



PHYSICO-CHEMICAL CHARACTERISTICS OF SOIL AND INFLUENCE OF CATION EXCHANGE CAPACITY OF SOIL IN AND AROUND CHENNAI

N.Raman* and D.Sathiyarayanan

Department of Chemistry, VHNSN College, Virudhunagar-626 001, India.

E-mail: drn_raman@yahoo.co.in

ABSTRACT

Soil is an essential component for the survival of organisms. In this work, the soil samples collected from 34 places which are located in and around Chennai have been subjected to systematic physico-chemical examination to assess the quality of soil. The data indicate that the quality of soil considerably varies from location to location. This wide variety is mainly due to the waste materials released. From the results obtained during the course of present investigation, the quality of soils in and around Chennai region, most of the soil samples are in the permissible limit except in some places. The pH of the soil is found to be acidic in Tondiyarpet, Oldwashermanpet and Tambaram and neutral in all areas except Vadapalani and Annanagar West. Sodium values are higher in Ponneri, Nandampakkam, Ponnemalli, Westmambalam, T.nagar, Adyar, Kottur and Taramani while the potassium values are normal in all the areas. The Total Organic Carbon and Total Organic Matter are higher in Vadapalani, Annanagar West and the ICF Colony areas. The Values of arsenic and lead are higher in Asock Nagar, Taramani, Ambattur and Tambaram. In Velachery, Nandambakkam, Ambattur and Guindy the soil quality is in polluted condition which is only due to the industrialization. Hence, it is recommended that suitable soil quality management is essential to avoid any further contamination.

Key words: Cation exchange capacity, Chennai, Soil quality, Physico-chemical examination

INTRODUCTION

One of the most serious threats faced today by mankind is the pollution of our environment. In fact, most of the developed countries have already realized that the very existence of life on the earth may be endangered if suitable steps are not taken for the control and abatement of air, soil and water pollution. This is why the industrialized nations are already spending vast sum of money to control the environmental pollution and the developing nations are beginning to follow their example within the constraints imposed by the limited financial resources and the scarcity of trained man power¹. In recent years, the environmental abuse in India has increased rapidly. The modern civilization, industrialization and increase in population have led to fast degradation of our environment. The Government of India showed its commitment for the protection of our environment more than three decade ago by passing the water (Prevention and control of Pollution) Act in 1974, followed by the Air (Prevention and Control of Pollution) Act in 1981. This shows that in India the pollution problems are mostly concerned with the soil pollution. The soil in Chennai is used for numerous industrial activities resulting in many negative effects that curb the production of land. One of the most remarkable problems that encounter the Chennai soil is the excessive drain of wastage of their effluents into the lands. Due to the huge increase in population and the small surface area of agricultural lands, the soil is highly polluted. The accumulation of waste threatens the health of people in residential areas. Waste decays, encourages household pests and turns urban areas into unsightly, dirty and unhealthy places to live in.

Description of the Study Area

Chennai, formerly called Madras, is capital of Tamilnadu and also India's fourth largest metropolitan. It is located on the Coromendal Coast of the Bay of Bengal. It is located at 13.04° N 80.17° E on the

southeast coast of India and in the northeast corner of Tamil Nadu. It is located on a flat coastal plain known as the Eastern Coastal Plains. The city has an average elevation of 6 metres (20 feet), its highest point being 60 m (200 ft). Two rivers are passing through Chennai, the Cooum (or Koovam) in the central region and the Adyar in the southern region. Both rivers are heavily polluted with effluents and trash from domestic and commercial sources. The Chennai Metropolitan area consists of three districts namely Chennai city and the districts of Kanchipuram and Thiruvallur. The city area covers an area of 174 km². The metropolitan area covers 1,177 km². The city is divided on the basis of composition into four major parts: North, Central, South and West. North Chennai is primarily an industrial area. Central Chennai is the commercial heart of the city and the downtown area. South Chennai and West Chennai, previously predominantly residential areas are fast turning into commercial areas, hosting a large number of IT and financial companies.

