CHAPTER FOUR

SOIL CHARACTERISTICS
OF THE
JHARIA COALFIELD
4.1 Introduction

Soil is regarded as one of the most important and fundamental resource provided to us by the nature. Soil constitutes a major element in the natural environment, linking climate and vegetation, and it has a profound effect on man’s activities through its relative fertility (Bryant, 1986). To a great extent, quality of the soil determines the nature of the plant ecosystems and the capacity of land to support animal life and society (Brady and Weil, 2002). The importance of soil is not limited to biological life only, but it also provides foundation to almost all civil and mechanical structures developed by man on the earth. Everywhere on this earth, the soil properties vary from region to region since the intensity and duration of soil forming processes and soil forming factors both vary across different regions. Thus the soil shows a marked variation in its potential and ease to different uses. If soil of any region is used by keeping in mind its potentiality, it proves a nearly inexhaustible natural resource available to man. But soil’s potentiality has its own limitations and if we exploit it unjudiciously beyond its sustainability, soon it will become unusable. This fact becomes even more important, when we consider the fact that under natural conditions it takes around thousand of years to develop a few centimeters of topmost and most fertile layer of soil. Soil is often dismissed as being rather lifeless and merely the static medium for plant growth, but it is very much a dynamic entity in which physical, chemical and biological activities are continually taking place (Bryant, 1986). As human societies become increasingly urbanised, fewer people have intimate contact with the soil, and individuals tend to lose sight of the many ways in which they depend upon soil for their prosperity and survival. Indeed, the degree to which we are dependent on soil is likely to increase, not decrease, in the future (Brady and Weil, 2002).

Thus, a proper understanding of soil system of any region is a prerequisite for the sustainable and environmentally harmonious use of land. Since the factors influencing soil, both natural and anthropogenic, varies place to place and so it is practically impossible for anybody to go and study each and every soil of any region. Therefore, an understanding of soil of any region is basically based on representative sampling and its study.
4.2 Soil Sample Collection

In any soil analysis we usually give much attention to laboratory procedures, and the process of obtaining soil for all laboratory analysis, i.e. soil sampling, is often ignored or poorly considered. If a sample is not representative of the field or is incorrectly taken, the resulting analytical data would be meaningless, or at best, difficult to interpret (Ryan and Rashid, 2001). The importance of having a truly representative sample can be very much realised from the fact that only a minute fraction of the huge soil mass of the field representing all its heterogeneity is actually used for analysis in the laboratory. Hence, even a small error committed during sampling gets magnified. Thus any soil test results are only as good as the soil sample itself or error in field sampling is generally much greater than that due to chemical analysis (Ryan and Rashid, 2001).

Keeping in mind the above facts, following points have been considered with due attention while collecting the soil samples from the Jharia Coalfield:

(i) The sample must truly represent the field it belongs to.

(ii) To identify the sample field, first the entire coalfield is divided into different land-use pattern namely mining, overburden dump, agricultural land, settlement etc. and then within each land-use a representative field is randomly selected to count 69 in total (figure-4.1).

(iii) From each such representative field wherever possible a total of eight sub-samples were collected. These sub-samples are planned in zigzag way to collect four from each diagonal.

(iv) These sub-samples were thoroughly mixed on polythene sheet, leveled and quartered and finally two opposite part are discarded. This process continued till about 500 gm of sample of that field are left. Here due attention is given in keeping all sub-samples weight nearly equal as far as possible.

(v) Instrumentally, soil auger is generally used to extract sub-samples, but where soil is stony or very hard, steel ring are used to dig soil inside it. This insured two important soil sampling requirements, first that a uniform slice should be taken from the surface to the depth of insertion of the tool and second, that the same volume of soil should be obtained in
each sub-samples. As far as the depth is concerned, sub-samples are collected from 0-15 cm depth, since this zone is also useful for general agricultural activities.

(vi) Before taking sub-samples all areas around one meter of tree stems, animal holes, disturbances like wind thrown trees and trails, bunds, marshy tracts etc. are avoided to collect true representative of the soil. Surface dirt is also scrapped away before collecting the sub-sample. To minimise the possibility of biological activities all sub-samples are collected in dry season just before the setting of rainy season.

(vii) To avoid micronutrient or any other type of contamination of sub-samples, care has been taken that collecting instrument and container used should not be rusted, galvanized or chrome plated.

(viii) All composite samples are air dried, crushed for unnecessary compaction and passed through 2 mm dry sieves as a preparation for further analysis. Then these are packed in labeled air tight polythene bags and stored at 4°C to avoid any microbial growth in the sample.

(ix) All samples are collected by simultaneous filling of an inventory sheet pertaining to GPS location of sample site, date, prevailing land-use, any peculiarity etc. It will help in sample properties interpretation, and also in recollection of any sample if required and in avoiding any multiple collections from the same area.
Figure: 4.1 Map showing distribution of soil sampling locations.
4.3 Laboratory Analysis

After proper soil sample collection, laboratory analyses of these samples are the next important step in any soil study. A soil may be analysed for a variety of parameters, some of them may be physical, chemical, biological and of course a combination of more than one also. Among different parameters related to soil study soils relative particle size study (texture and coarseness), soil reaction (pH), soil electrical conductance and total dissolved salt may be regarded as most basic and fundamant since they are directly or indirectly involved in influencing a variety of soil properties. Besides them, concentration of heavy metals, some of them are essential micronutrients but in excess concentration may become toxic to plant system, are also important in deciding soil quality. In the present study these basic parameters have been analysed and discussed.

4.3.1a Soils Relative Particle Size Study

'Soil physical properties profoundly influences how soil function in an ecosystem and how they can best be managed. Success and failure of both agricultural and engineering projects often hinges on the physical properties of the soil used. The occurrence and growth of many plant species are closely related to soil physical properties' (Brady and Weil, 2002). Among different physical parameters the soil texture in general and to some extent its coarseness (where particle size are relatively large) is regarded as most fundamental physical parameter influencing different soil characteristics in a big way.

Since the parent material from which soil derived and their weathering rates, both vary place to place, therefore everywhere the individual particle size not remain same or uniform. Different particle size has been classified differently by different organisations but United States Department of Agriculture’s (USDA) criteria are most widely accepted. It classifies the particle size in following way (table-4.1):
Table 4.1 Size of soil particles

<table>
<thead>
<tr>
<th>Grade Name</th>
<th>Diameter Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Coarse Sand</td>
<td>1.0 - 2.0 mm</td>
</tr>
<tr>
<td>Coarse Sand</td>
<td>0.5 - 1.0 mm</td>
</tr>
<tr>
<td>Medium Sand</td>
<td>0.25 - 0.5 mm</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>0.10 - 0.25 mm</td>
</tr>
<tr>
<td>Very Fine Sand</td>
<td>0.05 - 0.10 mm</td>
</tr>
<tr>
<td>Silt</td>
<td>0.002 - 0.05 mm</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt;0.002 (mm) (2 microns)</td>
</tr>
</tbody>
</table>


Based upon relative particle size, all particles with diameter greater than 2mm are classified as coarse fragments (Gravels, pebbles, cobbles and boulders) whereas particles less in size to 2mm is considered as fine earth fraction. Among the fine earth fractions the relative presence of sand, silt and clay is used to identify the texture of any soil. Gravel or rocks greater than 2mm in diameter are not considered when determining texture (CUCE, 2007). Thus soil texture refers to the composition of the soil in terms of the proportion of small, medium and large particles (clay, silt and sand respectively) in a specific soil mass. For example, a coarse soil is a sand or loamy sand, a medium soil is a loam, silt loam or silt, and a fine soil is a sandy clay, silt clay or clay (Ball, 2001).

Sand: Sand particles are those particles which are smaller than 2mm but larger than 0.05mm. They may be rounded or angular, depending upon their extent of abrasion during soil formation. The coarsest sand particles may be rock fragments containing several minerals, but most sand grains consist of a single mineral, usually quartz (SiO₂) or other primary silicates. The dominance of quartz means that the sand separate generally has a far smaller total content of plant nutrients than do the finer separates (Brady and Weil, 2002) (figure 4.2). Sand feels gritty and particles are visible by naked eyes. Due to their relative large size, void between them are also relatively large. Because of their relative large size, particles of sand have low specific surface area.
Silt: Particles smaller than 0.05mm but larger than 0.002mm in diameter are classified as silt. Individually these particles are not visible by naked eye and also they don’t feel gritty to our fingers. These are essentially micro-sand particles, with quartz generally the dominant mineral. If silt is composed by weatherable minerals, they after weathering produces significant amount of plant nutrients. When wet, silt do not show any plasticity or stickiness. Since they are smaller in size, therefore their specific surface area is relatively larger than sand.

Clay: Particles further smaller in size (< 0.002mm) are classified as clay. When wet they are sticky. They are so smaller that they behave as colloids and due to its smaller size they have very high specific surface area in contrast to sand and silt. It is important here that each unique clay mineral impart very different properties to the soil in which it is prominent.

Since different physical and chemical properties of sand silt and clay vary, and they are present in different proportion in soil at different places, combinedly they influence many soil characteristics according to their relative importance in the soil. Following are the general features which get influenced by the texture of that soil:

- Movement of Soil Water
- Water Holding Capacity
- Water Availability
- Aeration and Temperature
Movement of Soil Water

Water moves in different soil differently in relation to its unique physico-chemical property. Generally three types of water movement have been identified in soil namely saturated flow; unsaturated flow and water vapour movement. Out of these three, barring water vapour movement, other two are significantly influenced by the texture of soil in association with other deciding factors.

Water moves because of water potential gradients in the soil caused mostly by gravity, salt content and water usage and the direction of flow is from a zone of higher to zone of lower moisture potential (Das, 1996). When water moves in soil mainly due to gravity, the movement is called saturated flow. A saturated flow starts with infiltration. Infiltration is the movement of water into the soil when precipitation or irrigation water is on the surface of soil. When soil profile is completely saturated with water, the movement of more water flowing through the saturated soil is termed percolation. The flow of water in saturated condition is determined by two major factors- the hydraulic force driving the water through soil and the ease with which the soil pores permit water movement.

\[ V = kf \]

Where, \( V \) = total volume of water moved per unit time
\( f \) = water moving force (hydraulic gradient)
\( k \) = hydraulic conductivity or permeability

Here, hydraulic conductivity or permeability of any saturated soil is essentially a constant and is dependent on the size and configuration of the soil pores. Since coarse textured soil have larger size particles, thus larger pores and due to this reason they have higher hydraulic conductivity than fine textured soil.
In unsaturated flow in soil, the water moves from a region of higher potential towards a region of lower potential. In other words, if soil is uniform, then water will move from wetter to drier areas. Unlike saturated water flow in soil where flow direction is either downward or horizontal, in unsaturated water flow in soil, the movement may be in any direction (figure-4.3). Two forces are basically responsible for this unsaturated water movement in soil—adhesive force and capillarity. With finer texture, the specific surface area increases drastically and capillary becomes narrower, and so in such soil, the unsaturated water flow is slower. The rate of unsaturated water flow in soil is greater as the water potential gradient (the difference in potential between wet and dry heads) increases and the size of water-filled pores also increases (Das, 1996).

**Figure: 4.3** Schematic diagram showing typical wetting pattern expected for saturated and unsaturated flow as influenced by texture and location of water source. Saturated Flow (A) mostly vertical in coarse-textured soil, (B) more lateral movement in fine-textured soil, (C) a temporary inhibition to flow when sand is below fine-textured soil, and (D,E,F) Unsaturated flow in different directions.

*Source: After Das, 1996.*
**Water Holding Capacity**

Soil texture is a key factor in influencing soil’s water holding capacity. Coarse textured soil which has high content of sand and lower content of other materials, are having lower specific surface area as compared to fine textured soil. Water is retained in soil as thin film on the surface of the soil particles. Therefore greater is the surface area, the greater the soil’s capacity to hold water. In fact due to larger size of individual grains in coarse textured soil the pores between individual particles are much larger as compared to fine textured soil which has higher percentage of very finer materials. Due to large size pores, in general water easily drains out from coarse textured soil under gravity and thus its water-holding capacity is much lower than a fine textured soil.

