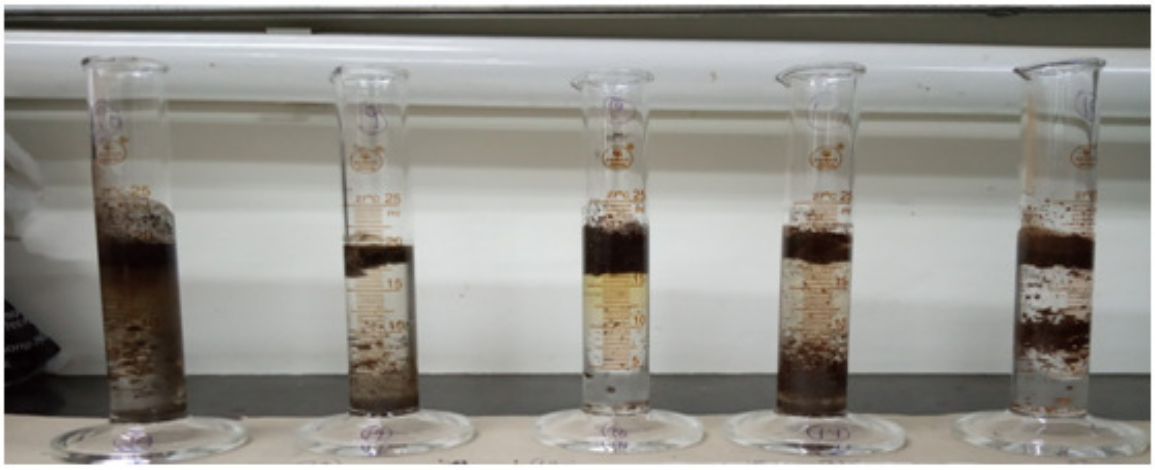

**Figure-18:** Sample 20, Sample 19, Sample 18, Sample 17. Sample 16.

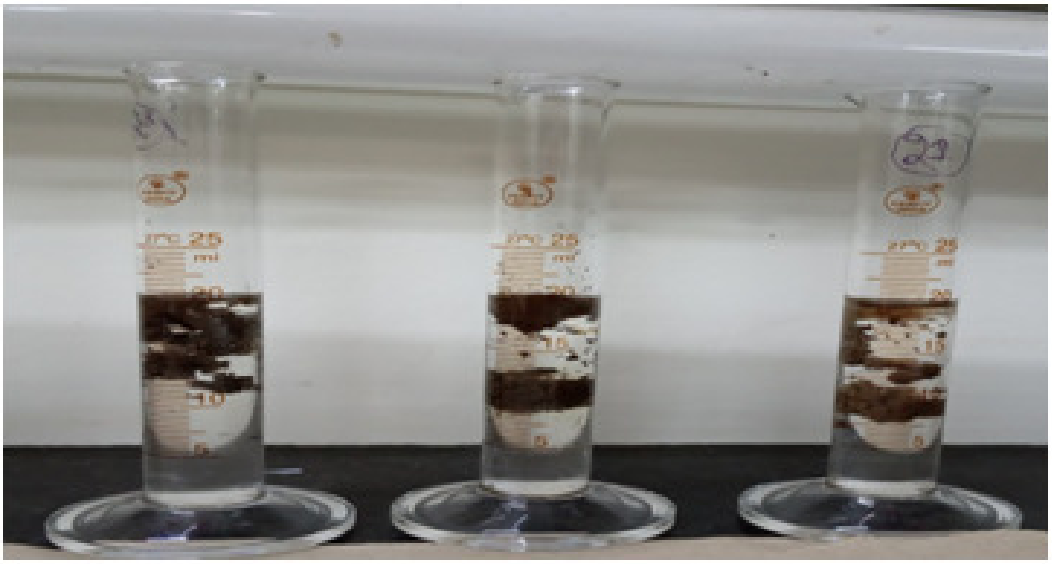

**Figure-19:** Sample 23, Sample 22, Sample 21.

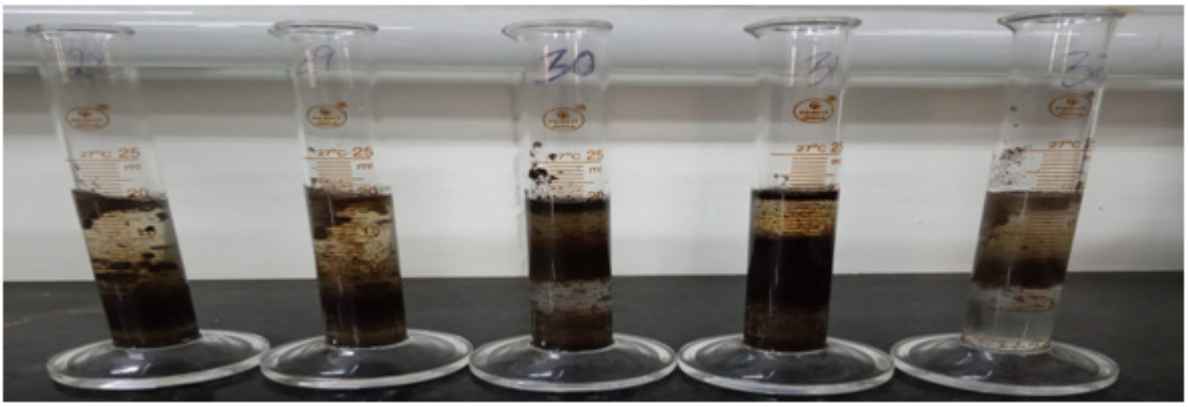


**Figure-20:** Sample 28, Sample 29, Sample 30, Sample 31, Sample 32.

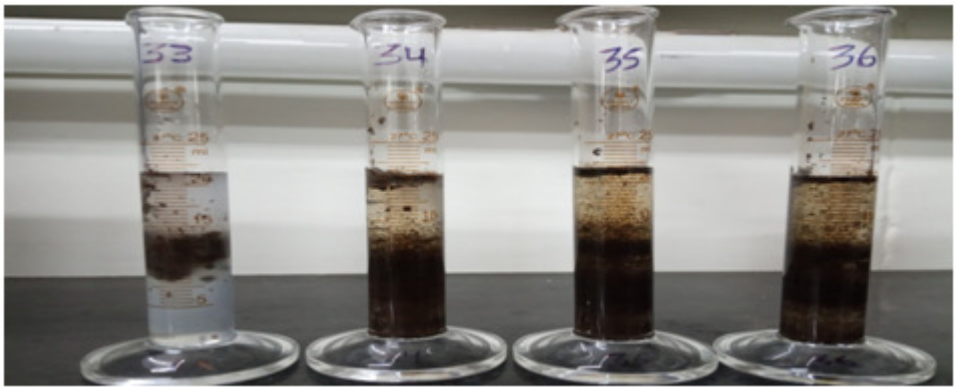


**Figure-21:** Sample 33, Sample 34, Sample 35, Sample 36.

**Table-7**: Shows the general location wise comparison of density gradient of soil from India and Bhutan

| Location | Sum of layers | Mean |
|---|---|---|
| Punjab | 4+3+4+2+3+2+2+2+2+3 | 2.7 |
| Haryana | 2+4 | 2 |
| Rajasthan | 3+2+1+2+3+4+4 | 2.7 |
| West Bengal | 3+3 | 3 |
| Meghalaya | 2+3+2+2+3 | 2.4 |
| Nagaland | 2+3+3+3 | 2.74 |
| Bhutan | 1+3+3+4+3+2 | 2.66 |

In Indian soil the formation of layers of soil in density gradient method varies from 2-3 layers whereas in Bhutan it is 2.66 layers.

In the present analysis, two solvents, of varying density, i.e. Bromoform (2.89g/cm$^3$) and Bromobenzene (1.52g/cm$^3$) have been used. The solvents Tetra methane (2.46g/cm$^3$), Sodium Polytungstate (2.94g/cm$^3$), and Bromophenol (2.2g/cm$^3$), can be used as denser and chloroform (1.50g/cm$^3$), dichloromethane (1.33g/cm$^3$), Carbon tetrachloride (1.594g/cm$^3$), and nitro methane (1.382g/cm$^3$) can be used as less denser solvent, in the soil density gradient analysis. Concentrated solution of Zinc Bromide (4.2g/cm$^3$) can be used with acidified distilled water (1g/ml) for Forensic examination of soil evidence by density gradient method[12].

## Conclusion

In present study characterization of soil has been done by microscopic analysis pH determination and soil density gradient method. It has been found that these methods are easy to perform, time effective and sample can be directly analyzed without any sample preparation. Earlier work has been done on analysis of soil by different cost- effective techniques however no work has been reported on comparison of soils of different states of India and Bhutan.

In forensic scenario, in a number of cases like to link primary crime scene to secondary crime scene etc soil can be submitted as an evidence and preliminary analysis can be performed by applying these methods. Present study will serve as a database to characterize the soil of India and Bhutan.

However, confirmatory analysis of soil can be performed by applying different instrumental techniques such as X-Ray florescence analysis and spectrophotometer analysis etc.

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