The geology of Chennai comprises of mostly clay, shale and sandstone. The city is classified into three regions based on geology, sandy areas, clayey areas and hard-rock areas. Sandy areas are found along the river banks and the coasts. Clayey regions cover most of the city. Hard rock areas are Guindy, Velachery, Kodambakkam and a part of Saidapet. In sandy areas such as Tiruvanmiyur, Adyar, Kottivakkam, Santhome, George Town and the rest of coastal Chennai, rainwater run-off percolates very quickly. In clayey and hard rock areas, rainwater percolates slowly, but it is held by the soil for a longer time. The city's clayey areas include T.Nagar, West Mambalam, Anna Nagar, Kolathur and Virugambakkam. Chennai is well known for its Pollution, because it is surrounded by a number of different types of Industries. Most of the Industries dump their wastes in the land both domestic as well as Industrial. This may affect the nature of the soil. Hence, this work aims to analyse the soil samples in and around Chennai.

EXPERIMENTAL

Sampling procedure

The Samples were collected from different areas in and around Chennai. Sampling places were located in the Parks and Residential areas. The samples were collected from January to June during the morning hours. In this work, the samples (34 places: S1-S3) have been subjected to systematic physico-chemical examination to assess the quality of soil to use it for domestic and industrial purposes. The location of the soil collected area is given in Table-1. The methods involved in the preparation of the soil samples for physicochemical analysis are given in Table-2.

Air-drying

The entire sample was spread on a tray and placed beneath the dryer overnight. Microwave drying is a relatively rapid method to dry a few soil samples². However microwave drying appears to change many nutrient analyses as compared to air-drying and is not recommended. Sample handling before affecting Soil Test results has been shown that drying can result in increased release of exchangeable potassium in many soils and in fixation in others³. The fixation tends to occur in recently fertilized soils at higher test levels. The extent of reversion on rewetting varies among soils and is seldom, if ever complete. Increased temperature can increase exchange level⁴.

Sieving with a 2 mm mesh

The sample was crumbled mechanically and passed through a sieve with a 2 mm mesh. Samples containing large stones or clods are first sieved on a 10 mm mesh and then a 5 mm mesh before passage through a 2 mm mesh. The sieved material collected in the tray forms the sample for the 'fine soil' test. Weighing of the material remaining on the sieves, consisting of the sum of the fractions collected on the 2, 5 and 10 mm sieves.

Sample division

If the quantity of 'fine soil' exceeded analytical requirements, an aliquot (maximum 1000 grams) was prepared using a sampler/divider.

Preparation of 're-ground soil'

A fine soil aliquot (20 to 100g) was taken and ground to a homogeneous powder.

pH measurement

Soil pH is normally measured in a soil / water /slurry. The presence of soluble salts will affect pH. For that reason, the pH values of the soil samples were measured in an ELICO pH meter using a mixture of soil and 0.01 M CaCl₂⁵. The standard error in the instrument is ±0.1 pH unit.

Electrical Conductivity

The Electrical Conductivity of the samples was measured in an ELICO Conductivity meter. The standard error in the instrument is ±1.0 μmhos/cm.

Cation Exchange Capacity(CEC)

Cations held on the clay and organic matter particles in soils can be replaced by other cations; thus, they are exchangeable. For instance, potassium can be replaced by cations such as calcium or hydrogen, and vice versa. The total number of cations a soil can hold or its total negative charge is the soil's cation exchange capacity. The higher the CEC, the higher the negative charge and the more cations that can be held. CEC is measured in millequivalents per 100 grams of soil (meq/100g). A meq is the number of ions which total a specific quantity of electrical charges. In the case of potassium (K⁺), for example, a meq of K ions is approximately 6 x 10²⁰ positive charges. With calcium, on the other hand, a meq of Ca²⁺ is also 6 x 10²⁰ positive charges, but only 3 x 10²⁰ ions because each Ca ion has two positive charges.