**Water Availability**

Available water simply means water that is made available to plant in soil for its healthy growth. Not all water with soil is available to plant. Here soil physics in association with physical characteristics of soil particles play a key role in deciding the difference between field capacity (maximum amount of water which a soil can hold against gravity when it’s all macropores are filled with air and micropores are still saturated with water) and permanent wilting point (when osmotic pressure within root becomes higher than the pressure of water inside the soil). As the coarseness of soil texture increases, its macropores increases, micropores decreases and specific surface area decreases, and therefore field capacity and wilting point both decreases. In fine textured soil ample micropores are available, it has very large specific surface area, and therefore not only such soil has higher field capacity but also higher level of wilting point. Due to this fact coarse textured soil have lesser water availability, fine textured soil have medium water availability and medium textured soil have highest water availability (*figure-4.4, table-4.2*).
Aeration and Temperature

Soil aeration and temperature are two closely related soil features which have a very important role in deciding plant and microbial growth in any soil. Since air and water shares the same pore space available with soil, therefore soil air is also influenced by soil texture as soil water be. Coarse textured soil which has larger macropores are easily loses its soil air to the environment with the fresh influx of rainwater and irrigation. This water brings with them their heat to surrounding soil particles. Water also quickly drains out from larger sized pores and thus paved the way for atmospheric air. Surface roughness of coarse textured soil also quickly
absorbs solar radiation in contrast to finer textured soil. Thus coarse textured soils in general have better condition for soil micro-organism growth. Therefore, coarse textured soil are more prone to quicker aeration and temperature change due to its low specific surface area, high macropores and low water holding capacity (specific heat capacity of water is higher than soil particles itself) in contrast to finer textured soil. Thus rate of aeration and temperature change is higher in coarse textured soil whereas these changes are slower in fine textured soil.

**Soil Tilth and Crust**

Soil tilth is the ease or difficulty which a soil poses for healthy plant growth or more specifically to support plant root development. Tilth is technically defined as the physical condition of soil as related to its ease of tillage, fitness of seedbed, and impedance to seedling emergence and root penetration. Further, a soil with good tilth has large pore spaces for adequate air infiltration and water movement (roots only grow where the soil tilth allows for adequate levels of soil oxygen). It also holds a reasonable supply of water and nutrients (Whiting et al., 2008). Soil crusts are relatively thin, somewhat continuous layers of the soil surface that often restrict water movement, air entry, and seedling emergence from the soil. They generally are less than 2 inches thick and are massive (USDA, 1996). These are somewhat continuous layer of non-aggregated soil particles on the surface of tilled and exposed soils. Water flowing across soil breaks the soil aggregates into individual soil particles which flow as particles wash. These finer particles settle into and block surface pores causing the soil surface to seal over and thus water infiltration/percolation remarkably reduced and dryness of this muddy layer develops into crust.

Thus a coarse textured soil has high tilth in comparison to fine textured soil. It is always easy to work with coarse textured soil, however frequent watering is required as its macropores water holding capacity is lesser. In contrast to it, fine textured soils are difficult to work. When it is wet, it becomes too sticky to work and when dry becomes too hard to work. Also with dryness it generally develops larger size cracks sealing some pores very tightly and exposing some pore completely. This cracking also causes some plant roots to destroy.

As far as soil crusting is concerned different study has shown that surface soil crust are more common on fine textured soils, like silts, loams and clays than coarse
textured or lighter soils. Since fine textured soil are more prone to splashing effect of raindrops than coarse textured soil, therefore crust developed on fine textured soil are thicker and relatively stronger in comparison to thinner and weaker crust developed over coarse textured soil. In any case soil crust is known to cause poor infiltration, problematic seedbed and reduced air exchange between the soil and atmosphere. Thus crust with fine textured soil poses difficulty for seed germination, its reduced infiltration means higher possibility of runoff and erosion and comparatively lesser water availability to plant root system. Solar radiation reflectance of crust is higher and thus soil temperature may be lowered and surface evaporation may be reduced. These conditions have a negative effect on germination and development of healthy seedlings especially during winter season. Thus crust associated problem in fine textured soils are much higher than what with coarse textured soils.

**Bulk Density**

Bulk density is one of the important physical properties of soil in which soil texture play a key role. Bulk density which is an indicator of soil compaction is calculated by dry weight of soil divided by its volume (both solids and pores). Since unlike particle density it considers the volume of pores also, therefore the factor which influences pore spaces in soil in contrast to solid particle present in the soil also influences bulk density. Near the soil surface it is generally the texture which influences prominently the bulk density. Heavier textured soil or fine textured soil such as silt loams, clays and clay loams generally have lower bulk density than do sandy soils. Fine textured soil tends to organise in porous granules, they have larger specific surface area and therefore they tend to have low bulk density. In contrast the coarser soils have low organic content, solid particles are less likely to be aggregated and thus the bulk densities are commonly higher than fine textured soils. Even with coarse textured soil if particle size are well sorted or generally of same size then it tends to have lower bulk density than those coarse textured soil which have well-graded or a mixture of different size of coarse particles since smaller particles fills the space between larger particles. Bulk density reflects the soils ability to function for structural support, water and solute movement, and soil aeration. High bulk density may cause restriction to root growth and poor movement of air and water through the soil (*table-4.3*). Compaction can result in shallow plant rooting and poor plant growth, influencing crop yield and reducing vegetative cover available to

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protect soil from erosion. If it is low lying area, then high bulk density may cause waterlogging by reducing soil infiltration. In addition, bulk density has an indirect influence on the concentration of air pollutants in the soil (Vanmechelen et al., 1997).

**Table: 4.3 Bulk density of soil**

<table>
<thead>
<tr>
<th>Soil Texture Class</th>
<th>Ideal</th>
<th>Upper Limits to Restrict Root Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy</td>
<td>&lt;1.60</td>
<td>&gt;1.80</td>
</tr>
<tr>
<td>Silty</td>
<td>&lt;1.40</td>
<td>&gt;1.65</td>
</tr>
<tr>
<td>Clayey</td>
<td>&lt;1.10</td>
<td>&gt;1.47</td>
</tr>
</tbody>
</table>

*Source: After USDA, 2001.*

**Soil Pest Relation**

Pesticide movement in soils depends upon physical and chemical properties of the compound, soil type and climatic conditions. Soil-applied herbicides that move readily into the soil may fail to control weeds because of dilution and leaching. In addition, high mobility may damage desirable vegetation by moving off-sites and may potentially contaminate water resources. Conversely, persistent non-selective herbicides that are immobile in soil may cause residue problems. Therefore, herbicide mobility and bio-availability in soils are both agronomic and environmentally important. Thus in one hand coarse textured soil facilitates quicker infiltration to make agriculturally important chemicals less effective to crop and pollution danger at sub-surface layer, on the other hand fine textured soil may cause their persistence at surface layer and by runoff with irrigation and rainwater to surrounding unwanted areas. Not only chemicals, occurrence, severity and management of seedling diseases and insects are also largely influenced by soil texture. For example pre-emergence damping-off is less serious problem in coarse-textured soil than in fine textured soils because the slower rate of seedling emergence in fine textured soil extends the time seedlings are exposed to fungus pathogens. Similarly corky root disease is more common in coarse-textured soils. As per the pest management is concerned, it is more effective on coarse-textured sandy soils because it is easier to control soil temperature and moisture conditions. In addition, soil fumigation is more effective in coarse textured soils because the fumigant moves more easily through the larger pores (Andersson and Sutherland, 2004).
Cation-Exchange Capacity (CEC)

Cation Exchange Capacity refers to negative charges in soil existing on the surface of clay and organic matters. These negative charges attracts the positive charges i.e. cations like NH$_4^+$, K$^+$, Ca$^{2+}$, Fe$^{3+}$, etc. and thus cation exchange capacity can be defined as the degree to which a soil can absorb and exchange cations. Soil particles and organic matter have negative charges on their surfaces. Mineral cation can absorb to the negative surface charges or the inorganic and organic soil particles. Once absorbed, these minerals are not easily lost when the soil is leached by water and they thus provide a nutrient reserve available to plant roots. Soil texture is one of the key in deciding cation exchange capacity, though organic matter content is also important. In general higher the clay mineral in soil, the higher be the cation exchange capacity (table-4.4). Clay content are more important than sand since these small particles have a high ratio of surface area to the volume.

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>CEC (Values in meq/100gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands (Light Coloured)</td>
<td>3-5</td>
</tr>
<tr>
<td>Sand (Dark Coloured)</td>
<td>10-20</td>
</tr>
<tr>
<td>Loams</td>
<td>10-15</td>
</tr>
<tr>
<td>Silt Loams</td>
<td>15-25</td>
</tr>
<tr>
<td>Clay and Clay Loams</td>
<td>20-50</td>
</tr>
<tr>
<td>Organic Soils</td>
<td>50-100</td>
</tr>
</tbody>
</table>


Organic Matter

Soil organic matter consists of decomposing plant and animal residues. In addition to these materials, soil organic matter contains living and dead microbial cells, microbially synthesised compounds and a number of derivatives produced as a result of microbial activity. It is the store house of essential plant nutrients. It protects soil against erosion and helps to form good soil structure. Although soil texture do not directly influences the organic matter content in soil but it facilitates a condition which are linked with organic matter availability. Soil texture can influence soil CO$_2$ efflux through its effects on soil moisture (Saxton et al., 1986), temperature (Fang and Moncrieff, 2001; Lloyd and Taylor, 1994), all of which influence microbial and root activity. Coarse textured soil warms up quickly in relation to fine textured soil, aeration of coarse textured soil is much better than fine texture soil, but its moisture
holding capacity is limited in contrast to fine textured soil. Since extremes of both dry (aerobic) and waterlogged (anaerobic) conditions retard the process of organic matter decomposition, so soil with finer texture tends to have higher organic matter in contrast to coarse textured soil. This also partly explains why coarse textured soil is relatively more prone to soil erosion. High occurrence of organic matter with finer textured soil is also supported by binding capacity of humus by finer clay particles.

**Engineering Uses**

Soil texture not only important from agricultural point of view but they are also significant in deciding many engineering structures development at any particular place. It is basically their relative proportion of different sized particles, their available pores and associated physical behavior which play key role in engineering planning. Coarse textured soil which usually have higher bulk density are more suited to road foundation and building sites whereas fine textured soil which are less stable with water addition are less suited to building, roads, etc. due to its contraction and expansion properties.

Based on the above discussion it can be safely inferred that soil texture have a great bearing either directly or indirectly in deciding and/or influencing many soils associated physical and chemical features. So a proper understanding of soil texture is very useful in any soil analysis.

**4.3.1b Calculation of Soil Texture and Coarseness**

Soil textural analysis is related to separating of different grain size part of soil and calculating their relative proportion. To separate different grades of particles first samples are decloded to avoid unnecessary soil aggregation and then all unwanted materials like plant roots, weeds, etc. if any, has been removed manually. Now each sample is passed through mechanical sieve shakers to separate soil coarse fraction (>2mm), sand fraction (0.05-2mm) and grade size less than it. This smaller fraction is treated with hydrogen peroxide to oxidize organic matters, which helps in binding individual soil particles into aggregates. Finally all smaller fractions are analysed in laser particle sizer to estimate fractions of silt and clay. Here it must be noted that instrumentally mechanical sieve shaker is not too perfect and may give some aberrations in result due to mechanical tear and wear of soil particle while operating.
the machine. Finally texture class for each sample has been estimated based on relative proportion of sand, silt and clay fractions. Coarseness is not much significant in soil analysis since it has less significance in explaining soil features but it higher presence may reduce nutrient and water availability to plant. Coarse fraction of soil (> 2mm) basically tells us that how much stony a soil is. BCCL (1997) observes that coarse fragments less than 5 per cent are good for soil quality, 5 to 30 per cent are acceptable but beyond it soil becomes poor for healthy agricultural purposes. Thus in general if coarseness is greater than 20-30 per cent then agricultural productivity may reduce significantly and if it is present in amount excess to 60 per cent the soil need to be classified keeping in mind its importance also.