Measuring Cation Exchange Capacity

Since a soil's CEC comes from the clay and organic matter present, it can be estimated from soil texture and color. Table 3 lists some soil groups based on color and texture, representative soil series in each group, and common CEC value measures on these soils. The cation exchange capacity of soils is important in determining the supplemental potassium needs and appropriates the quantities of soil applied herbicides to use. The estimation of Cation Exchange Capacity by summation of exchangeable calcium, potassium, magnesium and neutralisable acidity is acceptable for most soils⁶. Cation exchange capacity is usually measured in soil testing labs by one of two methods. The direct method is to replace the normal mixture of cations on the exchange sites with a single cation such as ammonium (NH₄⁺), to replace that exchangeable NH₄⁺ with another cation, and then to measure the amount of NH₄⁺ exchanged (which was how much the soil had held). More commonly, the soil testing labs estimate CEC by summing the calcium, magnesium and potassium measured in the soil testing procedure with an estimate of exchangeable hydrogen obtained from the buffer pH. Generally, CEC values arrived at by this summation method will be slightly lower than those obtained by direct measures.

Procedure for CEC

1.3 g of soil was taken in the centrifuge tube. 11 mL of 1N sodium acetate solution was added into the centrifuge tube. It was shaken well and centrifuged. The supernatant liquid was decanted. 11 mL of isopropyl alcohol was added into the centrifuge tube. The centrifuge tube was shaken it well and centrifuged. The supernatant liquid was decanted. 11 mL of 1 N ammonium acetate solution was added into the centrifuge tube. The centrifuge tube was shaken well and centrifuged. The supernatant liquid was poured into the 100 mL flask. The solution in the 100 mL Standard Measuring Flask was made upto 100 mL. The flame photometer was calibrated with standard sodium solution. The made up solution was injected into the instrument and the readings were taken.

Influence of Cation Exchange Capacity

The cation exchange capacity (CEC) is a value given on a soil analysis report to indicate its capacity to hold cation nutrients. The CEC, however, is not something that is easily adjusted. It is a value that indicates a condition or possibly a restriction that must be considered when working with that particular soil. Unfortunately CEC is not a packaged product. The two main colloidal particles in the soil are clay and humus and neither are practical to apply in large quantities. The CEC of the soil is determined by the amount of clay and/or humus that is present. These two colloidal substances are essentially the cation warehouse or reservoir of the soil and are very important because they improve the nutrient and water holding capacity of the soil. Sandy soils with very little organic matter (OM) have a low CEC, but heavy

clay soils with high levels of OM would have a much greater capacity to hold cations. The importance of Cation Exchange in the way soil functions cannot be overstated. It is one of the important mechanisms by which plants obtain nutrients and it has a strong influence over soil structure and agricultural productivity (Fig.1 and Fig.2).

If a soil has a very low CEC, adjustments can and should be made but not solely because of the CEC. A soil with a very low CEC has little or no clay or humus content. Its description may be closer to sand and/or gravel than to soil. It cannot hold very much water or cation nutrients and plants cannot grow well. The reason for the necessary adjustment is not for the need of a higher CEC but because the soil needs conditioning. A result of this treatment is higher CEC. The disadvantages of a low CEC obviously include the limited availability of mineral nutrients to the plant and the soil's inefficient ability to hold applied nutrients. Plants can exhaust a fair amount of energy (that might otherwise have been used for growth, flowering, seed production or root development) scrounging the soil for mineral nutrients. Soluble mineral salts (e.g. Potassium sulphate) applied in large doses to soil with a low CEC cannot be held efficiently because the cation warehouse or reservoir is too small.

RESULTS AND DISCUSSION

The goal of soil testing is to provide guidelines for the efficient use of soil amendments. The Soil Quality Parameters of the various soil samples collected from in and around Chennai areas are shown in the following Tables (Table 4 – Table 6). The Physico-Chemical values of the soil sample collected at different sampling sites were calculated. The result indicates that the quality of soil considerably varies from location to location. This wide variety is mainly due to the waste materials released .

The pH of the samples varies from 5.0 to 8.5. Soil pH is a measure of the acidity of the soil and is a primary factor in plant growth. When pH is maintained at the proper level for a given crop, plants nutrients are at maximum availability, toxic elements are often at reduced availability, and beneficial soil organisms are most active. Most plants prefer a soil pH between 5.5 and 7.5 and the majority do best in the middle part of this range.