<table>
<thead>
<tr>
<th>Particle Size</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Sand</td>
<td>19.53</td>
<td>5.26</td>
<td>24.79</td>
<td>13.45</td>
<td>4.44</td>
</tr>
<tr>
<td>Medium Sand</td>
<td>27.85</td>
<td>7.21</td>
<td>35.06</td>
<td>15.47</td>
<td>6.53</td>
</tr>
<tr>
<td>Coarse Sand</td>
<td>14.57</td>
<td>4.53</td>
<td>19.10</td>
<td>11.44</td>
<td>3.73</td>
</tr>
<tr>
<td>Very Coarse Sand</td>
<td>25.44</td>
<td>2.37</td>
<td>27.81</td>
<td>12.08</td>
<td>4.93</td>
</tr>
<tr>
<td>Sand</td>
<td>27.46</td>
<td>49.45</td>
<td>76.91</td>
<td>62.53</td>
<td>7.44</td>
</tr>
<tr>
<td>Silt</td>
<td>32.83</td>
<td>5.41</td>
<td>38.24</td>
<td>20.68</td>
<td>6.53</td>
</tr>
<tr>
<td>Clay</td>
<td>21.39</td>
<td>7.72</td>
<td>29.11</td>
<td>16.79</td>
<td>4.28</td>
</tr>
<tr>
<td>Coarseness</td>
<td>72.61</td>
<td>2.32</td>
<td>74.93</td>
<td>35.55</td>
<td>15.61</td>
</tr>
</tbody>
</table>

4.3.1c Interpretation for Soil Texture and Coarseness

Appendix- III shows the laboratory analysed data for relative particle size fraction and its descriptive statistics has been presented in the table(table-4.5). The descriptive table shows details pertaining to range, minimum, maximum, mean and standard deviations for different grades of sand(very fine, fine, medium, coarse and very coarse), total sands, silts, clays and coarseness. The table reveals that total proportions of sand in the Jharia Coalfield are relatively higher than silt and clay fractions. The value of sand proportion in different soil samples as analysed varies from 49.45 to 76.91. The mean proportion of sand in the area is 62.53 with standard
value 7.44. Among different grades of sand, the minimum and maximum values for very fine sand, fine sand, medium sand, coarse sand and very coarse sand are 3.39, 22.81; 5.26, 24.79; 7.21, 35.06; 4.53, 19.10 and 2.37, 27.81 respectively. The average values of these categories are 10.10, 13.45, 15.47, 11.44 and 12.08 in that order. This shows that proportion of all fractions of sands are there but medium grain size sand has relatively higher proportion in contrast to others. In contrast to sand presence in the soil of the coalfield, the mean value showing presence of silt and clay fraction of the soil are low. Silt proportion in the soil varies from 5.41 to 38.24 with mean value being 20.68. These figures are 7.72, 29.11 and 16.79 for clay fractions in the soil of the coalfield. Clearly soils of the coalfield have are bias towards coarse texture. The texture class as calculated for all soil samples show out of total 69, 53 samples fall within the category of sandy loam, 13 fall within sandy clay loam and only 3 samples are loamy (Appendix- III). But here it must be noted that very fine and fine sand category of the soil on an average together accounts more than 20 per cent of the total soil fraction and in individual cases even more than 40 per cent. These fractions are close to silt in size and since silt is also regarded as micro sand therefore these grades of sand are very valuable in association with silt and clay for normal agricultural activities.
Figure: 4.5 Concentration of sand fraction in the soil of the Jharia Coalfield.
Figure: 4.6 Concentration of different fractions of sand in the soil of the Jharia Coalfield.
If we look at the coarseness of the soil in the coalfield, it varies between 2.32 per cent to a maximum as high as 74.93 per cent. Its mean value is 35.55 and its standard deviation value is as high as 15.60. Out of total 69 samples 24 samples have coarseness less than 30 per cent, 8 samples have very high coarseness more than 50 per cent while rest other comes within these categories. High coarse fragments may indicate human contamination in soil in the form of bricks, pottery, coal, bones, etc. (Baize, 1993). Large number of soil samples has results showing higher coarseness, greater than even 30 or even 35 percent. It means that soil texture is not as much problematic as the stony nature of soil in the area for normal agricultural activities to be pursued. Literature has shown that in early days about two third of area was devoted to gainful agricultural pursuit which is decreasing decade after decade. It might be possible that open cast mining in the area (except southern part and northwestern part) in association with rehandling of dumps, coal refuses, and transportation of coal from both open cast as well as underground mining areas etc., all together contributed in one way and other way in increasing the coarseness of soils in the area. However, here this fact cannot be ignored that there are some areas in the Jharia Coalfield which naturally have higher concentration of coarse fractions in the soil as witnessed during the field visit.

As discussed earlier, due to coarse nature of texture and also higher coarseness of soils in the Jharia Coalfield, most of the soils are devoid of higher plant nutrients. In general, they have poor water holding capacity but rate of infiltration and percolation is higher in the soils of the coalfield. They are less likely to develop soil crust and if developed such crust are thin and weak in nature. Soils of the area in general also have larger pores, higher aeration, quicker response to temperature and lower specific surface area. All these suggest that for a successful agriculture in the area the frequent watering is a must. Since soil of the area is coarser therefore they are also having higher bulk density. Higher bulk density retards root growth in soil. Their low clay content suggest that their cation exchange capacity or reserve pool of nutrients are also low. Since their texture is coarse, so on one hand effect of pesticides, weedicides and chemical fertilizers are less effective in the soils of the coalfield on the other hand they may cause pollution to unwanted sites. In tropical climate, coarse texture also indicates that their organic matter content may be low and thus these soils are relatively more prone to erosion. However from engineering point of view these soils are very good and favour various civil and mechanical
constructions in the area. All parameters as discussed here related to soil texture and coarseness, are not uniform over the entire area of the Jharia Coalfield. There are regional variations in these properties. Spatial distribution of sand in the coalfield shows that areas near to the Damodar, has less sand content in their surface soil and as one moves away from it the sand content in the soil increases with some aberrations (figure-4.5). Thus entire northern area has higher sand proportion in contrast to southern area of the coalfield except eastern and south-eastern part. Within the northern part, and also in the eastern and south-eastern part the area adjacent to open cast mining operations and those associated with coal washery, etc. have high sand content in their soil. Relatively higher sand content in the soil of north-western part than the southern part, seems the result of natural phenomena since this area do not have mining and related activities by and large. The spatial distribution of proportions of different particle sizes of sand, closely reflect the similar pattern as shown by the total sand category alone (figure-4.6).
Figure 4.7 Concentration of silt fraction in the soil of the Jharia Coalfield.
As the diameter of different grades of soil increases it tends to concentrate away from the Damodar. Thus very fine sand and fine sand have higher concentration in southern part near the Damodar whereas other categories viz. medium, coarse and very coarse sand have their higher concentration mostly near open cast mining operations in peripheral areas. Now as far as the silt concentration in soils of the coalfield are concerned it has highest proportion in the central part of the eastern half of the coalfield sandwiched between the bank of the Damodar and the open cast mining operations (figure-4.7). From here it decreases in all direction but rate of decrease is relatively higher in northern, eastern and western direction than in southern direction. Spatial distribution of clay fraction in the coalfield as shown in the figure reflects that it is not widely distributed in higher proportion throughout the area but only one area in south-western part near the Damodar has higher concentration of it (figure-4.8). From here it decreases in all directions in the coalfield to give minimum value in south-eastern part and in some other scattered patches also. The coarse fraction of soil in the coalfield has high concentration in most of the area except few small patches (figure-4.9). Very high coarseness in soil are found in two big and few small scattered patches which are either in the open cast coalfield or close to it. The figure also reveals that the western half of the coalfield has more coarse grain soil than the eastern half of the coalfield.
Figure: 4.8 Concentration of clay fraction in the soil of the Jharia Coalfield.
Figure: 4.9 Concentration of coarse fraction in the soil of the Jharia Coalfield.
Thus coarse texture of soil in the coalfield seems associated more with the open cast mining operations and other related mine product handling whereas higher proportion of silt and clay fractions or finer texture soils are more common in those areas which are not directly involved in mining operations and these areas may have natural vegetation, agriculture, etc. on them. Coarse fraction of soil in general have higher proportion nearly in all parts of the coalfield and no specific land-use association can be seen except where it is extremely high and seems associated with open cast mining and related activities. From here it can be also inferred that the different soil properties influenced by texture, as discussed earlier, have more biasness to the coarse texture in general and this trend loses a bit in favour of fine texture in southern part of the coalfield where silt and clay fractions are relatively abundant.

4.3.2a Soil pH (Soil Reaction)

Soil pH is one of the most indicative measurements of the general chemical status of soil. The degree of soil acidity or alkalinity, express as soil pH, is a master variable that affects a wide range of soil properties-chemical, biological and indirectly, even physical (Brady and Weil, 2002).

The pH is defined as the negative log of the hydrogen ion activity. Since pH is logarithmic, the H-ion concentration in solution increases ten times when its pH is lowered by one unit. Because soil pH is typically measured as soil-solution pH, it is also an indicator of the proportions of basic and acidic exchangeable ions present in the soil. This is because these ions in the soil solution are in equilibrium with the exchangeable ions.

Although pH vary between 0 to 14 indicating highly acidic to highly alkaline respectively, but in soil the pH value vary generally between 3 to 9. There are many factors or sources of hydrogen ion in the soil which decides its pH value like carbonic acid, organic matter, oxidation of sulfur and nitrogen, acid precipitation, rainfall intensity etc. Perhaps the most ubiquitous contributor to soil acidity is the formation and subsequent dissociation of H⁺ ions from carbonic acid (Brady and Weil, 2002). Root respiration and the decomposition of soil organic matter by micro-organism produces high level of CO₂ in the soil air which dissolved into water to give weak carbonic acid (H₂CO₃). Since H₂CO₃ is a weak acid, its contribution of H⁺
ions is negligible when soil pH is much lower than 5.0. In addition to carbonic acid, many other organic acids, some are weak like citric and malic acid and some are stronger like carboxylic and phenolic acid, are formed as microbes breakdown the soil organic matter. This is one of the reasons of higher acidity in soil. Higher accumulation of organic matter also influences acidity of soil in two ways. Firstly it forms soluble complexes with nonacid nutrient cations like Ca\(^{2+}\) and Mg\(^{2+}\), thus facilitating the loss of these cations by leaching and secondly there are numerous acid functional groups capable of releasing H\(^+\) ions are present in organic matter. Oxidation of sulfur either from organic–SH group or from pyrites (usually common in coal fields) give rise to very strong acid sulfuric acid (H\(_2\)SO\(_4\)) and causes acidity in the soil.

Nitrogen from organic matter or from most fertilizers released into soil as ammonium ions (NH\(_4^+\)) which oxidise either by specific soil bacteria or as normal chemical reaction to give nitrate ion (NO\(_3^-\)), the anion of a strong acid, nitric acid (HNO\(_3\)). Acid precipitation is also suppose to increase soil acidity especially in those areas where consumption of fossil fuels gives rise to higher concentration of nitrogen dioxide (NO\(_2\)) and sulfur dioxide (SO\(_2\)) in the atmosphere and thus releasing nitric and sulfuric acid as precipitation after their interaction with rainwater. In areas where precipitation is high and texture of soil is coarse, leaching of metallic cations are very common with rainfall and this leaves higher concentration of H\(^+\) ion in soil to increase its acidity. In addition to these, aluminum which is a major constituent of most soil minerals also causes acidity when hydrogen ion (H\(^+\)) are absorbed on clay surface and releasing Al\(^{3+}\) ion a cation of a weak base Al(OH)\(_3\). It has a strong tendency of splitting water molecules into H\(^+\) and OH\(^-\) ions and forming Al(OH)\(_3\) and leaving H\(^+\) to increase acidity.
4.3.2b Effect of Soil pH

Soil pH is regarded as one of the most important chemical parameters affecting the quality of soil for different uses by influencing the various soil properties like, physical, chemical, and biological, etc. The pH of the soil solution is a critical environmental factor affecting the growth of all organisms that live in the soil, including plants, animals, and microbes (Brady and Weil, 2002). Aluminum toxicity is one of the most important problems associated with high acidic soils. As aluminum is not a nutrient, so it is not desirable to plant. Unfortunately, it passes to the plant root either by osmosis or from damaged cell membrane. Here it can block the site of calcium uptake (a useful nutrient), interfere with the metabolism of phosphorus containing compound essential for energy transfer and genetic coding (DNA) and also restricts cell wall expansion. Manganese is an essential micronutrient but it becomes toxic if available in large quantity. With reduced pH (<5.6) manganese solubility and availability to plants greatly increased (in case of aluminum, this happens at pH below 5) (figure-4.10). As pH level lowers below 4.0 to 4.5, the hydrogen ions themselves are sufficient to cause toxicity to plants by damaging root membranes and killing certain soil beneficial bacteria like Rhizobium. At low pH (below 4.0) iron also

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**Figure 4.10** Effect of pH on plant availability of different elements
**Source:** After Das, 1996.
becomes toxic to plant. Different pH values not only affect toxicity level of plant but it also influences the nutrient availability to plant (figure-4.10). It is clear that primary and secondary nutrients-nitrogen, phosphorus, calcium and magnesium are available or more available at a pH of 5.5 and 6.5 for organic and mineral soils than at any other pH. Availability of molybdenum is significantly dependent on pH. In strongly acidic soil it is quite unavailable. On the other hand boron, copper, zinc, etc. are available even at relatively lower pH. Soil reaction (pH) also influences microbial activities in soil. In general, bacteria prefer near neutral to slightly alkaline reaction between pH 6.5 and 8.0, the activity being sharply curtailed when pH drops below 5.5. Fungi grow in acidic reaction between pH 4.5 and 5.5 and actinomycetes prefer slightly alkaline conditions. Fungi microorganisms are also supposed to stabilise large soil aggregates and it explains why acidic soil have large soil aggregates. The most diverse and numerous population of microorganism, which are very important for cycling of nutrients, are found near-neutral soils. Thus the effect of soil pH on plant uptake of main nutrient and trace elements has been rightly mentioned in many agricultural texts (Baize, 1993). Further, he advocated a pH between 6.5 and 7.5 (BCCL, 1997 accepts 6.0 to 7.5) is optimum from agricultural point of view (for non calcareous soils). Based on all these consideration soil pH is a classified into six board groups (table-4.6).

<table>
<thead>
<tr>
<th>Category</th>
<th>pH value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Acid</td>
<td>&lt;5.1</td>
</tr>
<tr>
<td>Moderately Acid</td>
<td>5.2-6.0</td>
</tr>
<tr>
<td>Slightly acid</td>
<td>6.1-6.5</td>
</tr>
<tr>
<td>Neutral</td>
<td>6.6-7.3</td>
</tr>
<tr>
<td>Moderately Alkaline</td>
<td>7.4-8.4</td>
</tr>
<tr>
<td>Strongly Alkaline</td>
<td>&gt;8.4</td>
</tr>
</tbody>
</table>

Source: After Marx et al., 1999.
4.3.2c Estimation of Soil pH

Soil samples with size <2mm are taken into 1:2 ratio with pure water into a beaker and thoroughly stirred for more than half an hour and then pH observation is taken by a pH-meter using glass electrode (Appendix-IV).

4.3.2d Interpretation of Soil Reaction

Soil pH is a very important chemical parameter in any soil analysis as discussed earlier. A quick look at the descriptives (table-4.7) shows that the minimum and maximum pH of the soils of the coalfield varies between 2.65 and 8.65 with mean value 5.02 and low standard deviation of 1.19. It is also clear from the figure (figure-4.11) that most of the soil samples show pH value in acid category. Thus it can be safely inferred that soils of the Jharia Coalfield have an acid biasness.

Table: 4.7 Descriptive statistics of soil pH, EC and TDS in the Jharia Coalfield

<table>
<thead>
<tr>
<th>Soil Property</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.00</td>
<td>2.65</td>
<td>8.65</td>
<td>5.0286</td>
<td>1.19352</td>
</tr>
<tr>
<td>EC</td>
<td>2957.00</td>
<td>33.00</td>
<td>2990.00</td>
<td>238.1174</td>
<td>387.26871</td>
</tr>
<tr>
<td>TDS</td>
<td>1958.00</td>
<td>22.00</td>
<td>1980.00</td>
<td>156.9768</td>
<td>258.51607</td>
</tr>
</tbody>
</table>

*Soil Reaction

*Electrical conductance

*Total dissolved salt
Higher acidity means increased possibility of aluminum, manganese, hydrogen and iron toxicity to the vegetation of the area. It also indicates that although some essential micronutrients needed only in small amount are abundantly available in the soil whereas essential primary and secondary nutrients needed in large amount like phosphorous, calcium etc. are less available to plant. In Lower pH fungi will thrive best whereas bacteria will become less active. This will have a bad effect on nutrient recycling.

Like texture and coarseness, soil reaction in the Jharia Coalfield also shows marked regional variations (figure-4.12). A large part of the study area has pH value less than 5.06 and even in some pockets it is less than 3.86, which show presence of high acidity in these soils. The areas which are moderately acidic with pH value ranges between 5.06 to 6.26 covers second largest area. The spatial distribution pattern of pH also shows that there is no clear cut association between prevailing land-use viz. mining, agriculture, etc. and the pattern of acidity in the soil.
Figure: 4.12
Since coal of the Jharia coalfield have no higher content of pyrites and so its contribution to acidity also seems limited. Perhaps it is basically excessive use of nitrogenous fertilizers, coarse texture and thereby rapid leaching of metallic cations and acid rainfall due to higher use of fossil fuels in this region are the main culprit of such higher acidity of soils.

4.3.3a Electrical Conductance and Total Dissolved Salt (Salinity)

Salt affected soil is regarded as problem soil since they make soil unproductive unless excess salt are removed or reduced. In soil science, soluble salts are referred as those inorganic chemicals which are more soluble than gypsum (0.241 gm per 100 ml water at 0°C). Most soluble salts in the soil are composed of cations like Na⁺, Ca⁺² and Mg⁺² and the anions like Cl⁻, SO₄²⁻ and HCO₃⁻. Usually smaller quantity of K⁺, NH₄⁺, NO₃⁻ and CO₃²⁻ also occur in soil. Weathering of primary mineral is the most important source of these salts, besides they also get accumulated due to aridity (thus low leaching) and saline water irrigation etc.

Salt-affected soil adversely affects plants because of the total concentration of salts (salinity) in the soil solution and because of concentration of specific ions, especially sodium (sodicity) (Brady and Weil, 2002). As the concentration of salt increases, osmotic potential within root system and soil solution changes. Due to higher concentration of salt in soil water, it becomes difficult for root to tap water and other nutrient with it. Small seedling may even destroy or seed may not germinate since water started moving to soil from plant system according to the osmosis in which liquid moves from lower concentration towards higher concentration. Besides it there are certain ions which are quite toxic to many plants say Na⁺, Cl⁻, H₂BO₄⁻, HCO₃⁻ etc. For example Na⁺ competes with K⁺, an essential plant nutrient, to transport across cell membrane during uptake. Salinity particularly sodicity is also suppose to degrade physically any soil. It causes colloidal dispersion which causes deficiency of soil oxygen due to breakdown of soil structure. Water availability also reduced due to very slow rate of infiltration and percolation in such soil. Based on electrical conductance Richards (1954) gave the following categorisation for soil salinity (Table-4.8).
Table: 4.8 Effect of soil salinity on crop

<table>
<thead>
<tr>
<th>Classes</th>
<th>EC (dS/m)</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Saline</td>
<td>&lt;2</td>
<td>Negligible</td>
</tr>
<tr>
<td>Slightly Saline</td>
<td>2 - 4</td>
<td>On very sensitive crop</td>
</tr>
<tr>
<td>Moderately Saline</td>
<td>4 - 8</td>
<td>On many crop</td>
</tr>
<tr>
<td>Very Saline</td>
<td>8 - 16</td>
<td>Only tolerant crop sustain yield</td>
</tr>
<tr>
<td>Extremely Saline</td>
<td>&gt;16</td>
<td>Only very few tolerant crop sustain yield</td>
</tr>
</tbody>
</table>

Source: After Richards, 1954.

Figure: 4.13
Figure: 4.14
4.3.3b Estimation of EC and TDS

Pure water is non-conductor of electricity. As salt proportion into it increases its electrical conductivity increases. This principle is used to estimate the salinity of any soil. Electrical conductance is measured by mixing soil sample (< 2mm) with pure water in 1:2 ratio and then stirred for more than half an hour and finally reading is taken from digital conductivity meter (Appendix-IV). Since electrical conductivity varies not only in proportion to salt dissolved, there are some nutrients like ammonium sulfate which naturally has higher conductivity, but also with respect to conductivity of individual elements, so there exist only a close theoretical relationship between electrical conductance and total dissolved salt in soil solution. Simultaneously total dissolved salt readings are also observed with the same instrument (Appendix-IV).

Figure: 4.15
Figure: 4.16
4.3.3c Interpretation for Electrical Conductance and Total Dissolved Salt

As already discussed that pure water is electrically neutral and a strong correlation exist between soil solution electrical conductance and its salinity (total dissolved salt), this feature is also observable in the present study. The minimum and maximum value of electrical conductivity and dissolved salt both vary very much (table-4.7). Minimum and maximum values for electrical conductivity vary between 33 to 2999 where as these figures for dissolved salt are 22 and 1980. Their mean value are 238.11 and 156.97 respectively with both having higher standard deviation figures 387.26 and 258.51.

Thus in general, barring few exceptions the electrical conductance (figure-4.13 and 4.14) and salinity (figure-4.15 and 4.16) levels of the soils of the Tharia Coalfield are lower. This might be due to coarse texture and concentrated few months monsoonal rainfall which causes faster leaching and thereby reducing salt content in the soil. So, salinity is not a problem in this area as far vegetation is concerned.

4.3.4a Heavy Metals

Heavy metals are not easily defined but adopted as a group name for metals and metalloids which are associated with pollution and toxicity, but also includes some elements which are essential for living organisms at low concentration (Alloway, 1990). Further he observes, being at the interface between the atmosphere and the earth’s crust as well as the substrate of natural and agricultural ecosystem, the soil is open to inputs of heavy metals from many sources and heavy metals occur naturally in soils, usually at low concentration, as a result of weathering and other pedogenic process acting on the rock fragments on which the soils develops. Usually they are found in low concentrations in soils but studies have shown their higher concentration to the level of toxicity near mining areas, large urban and industrial complexes, etc. as a result of increased anthropogenic activities. Among different heavy metals an analytical study has been presented for some important heavy metals which are either essential micronutrient for plant system or whose excessive concentration may produce toxic effect on them or both.
4.3.4b Estimation of Heavy Metal Concentration in Soil

To estimate the heavy metal concentration in the soils of the Jharia Coalfield, first each sample are crushed to powdery level and then soil pellets are prepared on the base of boric acid using hydraulic press. Finally they are analyzed carefully in WDXRF for different elemental concentration.

4.3.4c Results and Discussion for Different Heavy Metals in the Study Area

Table: 4.9 Descriptive statistics of elemental concentration, CIA and SDI in soil of the Jharia Coalfield

<table>
<thead>
<tr>
<th>Heavy Metals</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn</td>
<td>236.71</td>
<td>26.48</td>
<td>263.19</td>
<td>85.71</td>
<td>42.70</td>
</tr>
<tr>
<td>Ni</td>
<td>108.31</td>
<td>15.25</td>
<td>123.56</td>
<td>56.57</td>
<td>21.83</td>
</tr>
<tr>
<td>Mn</td>
<td>1548.91</td>
<td>232.34</td>
<td>1781.25</td>
<td>654.15</td>
<td>253.01</td>
</tr>
<tr>
<td>Fe</td>
<td>34271.85</td>
<td>4091.64</td>
<td>38363.49</td>
<td>18622.97</td>
<td>6487.19</td>
</tr>
<tr>
<td>Co</td>
<td>29.08</td>
<td>5.19</td>
<td>34.27</td>
<td>18.62</td>
<td>6.01</td>
</tr>
<tr>
<td>Cu</td>
<td>76.58</td>
<td>18.92</td>
<td>95.50</td>
<td>36.39</td>
<td>13.07</td>
</tr>
<tr>
<td>Pb</td>
<td>346.72</td>
<td>11.18</td>
<td>357.90</td>
<td>55.16</td>
<td>49.71</td>
</tr>
<tr>
<td>Mo</td>
<td>2.12</td>
<td>1.21</td>
<td>3.33</td>
<td>2.07</td>
<td>0.36</td>
</tr>
<tr>
<td>Cr</td>
<td>157.36</td>
<td>82.46</td>
<td>239.82</td>
<td>144.41</td>
<td>31.18</td>
</tr>
<tr>
<td>V</td>
<td>246.88</td>
<td>82.05</td>
<td>328.93</td>
<td>154.52</td>
<td>40.85</td>
</tr>
<tr>
<td>Fe-Mn Ratio</td>
<td>41.20</td>
<td>13.63</td>
<td>54.83</td>
<td>29.78</td>
<td>9.15</td>
</tr>
<tr>
<td>CIA</td>
<td>32.26</td>
<td>-120.86</td>
<td>92.20</td>
<td>82.92</td>
<td>4.81</td>
</tr>
<tr>
<td>SDI</td>
<td>124.09</td>
<td>-120.86</td>
<td>3.24</td>
<td>-11.16</td>
<td>16.77</td>
</tr>
</tbody>
</table>

**Zinc (Zn)**

Zinc is a white-bluish lustrous metal placed in d-block, Periodic 4 and Group 12 of the Periodic Table with its atomic number 30 and atomic weight 65.38. These are 21 known isotopes of zinc, 5 of them are stable and rest is unstable. Natural Zn contains 5 stable isotopes. Zn is an essential element for humans, animals and higher plants (Alloway, 1990). Raheja (1966), Kabata-Pendias and Pendias (1984) and Alloway (1990) all agrees that Zn is essential component of variety of enzymes like dehydrogenases, proteinases, peptidases, phosphohydrolases, carbonic anhydrases, Cu-Zn superoxide dismutases, etc. and thus play essential metabolic roles in plant. Metabolic functions related to carbohydrates, proteins, phosphates, auxins RNA and ribosome formation are linked to Zn (Lindsay, 1972b; Price et al., 1972 and
Shkonlnik, 1974). Further Zn known to influence membrane permeability, stabilises cellular components and system of microorganism (Shkonlnik, 1974 and Weinberg, 1977) and also plant resistance to dry and hot weather and bacterial and fungal diseases (Kabata-Pendias and Pendias 1984). Besides these Brady and Weil (2002) also agrees that Zn is important for starch formation and also for seed maturity and production. Thus Zn is one of very essential trace element required by plant. But plant species and varieties have different susceptibility to Zn deficiency because of difference in soil, climate and plant genotype. In any case if Zn deficiency in plant may occur, it will lead to disturbed metabolism symptomising as interveinal chlorosis, stunted growth, ‘little leaf’ rosette of trees, violet red points on leaves, malformation of stems, etc. In contrast to Zn deficiency in plant, Kabata-Pendias and Pendias (1984) observe that most plant species and genotypes have great tolerance to excessive amount of Zn. Further toxicity limit depends not only to species and genotypes, but also to stage of growth but in general acidic and heavily sludged soils have higher chance to produce this toxicity. Zn toxicity in plant may lead to chlorotic and necrotic leaf tips, interveinal chlorosis, retarded growth of entire part and injured roots like barbed wire. It is not only the deficiency or toxicity of Zn to plants is important, but its relation with other elements in plant system is also very significant.

In this connection Kabata-Pendias and Pendias (1984) reported that Zn is relatively active in biochemical process and is known to be involved in several biological and chemical interactions with several elements. Zn is known to have antagonistic relation with several elements like Mg, Cu, B, Fe, P and N. Thus for healthy plant development available Zn should be in balance with other elements in soil.

The average Zn content of the lithosphere is 80 PPM while the Zn contents of soils ranges from 10-300 PPM (Davies, 1980). Further average concentration of Zn in basalt is 100 PPM while in granite it is only 40 PPM. In sedimentary rocks Zn varies from 95 PPM in shale to 20 PPM and 16 PPM in limestone and sandstone respectively (Lindsay, 1972a). Raheja (1966) observes that Zn vary in soils from 0.003 to 0.008 per cent. Further, he said surface soils have higher content of Zn than subsurface soils. Kabata-Pendias and Pendias (1984) estimated that Zn vary in surface soils generally between 17 to 125 PPM. Alloway (1990) agreed that higher plant predominantly absorbs Zn as a divalent cation (Zn^{2+}) in plant system. Further based on the consideration of Kabata-Pendias and Pendias (1984), Alloway (1990) accepts critical limit of Zn concentration in soil as 70-400 PPM.
The descriptive statistics shows that the Zn concentration in the surface soils of the Jharia Coalfield vary between 26.48 PPM to 263.19 PPM with mean value of 85.71 PPM and standard deviation 42.70 (table-4.9). This mean value is closer to the lower end of the data variation which show that large number of samples has lower zinc concentration. The bar diagram showing distribution pattern of zinc concentration also support this view (figure-4.17). A considerable number of soil samples (>50 per cent) shows slightly higher Zn concentration in the soils of the Jharia Coalfield over the lower limit of critical concentration and few(3), have considerably higher concentrations (near 250PPM) but no soil sample show its concentration beyond upper critical limit (440 PPM). The spatial distribution pattern of Zn concentration in the soils of Jharia Coalfield show that in most part of the coalfield Zn concentration is under 121.05 PPM and there is three small pockets where its concentration is more than 215.18 PPM (figure-4.18). Very low concentration (<73.98 PPM) is seen in two area, one located in north-western part of the coalfield and other in the central part near the Damodar river in the southern part of the coalfield. Alloway (1990), notices metalliferous mining, coal and other fossil fuel burning, agricultural use of sewage sludge and compost materials and agro-chemicals like fertilizers and pesticides are the main reason behind Zn concentration in soils.
Figure: 4.18

LEGEND
(Values in ppm)
- < 73.98
- 73.98 - 121.05
- 121.05 - 168.11
- 168.11 - 215.18
- ≥ 215.18

Datum and Spheroid: WGS84
Also Verloo et al. (1998) calculated input/output ratio of 7.7 for Zn in Belgium soils which shows it has a progressive tendency of concentration. Since the area is not well developed in terms of technology so large scale use of agrochemicals, sewage sludge and compost in the soil of the area is not possible. Thus the general slight higher limit of Zn in the soils cannot be attributed to them. Also the spatial distribution of Zn with slight higher concentration than lower critical value covers all areas, open cast coal mining, underground coal mining as well as area put to other uses and so the mining alone cannot be blamed. Those pockets which have relatively higher Zn concentration around 250 PPM are definitely close to open cast mining areas and here the role of mining cannot be ruled out. Thus in general slight higher concentration of Zn than lower critical limit may be mostly attributed to large scale fossil fuel burning and other related uses.

**Nickel (Ni)**

Nickel is a transition metal of Group VIII of the Periodic Table number 28 and atomic weight 58.71. Of the seven known radioisotopes, $^{63}\text{Ni}$ (half life 92 years) is the most useful in soil-plant studies. Nickel can occur in a number of oxidation states, but only Ni(II) is stable over wide range of pH and redox conditions found in the soil environment (Alloway, 1990). Trace of nickel are commonly found in plants and animals but earlier due to lack of evidences supporting its essentiality, it has been only recently added in the list of essential elements for higher plants. It is found essential for ureas, hydrogenases, and methyl redutase; needed for grain filling, seed viability, iron absorption, and urea and ureide metabolism (to avoid toxic levels of these nitrogen fixation products in legumes) (Brady and Weil, 2002). The mechanism of Ni toxicity to plant is not well understood, although the restricted growth of plants and injuries caused by an excess of this metal have been observed for quite a long time (Kabata-Pendias and Pendias, 1984). Further, they observed that plant under Ni stress, the absorption of nutrients, root development, and metabolism are strongly retarded. Bazzaz et al. (1974) noticed increased concentration of this metal in plant tissues inhibits photosynthesis and transpiration before the acute Ni toxicity evident. It is found that cereals are one of the most sensitive crop to nickel toxicity. The general Ni toxicity in plant is reflected by grey-green leaves, chlorosis in new leaves and brown and stunted roots. Nickel is antagonistic to Ca and Fe for soil and root surface reactions and to Fe and Zn for plant metabolic reactions.
The uptake and use of Ca, Fe and Zn, particularly of Fe, are retarded due to presence of excess of Ni in soil and this is main reason of Ni toxication. Ni is 24th most abundant element of earth’s crust with an average concentration of 75 mg/kg rock (Alloway, 1990). Further Alloway noticed that the average concentration of Ni in world soils is 40 mg/kg, which obscures much variation between soil types. The Ni status in soil is highly dependent on the Ni content of parent rocks. However, the concentration of Ni in surface soil also reflects soil forming processes and pollution (Kabata-Pendias and Pendias, 1984). They further noticed, Ni concentration are highest in ultramafic rocks like peridotite, dunite and pyroxene (1400-2000 PPM) and its concentration decreases with increasing acidity of rocks like 5-15 PPM in granites. Sedimentary rocks contain Ni in the range of 5 to 90 PPM with highest range being for argillaceous rocks and the lowest for sandstones.
LEGEND
(Values in ppm)

<37.08
37.08 - 58.68
58.68 - 80.27
80.27 - 101.87
≥ 101.87

Datum and Spheroid: WGS84

JHARIA COALFIELD
NICKEL CONCENTRATION IN SOIL

Figure: 4.20
Based on the study of Bowen (1979) and Kobata-Pendias and Pendias (1984), Alloway (1990) mentions normal range of Ni in soil vary between 2-750 PPM and soil generally becomes toxic to plants beyond 100 PPM.

The descriptive statistics show Ni concentration in the soils of the coalfield varies between 15.25 PPM to 123.56 PPM with mean value 56.57 PPM and standard deviation 21.83 (table-4.9). The bar diagram shows that out of total samples only 3 samples have shown Ni concentration higher than the critical limit (100 PPM) in soils (figure-4.19). Out of these three samples, two are located close to each other in underground mining blocks of BCCL in western part of the coalfield and the third one is in the south-eastern part of the coalfield (figure-4.20). Most area of the coalfield have Ni concentration in the range 37.08 to 58.68 PPM. The second most important category in terms of area covered is 58.68 to 80.27. Also there are few pockets where Ni concentration is less than 37.08 PPM. As Alloway (1990) agrees that most of the Ni concentration in soils of any area are basically due to parent material but its concentration may rise due excessive use of fertilizers (particularly phosphates), burning of fossil fuels (particularly oil and then coal), Ni mining and smelting and also from some natural sources viz. wind blow soil, volcanic activity, forest fires, meteoric dust, sea salt spray or particles. The high Ni concentration in all three areas may be associated with coal mining and burning of fossil fuels since these high concentration areas are in close proximity to them. But except these areas most part of the coalfield do not show toxic concentration of Ni in the soil.

Manganese (Mn)

Manganese is an important and abundant trace element in the lithosphere. It has been placed in Group VIIb of the Periodic Table with atomic number 25 and atomic weight 54.938. Scientific interest in Mn in soils is primarily related to its role in plant and animal systems (Alloway, 1990). Kabata-Pendias and Pendias (1984), also reported that all Mn compounds are very important soil constituents because this element is essential in plant nutrition and controls the behavior of several other micronutrients besides having considerable effect on some soil properties. Raheja (1966) notices that Mn has the effect of activating oxidizing enzymes; in the cell it increases the oxidation of substances and is a constituent of some respiratory enzymes (probably in association with iron) to catalyse respiration. Thus a good supply of manganese may counteract the effect of poor aeration. Further, he agrees
that Mn concerned with chlorophyll formation and therefore, in photosynthesis and it also influences nitrogen metabolism in plant (Mn deficient plants have higher concentration of nitrates and amino acids than normal plants). Russell and Russell (1953) have the view that Mn may be a constituent of some protein synthesis enzymes.

Normally manganese content of plants ranges between 5 and 1000 or more PPM dry weight (Bear, 1965). If sufficient Mn uptake and transport is not happen in plant system, then the plant develop several complications. Some common Mn deficiency symptoms in plants are, structural impairment in chloroplasts to cause interveinal chlorosis, necrotic spots, browning of roots, retarded growth, reduced turgor etc. But if Mn concentration in plant system is more than desired level, it will cause toxicity to the plant. Some common symptoms of Mn toxicity in plants are Fe chlorosis, leaf puckering, necrotic brown spots, uneven distribution of chlorophyll in older leaves, accumulation of MnO₂ particles in epidermal cells, and stunted roots (Kabata-Pendias and Pendias, 1984). Not only this, Mn toxicity also influences the uptake of many heavy metals by plants. For example Mn oxides have strong affinity for Co and thus Mn toxicity makes native Co. unavailable to plants (McKenzie, 1977; McKenzie, 1980). Similarly deficient and normal Mn level in soils antagonise Fe absorption, whereas Fe antagonise Mn absorption when Mn reached its toxic concentration in plants (Alvarez-Tinat et al., 1980).

Now as far as the availability of Mn are concerned, it is one of the most abundant trace elements in the lithosphere ranging between 350 to 2000 PPM in rocks with highest concentration in mafic rocks (Kabata-Pendias and Pendias, 1984). Soil derives virtually all their Mn content from the parent materials, and the concentrations found in mineral soils reflect the composition of their parent materials (Alloway, 1990). Thus higher Mn levels are often reported for soils over mafic rocks, for soils rich in Fe and/or organic matter, and for soils from arid and semi-arid regions (Kabata-Pendias and Pendias, 1984). They further observes that on world scale, the range of Mn varies from 10 to around 9000 PPM, and maximum frequency distribution of values occurs approximately from 200 to 800 PPM with grand mean for world soils as 545 PPM. All these manganese are not available for plant use. The oxides of Mn³⁺ and Mn⁴⁺ in soils are equilibrium with those of Mn²⁺ in the soil solution and with the exchangeable Mn ions. The two latter forms which are available to plants, increases with decreasing redox-potential associated with bad
drainage under moist condition and with low pH values (Raheja, 1966). In this connection Troug (1953) observes that at moderate alkalinity Mn converted mostly into difficult available category to plants but at high alkalinity it is converted into moderately and readily available category to plants. In this connection Alloway (1990) agree with Kabata-Pendias and Pendias (1984) to accept 1500-3000 PPM of Mn concentration in soils as critical level.

The descriptive statistics shows that Mn concentration in the soils of the coalfield vary between 232.34 PPM to 1781.25 PPM with mean value 654.15 PPM and standard deviation 253.01 (table-4.9). Also only one sample out of total 69 has value exceeding the lower critical limit for soil concentration (1500 PPM) and no other sample has value in critical range or beyond it (figure-4.21). The one area with toxic Mn concentration is located near underground and open cast mining blocks of BCCL in the eastern half of the coalfield (figure-4.22). The figure also reveals that almost entire part of the coalfield have Mn concentration below 851.61 PPM which is nearly half the lower critical soil concentration. Virtually all manganese concentration in soils come from parent rock but it may also get additional Mn by the application of Mn to plant as micronutrient fertilizers (Alloway, 1990). Also, low and uniform distribution of Mn concentration in the coalfield soil and low level of agricultural development indicate that the coal mining has not played any significant role in the distribution and concentration of Mn in the soil of the area.

![Manganese Concentration in Soils, Jharla Coalfield](image-url)
Figure: 4.22
Iron is a member of Group VIII of the Periodic Table with atomic number 26 and atomic weight 55.847. There are 14 known isotopes of iron, but commonly iron consists of a mixture of 4 isotopes. Kabata-Pendias and Pendias (1984) have view that due to terrestrial abundance, iron is not considered as a trace element in rocks and soils but they play very special role in the behavior of several trace elements besides having an intermediate position between macro and micro nutrients as far as its content in plant is concerned. Further they observe that Fe is very significant for the optimal functioning of plant biochemistry. Fe occurs in heme and nonheme proteins and in chloroplasts; is involve in the mechanism of photosynthetic electron transfer, oxygen carrying component in respiratory ferment, reduction of nitrates and sulfates, and influences chlorophyll formation, nucleic acid metabolism besides certain other catalytic and structural roles. Roughly 0.2 per cent of iron concentration is found in plants.
Figure: 4.24
Any deficiency of iron in plant may lead to interveinal chlorosis especially of young organs causing yellowing or browning of leaves between green veins, poor quality and quantity of fruits etc. and even necrosis wherein premature death of plant cells and tissue take place. It is not only the deficiency, but also excess intake of iron by plant system is harmful to it. The toxicity of iron may result into margin and leaf tip necrosis, and chlorotic and red-brown points of leaves.

Iron is a constituent of most of the rocks whether igneous or sedimentary (Raheja, 1966). About 5 per cent of lithosphere comprises iron mostly confined in mafic series of magmatic rocks. These parent rocks and also soil processes both contributes to iron in soil which vary between 0.50 to 5.00 per cent, with the average being 2.5 per cent in the surface soils. All these iron present in soils are not available to plant for uptake. It is the soluble amount of iron which a plant can uptake and transport between plant organs. Kabata-Pendias and Pendias (1984) found that usable iron in soils depend on several plant and environmental factors, of which soil pH, concentration of Ca and P, and ratios of several heavy metals are most pronounced.

![Iron-Manganese Relative Concentration in Soils, Jharia Coalfield](image)

**Figure: 4.25**
Figure: 4.26

LEGEND
- < 21.89
- 21.89 - 30.10
- 30.10 - 38.31
- 38.31 - 46.52
- ≥ 46.52
Further they observe, generally a high degree of oxidation of Fe compounds, Fe precipitation on carbonates and/or sulfates, and competition of trace metal cations with Fe$^{2+}$ for the same binding sites of chelating compounds are responsible for a low Fe uptake and for a disturbance in Fe transport within plants. Thus higher pH, aerobic condition in soil, and presence of excess amount of antagonistic elements like Mn, Ni, Co, Zn, P, Cu, B, Mo, S etc. disturbs the normal uptake and transport of Fe in plant system. Since plant requires Fe in very small fraction and so even for a Fe poor soil there is no deficiency of Fe for plants, but only a deficiency of readily soluble amounts (Kabata-Pendias and Pendias, 1984).

The descriptive statistics shows that iron concentration in the soils of the Jharia Coalfield vary from 4091.64 PPM to 38363.49 PPM (table-4.9). The mean value is 18622.97 PPM with standard deviation 6487.19. From figures (figure-4.23 and 4.24) it is evident that the most part of the coalfield have Fe concentration between 10927.12 PPM to 24529.99 PPM and only few small pockets, one located in the western half and other in the eastern half of the coalfield, have value of higher concentration (>24529.99 PPM). Similarly one main area of low concentration (<10927.12 PPM) can be identified in the north-eastern part of the coalfield. These low concentrations as well as high concentration pockets do not show any peculiarity in terms of their distribution and different types of mining activities going on in the area. However since Fe and Mn are having antagonistic relationship with each other, so most of the researcher have suggested Fe/Mn ratio as the identification for critical iron concentration in soils. Ideally Fe/Mn ratio should range between 1.5 to 2.5 (Kabata-Pendias and Pendias, 1984). Two figures (figure-4.25 and figure-4.26) show the relative Fe-Mn concentration in the soils of the Jharia Coalfield. It is clearly evident that iron concentration is considerably higher than the critical permissible range for good soil-plant system. Nearly northern half of the area has this value <30.10 and southern half have value more than it. This spatial distribution of relative iron-manganese ratio also not gives any clear association with the prevailing land-use in the coalfield.
Cobalt (Co)

Cobalt is a transition element placed in Group VIII of the Periodic Table with its atomic number 27 and atomic weight 58.9332. Till now 26 isotopes of Co has been identified. Out of them Co$^{59}$ occurs naturally and is stable. The primary interest in Co as a constituent of soils lies in its essential roles in ruminant animals and microorganisms, rather than in its mineralogical or geochemical characteristics (Alloway, 1990). The Co content of plants is normally less than 0.1 PPM dry matter (Bear, 1965). Also essentiality of Co for higher plants has not been established (Bear, 1965; Kabata-Pendias and Pendias, 1984). It is reported that Co is essential only to nitrogen fixing bacteria (legumes) and blue-green algae. Co has also been recognized as a component of a precursor or Vitamin B$_{12}$ for ruminant animals (Kabata-Pendias and Pendias, 1984). Thus if adequate supply of Co is lacking in soil then legumes may not develop fully since this deficiency inhibit the formation of leghemoglobin and thereby nitrogen fixation. Thus due to Co deficiency nodules do not develop fully in number and size. However, the cases of Co deficiency are rare. When Co is taken up in excess by roots, it principally follows the transpiration stream, resulting in an enrichment of Co at the leaf margins and tips. Therefore, the common symptoms of Co toxicity are white, dead margins and tips of leaves. However, the primary reaction of plants to an excess of Co is interveinal chlorosis of new leaves, which is closely linked with Fe chlorosis (Kabata-Pendias and Pendias, 1984). Further, Rauser (1979) and Smith and Carson (1981) reported inhibited mitosis, chromosome damage, damaged endoplasmic reticulum of root tips and disorganized phloem of minor veins as cytological effect of excess of Co uptake. Among interaction of Co with different elements, Kabata Pendias and Pendias (1984), observes interaction between Co and Mn or Fe in soil and between Co and Fe in plant are very significant since they are both geochemically and bio-chemically antagonist and fight for same sites in crystalline structures and forms similar metallo-organic compounds.

The availability of Co in soil depends upon their parent rocks. Since mafic rocks contain high concentration of Co among igneous and clay dominant sedimentary rocks among all sedimentary rocks so soils developed on them also have higher Co concentration. Kabata-Pendias and Pendias (1984) reported that normally the Co concentration of surface soils ranges between 1 to 40 PPM, with the highest frequency in the range of 3 to 15 PPM and worldwide mean concentration 8.5 PPM.
However, all these Co are not available to plant use. Uptake of Co by plants is a function of the concentration of Co in the soil solution and on the exchange sites of the cation exchange complex (Alloway, 1990). Further he agrees that uptake of Co by plant increases as the soil pH decreases and also at given pH in poorly drained soils its uptake is higher in contrast to well drained soils i.e. anaerobic condition favours its uptake. Thus based on the study of Kabata-Pendiasa and Pendias (1984), Alloway (1990) agrees that 25-50 PPM is the critical level of Co concentration in soils.

Figure: 4.27

Cobalt Concentration in Soils, Jharia Coalfield

Figure: 4.27
Figure: 4.28

LEGEND
(Values in ppm)

- < 11.01
- 11.01 - 16.78
- 16.78 - 22.55
- 22.55 - 28.32
- ≥ 28.32

Datum and Spheroid: WGS84
The descriptive statistics shows that the Co concentration in the soils of the coalfield vary between 5.19PPM to 34.27PPM with mean value 18.62PPM and standard deviation 6.01. The diagram shows that only few samples have Co concentration higher than its lower critical limit in soils and no samples are having value up to or beyond upper critical soil concentration of Co (figure-4.27). The spatial distribution figure clearly reveals that three areas have high Co concentration (> 22.55 PPM), one located in western part of the coalfield, other in the central part of the eastern margin and third one in the south-eastern part of the Coalfield (figure-4.28). The first high concentration area has mixed land-use, and the second and the third area have dominantly mining operations. Rest of the part predominantly have concentration lower than 22.55 PPM but above than 16.78 PPM. The main sources of Co, like that of Mn, in soils are parent material and their application as fertilizers. Also Co are known to have a general high availability in soils with relative high clay and high pH (Alloway, 1990). Thus as far as mining and other related uses are concerned they are not seems to have played any important role in the concentration and distribution pattern of Co in the area.

Copper (Cu)

Copper is a transition element with Group II, Period 4 of the Periodic Table with atomic number 29 and atomic weight 63.546. It has two isotopes, $^{63}$Cu and $^{65}$Cu, former being more abundance. Copper is recognised as one of essential and important micronutrient for plants and animals. Kabata-Pendias and Pendias (1984) found that Cu play a lot of roles in plant system like- it complexed with organic compounds of low molecular weight and with proteins; it forms some important enzymes like ascorbic acid oxidase, laccase, tyrosinase; play significant role in some important physiological process-photosynthesis (oxidation-reduction process), respiration, carbohydrate distribution, N reduction and fixation, protein metabolism and cell wall metabolism; water permeability of xylem vessels; controlling the production of DNA and RNA and also involve in plant disease resistance mechanism. Besides these Raheja (1966) also accepts indirect role of copper in synthesis of chlorophyll. The roles of Cu in plant system clearly suggest that its deficiency (generally < 2 PPM dry weight in plant) greatly affect different physiological processes and thereby plant production. Thus copper deficiency in plants may symptomise as wilting, melanism, white twisted tips, reduction in panicle
formation and disturbance of lignifications (Kabata-Pendias and Pendias, 1984). Like other micronutrients excess concentration of Cu in plant is equally harmful. Its toxicity may lead to tissue damage, elongation of root cells, alteration of membrane permeability, peroxidation of chloroplast membrane lipids, inhibition of photosynthetic electron transport, immobilisation of Cu in cell walls, in cell vacuoles and in non-diffusible Cu-protein complexes and may symptomise as dark green leaves followed by induced Fe chlorosis, thick, short or barbed-wire roots, depressed tillering, etc. (Woolhouse and Waker, 1981; Sandmann and Boger, 1980 and Kabata Pendias and Pendias, 1984).

Not only the deficiency or excess of Cu in plant is important, but its balanced relation with other elements is also important for healthy plant system. Elements like Zn, Mo, Fe, P, N, Ca, Cr etc. have antagonistic relationship with Cu that may be due to similar affinity of Cu to proteins and other compounds and thus a unbalance situation may disturb health of plant system.

![Copper Concentration in Soils, Jharia Coalfield graph](image)

Figure: 4.29

187
LEGEND
(Values in ppm)
- < 34.36
- 34.36 - 49.57
- 49.57 - 64.78
- 64.78 - 79.99
- ≥ 79.99

Datum and Spheroid: WGS84

Figure: 4.30
As far as the availability of Cu are concerned it ranks 26th abundant element in the lithosphere with average abundance around 70 PPM which reduced to 24-55 PPM in earth’s crust and it has been further averaged for soils of the world as 30 PPM (Alloway, 1990). Further he identify Cu associates in soil with organic matter, oxides of Fe and Mn, soil silicate clays and other minerals, but the available from the Cu is only $[\text{Cu(H}_2\text{O)}_6]^{2+}$ in acidic soils and $\text{Cu(OH)}_2^0$ in neutral and alkaline soils. Thus Cu extraction by plants from soil is negligible in comparison to its concentration in the soil. A critical limit of 60-125 PPM of Cu concentration in soils has been accepted by Alloway (1990) based on the observations of Kabata-Pendias and Pendias (1984).

The descriptives shows that the Cu concentration in the soils of the coalfield vary between 18.92 PPM to 95.50 PPM with mean value 36.39 PPM and standard deviation 13.07 (table-4.9). Also no soil sample has shown Cu concentration higher than upper critical concentration in soil, only two samples have crossed the lower critical limit (figure-4.29). The distribution pattern of Cu shows that there is one area located in the central part of eastern margin of the coalfield which have Cu concentration greater than 64.78 PPM (figure-4.30). The central part of the southern half and north-western part and also few scattered patches have Cu concentration below 34.36 PPM while rest other part have concentration between these two categories. Although low concentration seems to have some association with low intensity coal mining or no coal mining activity but medium and high concentration area covering large part of the coalfield have shown no such associations. Alloway (1990) has accepted, Cu smelting, use of agrochemicals, land application of sewage sludge, passing high tension electricity cables, fly-ash etc. as potential source of Cu pollution in soil. He further accepted Cu pollution due to fly-ash would be negligible and while other possibilities in this coalfield seems bleak. So, there does not exist any direct correspondence between Cu concentration in soils of the coalfield and different types of mining there.

**Lead (Pb)**

Lead is a bluish-white lustrous heavy metal placed in period 6, Group 14 of the Periodic Table with its atomic number 82 and atomic weight 207.2. In total 31 isotopes of lead are known to the world out of which 27 are radioactive and natural lead is a mixture of rest 4 isotopes $^{204}\text{Pb}$, $^{206}\text{Pb}$, $^{207}\text{Pb}$ and $^{208}\text{Pb}$. Kabata-Pendias and
Pendias (1984) observe that though lead occurs naturally in all plants but, Kabata-
Pendas and Pendas (1984) and Alloway (1990), also says there is not significant
evidence to suggest that Pb plays any essential role in plant metabolism. Even if so, a
very small fraction 2-6 PPB ($10^{-3}$ PPM) in plant would be sufficient for the need
(Broyer et al., 1972). Although a very small portion of lead in soil is available for
plant uptake but since it has long residence time, Pb and its compounds tend to
accumulate in soils and sediments due to low solubility and relative freedom from
microbial degradation and thus a positive relation can be seen in concentration of Pb
in soils and that in the plants (Alloway, 1990). Increased concentration of lead in
plant may produce toxic effect on processes such as photosynthesis, mitosis and
water absorption and if may reflected by dark green leaves, wilting of older leaves,
stunted foliage and brown short roots (Kabata-Pendas and Pendias, 1984). Now
interaction of Pb with other trace element is also significant for plant system. It
stimulates the effect of Cd but have an antagonistic relationship with Zn (Kabata-
Pendas and Pendia, 1984). They further agree that Pb can mimic the physiological
behavior of Ca to inhibit some enzymes.

Now as far as lead concentrations in the environment are concerned, Alloway
(1990) notices it ordinarily as a trace element (< 0.1 per cent by weight) in rocks and
soils. Kabata-Pendas and Pendias (1984) have view that Pb has tendency to
concentrate in acid series of magmatic rocks and argillaceous sediments (ranges
generally from 10-40 PPM) while in ultramafic rocks and calcareous sediments its
concentration is low (0.1 to 10 PPM). Further they say natural Pb content in soil is
inherited from parent rocks, but widespread Pb pollution most likely to enrich this
metal in soils especially in the top horizon. Thus they accept natural occurrence of Pb
in top horizon range from 3 to 189 PPM with average value of 32 PPM and in
surface soil this average could be 25 PPM. Keeping in mind different complex
relation of Pb with plants and with other elements Alloway (1990) based on Kabata-
Pendas and Pendias (1984) accepts critical concentration of Pb in soil as 100-400
PPM.
The descriptive statistics shows that the Pb concentration in the soils of the Jharia Coalfield vary between 11.18 PPM and 357.90 PPM with mean value 55.16 PPM and standard deviation 49.71 (table-4.9). It is also evident that only 7 samples have crossed the lower value of critical soil concentration of Pb and no soil samples have shown value in excess to upper limit of the critical soil concentration (figure-4.31). The spatial distribution map reveals that there are three pockets, one located in central part of the northern half, and other two near boundary margins in the eastern half of the coalfield which have values higher than 80.57 PPM (figure-4.32). Entire rest of the coalfield has Pb concentration below it. It shows high lead concentration in the coalfield have tendency of localization. Alloway (1990) has suggests Pb mining and smelting, vehicle exhaust, sewage sludge, coal, plastic, rubber factory, insecticide, car batteries etc. as the possible sources of higher lead concentration in soil. All of three high concentration area of lead in soils of the coalfield are clearly associated with open cast mining area or close to it. Here higher concentration may be due to vehicular exhaust, rehandling of coal etc.
Figure: 4.32

LEGEND
(Values in ppm)
- < 80.57
- 80.57 - 149.41
- 149.41 - 218.25
- 218.25 - 287.09
- ≥ 287.09

Datum and Spheroid: WGS84
Molybdenum (Mo)

Molybdenum is a silvery white hard metal placed in Period 5, Group 6 of the Periodic Table with atomic number 42 and atomic weight 95.94. There are 35 known isotopes of Mo ranging in atomic mass from 83 to 117 but only seven occur naturally. $^{98}\text{Mo}$ is the most abundant isotope of it. Mo is an essential micronutrient, but the physiological requirement of this element is relatively low (Kabata-Pendias and Pendias, 1984). Further plant takes up Mo mainly as molybdate ion and is moderately mobile in plants. Mo is essential component of nitrogenase (nitrogen fixation) and nitrate reductase enzymes; essential for nitrogen fixation and nitrogen assimilation and is also present in enzymes catalyzing diverse and unrelated reactions (Kabata-Pendias and Pendias, 1984 and Brady and Weil, 2002). Since Mo is very closely related to nitrogen metabolism so the plant requirement of Mo is also related to its N requirement and any deficiency of Mo will produces similar symptoms as that of N deficiency. Not only plants but also certain microorganism like Rhizobium which fixes nitrogen, requires Mo to function properly. Thus legumes generally have higher Mo requirement. Severe Mo deficiency in some plant may even cause disturbed replication and transcription of DNA which may damage plant reproductive structure (Bozhenko and Balycieva, 1977). Kabata-Pendias and Pendias (1984) summarises the deficiency symptoms of Mo in plants as chlorosis of leaf margins, ‘whiptail’ of leaves and distorted curding of cauliflower, ‘fired’ margin and deformation of leaves due to $\text{NO}_3$ excess, and destruction of embryonic tissues. Excess concentration of Mo in plants are not very common, but 10-50 PPM in mature leaf tissue is regarded as toxic to plant and can lead to molybdenosis in livestock grazing over them (Kubota, 1985). Molybdenum toxicity in plant is reflected by yellowing and browning of leaves, depressed root growth, depressed tillering, etc. (Kabata-Pendias and Pendias (1984). In plant system study the complex relation of Mo with other elements are also important. Mo and Cu are in antagonistic relation with each other and they strongly affect N metabolism. Mo has antagonistic as well as synergistic relation with S. Mo is also antagonistic with Mn & Al but it has synergistic relation with P. Although Mo uptake and use by plant system depends upon variety of factors still its availability in soil is one necessary factor.

Kabata-Pendias and Pendias (1984) observe that terrestrial abundance of Mo reflects its higher concentrate (1-2 PPM) in granitic and other acidic magmatic rocks and also organic-rich argillaceous sediment have its content above 2PPM. Further
they accept Mo content in soil usually resembles their parent rocks to range between 0.013 to 17.0 PPM with world average of 2.0 PPM. But Mo availability is strongly pH-dependent with anionic availability increasing at higher pH due to hydroxyl ion completion for specific absorption sites (Alloway 1990). Further he accepts that poorly drained soils often have highly levels of available Mo; these soils are often of high pH and organic status, which favours the mobilization of anions. Keeping in mind above facts Alloway (1990), accepts Mo contamination as localised and agree with Kabata-Pendias and Pendias (1984) to accept 2-10 PPM as critical Mo concentration in soils.

Figure: 4.33
The descriptive statistics shows that Mo concentration in the soils of the coalfield vary from 1.21 PPM to 3.33 PPM with mean value 2.07 PPM and standard deviation value 0.36 (table-4.9). Further no samples have shown Mo concentration near to or above higher limit of critical soil concentration but a considerable number of samples have shown its concentration beyond lower limit of critical soil concentration (figure-4.33). Spatial distribution of Mo clearly shows that in four pockets of the area have Mo concentration beyond 2.07 PPM (2 PPM is lower critical limit) and only in south-western part its concentration is predominantly below 2.07 PPM (figure-4.34). An area around north-eastern margin of the coalfield have Mo concentration even beyond 2.91 PPM. Alloway (1990) suggest that besides parent rocks, Mo concentration in soils may be influenced by soil pH, fertilizer use, manufacturing and oil refining industries, burning of fossil fuels, sewage sludge, fly-ash etc. Mo distribution pattern in the soils of the coalfield do not reflect that it is directly associated with open cast or underground mining activities in the area, but may have some association with the burning of fossil fuels and fly-ash which have caused its widespread moderately high concentration in the soils of the coalfield.

**Chromium (Cr)**

Chromium is a steel grey, lustrous, hard, metal of d-block, placed in Period 4, Group 6 of the Periodic Table with atomic number 24 and atomic weight 51.9961. It has four known isotopes of which $^{52}$Cr is most abundant. Cr may exist in number of oxidation states (+2 to +6) but Cr(III) and Cr(VI) are most stable. Cr(VI) is an anion, it is more readily extracted from soil and sediment particles and is considered a more toxic from whereas Cr(III) are less mobile and absorbs to particulates more strongly (Alloway, 1990). As far as nutritional value of Cr is concerned Mertz(1969) and Alloway (1990) have view that while stimulatory affect on growth of Cr are noticed on plants grown over soil that have low soluble Cr content, but there is no significant evidence to suggest Cr is an essential plant nutrient.
Figure: 4.34
On the other hand high Cr concentrations in plants are regarded as highly toxic to many plants. Shanker et al. (2005) observe Cr toxicity may inhibit electron transfer; inactivation of Calvin Cycle enzyme; reduce CO\textsubscript{2} fixation; disorganises chloroplast; decrease water potential and increase transpiration; reduce diffusive resistance; wilting; reduction in tracheary vessel diameter; uptake of N, P, K, Fe, Mg, Mn, Mo, Zn, Cu, Ca and B affected; inhibit assimilatory enzymes; increase activity of ROS scavenging enzymes; change glutathione pool and no production of phytochelatins to several plants and in turn all these lead to adverse effect on germination; root, soot and leaf growth and yield and dry matter production. Kabata-Pendias and Pendias (1984) summarises symptoms of Cr toxicity in plants in the form of chlorosis of new leaves, injured root growth, chlorotic bands on cereals, wilting of tops and brownish-red leaves.

Now as far as the availability of Cr are concerned its highest concentration are found in ultramafic and mafic rocks (200-1600 PPM) while in acid igneous and sedimentary rocks Cr concentration vary between 5 to 120 PPM. Thus the soils developed over mafic and ultramafic rocks have higher Cr concentration. Kabata-Pendias and Pendias (1984) estimated grand means concentration of Cr in world soil to be 65 PPM. Since Cr (III) the most suitable and plant usable variety of Cr decreases its solubility at pH 4 and above pH 5.5 it starts precipitating, so plants uptake of Cr is very low and it is very stable in soils. All these consideration might lead to setting up a critical Cr concentration in soils as 75-100 PPM by Kabata-Pendias and Pendias (1984) and also agreed upon by Alloway (1990).
The descriptive statistic shows that the Cr concentration in the soils of the coalfield vary between 82.46 PPM to 239.82 PPM with mean value 144.41 PPM and standard deviation 31.18 (table-4.9). The Cr concentration in different soil samples show that there are only 3 soil samples which has shown Cr concentration between lower and upper critical limit of its concentration in soil and rest other exceeding even the upper critical limit (figure-4.35). The figure (figure-4.36) shows that areas with high concentration are scattered here and there in the coalfield while area with relatively low Cr concentrations are found in three pockets along peripheral part of the coalfield. Alloway (1990) identify fertilizers, animal manures, refractory bricks, coal combustion, iron and steel industry, sewage sludge, etc some of the important anthropogenic source of Cr high concentration in soil. In the case of the Jharia Coalfield coal combustion and metallurgical activities etc. may be regarded as main reason for widespread higher concentration of this metal in soil.
LEGEND
(Values in ppm)
- < 114.00
- 114.00 - 145.40
- 145.40 - 176.80
- 176.80 - 208.20
- ≥ 208.20

Datum and Spheroid: WGS84

Figure: 4.36
Vanadium (V)

Vanadium is a soft, ductile, bright white metal placed in Period 4, Group 5 of the Periodic Table with its atomic number 23 and atomic weight 50.9415. It has two isotopes $^{50}\text{V}$ and $^{51}\text{V}$, the latter is most abundant (99.75 per cent). Vanadium is a ubiquitous element in the biosphere, and trace levels are detectable in most living organisms. However, the role it plays in the metabolism of these organisms is currently a matter of debate. Although it has been recognized as an essential micronutrient for certain green algae (Arnon and Wessel, 1953), possibly of certain marine macroalgae (Fries, 1982) and is a specific catalyst of N$_2$ fixation and may partially substitute for Mo in this function (Kabata-Pendias and Pendias, 1984), but there is little evidence in support of their essentiality for higher plants. There is no evidence of V deficiency in higher plants was observed (Kabata-Pendias and Pendias, 1984), and if it is an essential element in higher plant then their tissue concentration of less than 2 PPB ($10^{-3}$ PPM) (dry weight) would be sufficient for plant (Welch and Cary, 1975). The proportion of ‘extractable’ V in soil is linked to extractant, soil type and drainage (Alloway, 1990). Further Kabata-Pendias and Pendias (1984) notices soluble soil V are easily taken up by plant roots and some plant species show a great ability to accumulate this metal.
Thus possibility of phytotoxicity due to its higher concentration in plants cannot be ruled out. However, concluding research in this field are still lacking, but V phytotoxicity was reported in early studies of phosphate fertilizers (Brenchley, 1993); on soya bean (Warington, 1951 and Warington, 1954); reduction in dry matter content in bush bean (Wallace et. al.1977); growth reduction in cabbage (Hara et. al., 1976); considerably reduced seedling growth (Lepp. 1977) etc.

Now as far as its availability is concerned V is ubiquitous in lithosphere with mean crustal abundance 150 PPM (Alloway, 1990) Further, in basic igneous rock V concentration is higher than acid and silicic igneous rocks (Jastrow et. al., 1981) and the concentration in metamorphic and sedimentary rocks comes in intermediate position. The V content of a soil depends upon the parent material and the pedogenic processes associated with its development (Alloway, 1990). Kabata-Pendias and Pendias (1984) estimated average V content of soils in the world to be 90 PPM. Based on the various research works further they accepted 50-100 PPM as critical level of V concentration in any soil. Alloway (1990) has also accepted it.
JHARIA COALFIELD
VANADIUM CONCENTRATION IN SOIL

LEGEND
(Values in ppm)

- < 131.48
- 131.48 - 180.81
- 180.81 - 230.14
- 230.14 - 279.47
- ≥ 279.47

Datum and Spheroid: WGS84

Figure: 4.38
The descriptive statistics shows that the minimum value of $V$ in the soils of the Jharia Coalfield is 82.05 PPM whereas its maximum concentration is 328.93 PPM with mean value 154.52 PPM and standard deviation 40.85 (table-4.9). The bar diagram showing the $V$ concentration in individual soil samples reveals that all samples have $V$ concentration higher than the lower critical limit while a large number of samples have also crossed the upper critical limit for $V$ concentration in soil (figure-4.37). The figure representing the spatial distribution pattern of $V$ concentration in the soil of the coalfield also reflect clearly the same point (figure-4.38). Alloway (1990) has accepted combustion of fossil fuels and wastes such as fly-ash, etc. as the major source of anthropogenic $V$ pollution in soil. High concentration of $V$ in soils of the Jharia Coalfield clearly reflects this point.

4.4 Chemical Index of Alteration (CIA)

Formation of soil is a very slow process and it takes about more than thousand years to make few centimeter of valuable top soil. Soils mostly have contents derived from their parent rock. Rock weathers at different rate depending upon its geochemical property and geo-environment of the locale. Higher rate of weathering indicates relatively faster rate of soil formation. As the rock weather it changes the physical, chemical and biological properties of the soils in their vicinity. Among different type of weathering, chemical weathering is known to affect along with rate of soil forming process, soil physical as well as mineralogical behaviours in a big way.

Different indices have been developed to measure the rate of chemical weathering based on the assumption that behaviour of chemical elements are controlled solely by the degree of weathering or more specifically as the intensity of weathering increases proportion of some immobile elements remain constant whereas of mobile elements decreases (Ceryan, 2008). Chemical Index of Alteration (CIA) is a similar index developed by Nesbitt and Young (1982) to measure the weathering rate of an area. Using this index degree of weathering can be estimated using following expression-

$$\text{CIA} = \frac{(\text{Al}_2\text{O}_3 \cdot (\text{Al}_2\text{O}_3 + \text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O}))}{100}$$ (After Nesbitt and Young, 1982)
LEGEND

- < 72.63
- 72.63 - 78.53
- 78.53 - 81.67
- 81.67 - 83.93
- ≥ 83.93

Figure: 4.39
CIA value for average shales ranges from 70 to 75, which reflects the composition of muscovites, illites and smectite. Intensely weathered rock yields mineral compositions trending towards kaolinite or gibbsite and a corresponding CIA that approaches 100 (Das and Dhiman, 2003). High values (76-100) indicate intensive chemical weathering in the source area whereas low values of 50 or less indicate unweathered areas (Shehata and Abdou, 2008). In the present study the same concept has been used to understand the degree of weathering in the coalfield (Appendix-V).

The descriptive statistics (table-4.9) shows that the value of CIA vary between 59.94 and 92.20 with its mean value 82.92 and very low standard deviation. Only in few scattered pockets located in south-eastern part and north-western part the CIA value is lower than 78.53 and in rest of the part it is above it (figure-4.39). Even a considerable area in the central and eastern part of the coalfield have CIA value above 83.93. It shows that rate of chemical alteration is very high in the coalfield and thereby soil forming processes are a bit faster. Thus addition of fresh minerals from parent material to the soil of the area is good. This natural process is helpful in maintaining soil quality of the area.

4.5 Soil Degradation Index (SDI)

Soil quality is a very complex concept in which physical, chemical and biological factors needs to be addressed. Also the quality of soil may vary according to the purpose or use. Thus same soil may be good for one purpose but may not suitable for the other. Here it may be noted that the concept of soil quality is a dynamic and the quality of same soil may change over time. Any change in soil properties whether physical, chemical, biological and/or a combination of more than one which makes it less suitable for a particular purpose lead to degradation in its quality. Soil degradation is a long-standing environmental issue which has received wide attention in recent years (Feddema, 1999; Fairhead and Scoones, 2005). Soil degradation is incompatible with sustainable development (Paza et al., 2006). Soil degradation is associated with long term change in ecosystem functions, changes physical structure and chemical components of soils, reduces soil nutrients, declines land productivity, biodiversity, and diminishes economic viability (Melegy, 2005). Sveistrupa et al. (2005) observes that landscape pattern impacts physical, chemical, and biological process of soil which further impacts on complex interaction between
natural environment and human activities and cause change of individual element in soil system and the spatial variations of the soil properties. This concept can be used to understand land degradation of any area.

Various index has been developed to assess the degradation of land in spatio-temporal context. Here the soil degradation index (SDI) as developed by Yugang et al. (2007) has been used. SDI is a measurement of soil degradation that takes the sample mean of a soil property as the reference value in a soil type of a landscape type, and then calculate the deviation of each soil sample to the reference value, finally calculate the weighted average of all soil properties by taking the reference values as weights (Yugang et al., 2007).

\[
SDI = \frac{\left(\frac{p_1 - p'_1}{p'_1} + \frac{p_2 - p'_2}{p'_2} + \frac{p_3 - p'_3}{p'_3} + \cdots + \frac{p_n - p'_n}{p'_n}\right)}{n}
\]

(After Yugang et al., 2007)

Where, \(p'_1, p'_2, p'_3, \ldots, p'_n\) are measured sample means of soil property 1, 2, 3, \ldots, \(n\) under a reference landscape type in the same soil type; \(p_1, p_2, p_3, \ldots, p_n\) are soil sample values of each soil property under all landscape type in the same soil type.

Positive and negative values of SDI show better or poor quality of soil in comparison to the reference soil type respectively. Also higher the value of the index higher be the degree of betterment or poorness of the soil as the case may be.

It is well recognised that in most of the cases human starts exploitation of a land resource first by cutting forest covers which has developed over a long period of time in an undisturbed natural conditions. Thus such area may represent most pristine state of soil. As the exploitation of a land proceeds it leads to many changes in pristine properties of soil. Such undisturbed natural forest area (Li et al., 2003; Adejuwon and Ekanade, 1998) and also any undisturbed, geo-environmentally fully developed vegetated area (Yugang et al., 2007) in any locality may be taken as reference landscape to asses soil quality in that area. In the present study the most pristine landscape of the coalfield is taken as naturally matured and least disturbed ‘dense vegetation’ category of the land-use as classified in the chapter three. Here dense vegetation developed by plantation has not been considered in deciding reference landscape due to human interference there. In total 21 soil properties,
proportion of sand, silt, clay, coarseness, pH, EC, TDS, Co, Ni, Pb, Zn, Cr, Cu, Mo, V, Mn, Fe, Al, Ca, K and Na in soil were taken from two locations (sample no. 15 and 53) and averaged to get reference soil quality for the area.

The descriptive statistics of SDI shows that it ranges from -120.86 to 3.24 (table-4.9). The mean SDI value is -11.16 whereas its standard deviation is 16.77. It indicates that the general soil quality of the study area is poorer in contrast to the reference soil quality. Three prominent type of soil quality area can be identified (figure4.40). Most part of the coalfield area has slightly poor quality of soil than the reference soil. Here the SDI value varies between -16.29 to 0. Soil within this range of SDI value has its spread over all part of the coalfield and found associated with all types of prevailing land-uses of the area. Thus in most part of the coalfields soil degradation is relatively higher than reference soil. Further, soil with very poor SDI value (< -16.29) found in few medium and small size scattered patches. They are mostly associated with open cast mining areas but their presence can also be felt in underground mining areas. They are not seen associated with any non-mining area. It show that very high soil degradation are closely related with mining areas in general and with open cast mining areas specifically. But since these areas are not present in the entire open cast or underground mining areas and so there is possibility that where mining land management are poor such degradation is high and by adopting suitable land management practices the adverse impact of mining on soil can be minimised. Besides these two SDI categories there is one small patch and few very small scattered patches which are marginally better than the reference soil. Thus the Jharia Coalfield has widespread land degradation but it is only very high degraded land category which shows some association with prevailing land-use there.
LEGEND

SDI

-120.71 - -62.43 Important Land-use

-62.42 - -30.38 Open Cast Mining Blocks (BCCL)

-30.37 - -16.3 Underground Mining Blocks (BCCL)

-16.29 - 0 TISCO

0.01 - 3.13 IIISCO

0.01 - 3.13 Open Cast Mines

Not in Mining Use

Datum and Spheroid: WGS84
4.6 Conclusions

Different land-use reflects the particular way of utilising a piece of land. Thus such land-use may create some change in the natural soil properties of an area. In the Jharia Coalfield though in general the entire coalfield is bias towards coarse texture and soil coarseness but soil of open cast mining areas have relatively more coarse texture and are stonier than other areas. Also because of sufficient presence of finer grades of sand in the soil of the coalfield, at many places coarse soil texture is not as problematic as stony nature of soil is. Chemically the soil of the coalfield may be regarded as slight acidic and some liming may be suggested at some places. Further the value of electrical conductance and total dissolved salt do not show any extremes to hinder normal agriculture activity. Among concentration of different heavy metals only few like Fe, Cr and V have clearly shown high concentration and most of others are either below critical soil concentration or some of soil samples have crossed lower limit of critical soil concentration. Thus heavy metal pollution as measured here do not show any alarming trend but some caution may be taken especially with respect to those metals which have relatively higher concentration than required. Further, the general rate of soil weathering and soil degradation as measured here show that the soil forming process in the area is faster but most of the soil of the coalfield has poor soil quality than the reference soil. Also spatial distribution of all these soil properties show a mix kind of relation in which some soil properties seems associated with prevailing land-use of the area while others are not.