The Electrical Conductivity of the samples varies from 60 $\mu\text{mhos/cm}$ to 250 $\mu\text{mhos/cm}$. Soil Electrical Conductivity is a measure of the soils acidity and is a primary factor in plant growth. When Electrical Conductivity is maintained at the proper level for a given crop, plants nutrients are at maximum availability, toxic elements are often at reduced availability, and beneficial soil organisms are most active. Cation exchange capacity (CEC) is an important measure of the soil's ability to retain and to supply nutrients. The Cation Exchange Values lie between 10 me/100g to 30 me/100g. The bulk of this capacity in soils resides in finely divided soil organic matter. A smaller contribution comes from the soil's clay particles. The basic nutrient cations (positively charged ions) of calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+), and the acidic cations of aluminum and hydrogen account for nearly all the adsorbed cations in the soil. Very sandy soils, low in organic matter, commonly have CEC's less than 5. The soils with very high CEC's (greater than 40) are invariably rich in organic matter. A CEC between 10 and 15 is typical and usually adequate.

Individual Nutrients

Phosphate

The phosphate values range from 10 ppm to 1212 ppm. Among other important functions, phosphate provides plants with a means of using the energy harnessed by photosynthesis to drive its metabolism. A deficiency of this nutrient can lead to impaired vegetative growth, weak root systems, and fruit and seed of poor quality and low yield.

Potassium

The potassium values range from 100 ppm to 586 ppm. Potassium rivals nitrogen as the nutrient element absorbed in greatest amounts by plants. Like nitrogen, a relatively large proportion of plant-available potassium is taken up by crops each growing season. Plants deficient in potassium are unable to utilize nitrogen and water efficiently, and are more susceptible to disease. Most available potassium exists as an exchangeable cation. The slow release of potassium from native soil minerals can replenish some of the

potassium lost by crop removal and leaching. This ability, however, is limited and variable. Fertilization is often necessary to maintain optimum yields.

Sodium

The sodium values range from 150 ppm to 2050 ppm. Sodium rivals nitrogen as the nutrient element absorbed in greatest amounts by plants. Like nitrogen, a relatively large proportion of plant-available sodium is taken up by crops each growing season. Plants deficient in sodium are unable to utilize nitrogen and water efficiently, and are more susceptible to disease. Most available sodium exists as an exchangeable cation. The slow release of sodium from native soil minerals can replenish some of the sodium lost by crop removal and leaching. This ability, however, is limited and variable. Fertilization is often necessary to maintain optimum yields.

Calcium

Calcium values range from 0.1% to 0.3%. Calcium is essential in the proper functioning of plant cell walls and membranes. Sufficient calcium must also be present in actively growing plant parts, especially storage organs such as fruits and roots. Properly limed soils with constant and adequate moisture will normally supply sufficient calcium to plants. High humidity and poor soil drainage hinder calcium movement into these plant parts and should be avoided.

Magnesium

Magnesium values also range from 0.1% to 0.3%. Magnesium acts together with phosphorus to drive plant metabolism and is part of chlorophyll, a vital substance for photosynthesis. Low magnesium levels in many soils will normally not cause problems provided the exchangeable cations are in good balance. If Mg levels are low and lime is required, dolomitic lime (rich in Mg) will be recommended. If Mg is low and lime is not required, Epsom salt (magnesium sulphate) may be incorporated at a rate of 5-10 lbs/1000 square feet.

Toxic Heavy Metals

Lead is naturally present in soils in the range of 15 to 40 parts lead per million parts soil (ppm). At these levels it presents no danger to people or plants. Soil pollution with lead-based paints and the tetraethyl lead of past automotive fuels have increased soil lead levels to several thousand ppm in some places. Unless the total lead level in soil exceeds 150 ppm, it is simply reported as low and can be considered safe (assuming the sample submitted is representative of the area of concern). Values above 300 ppm are potentially dangerous to people. In such cases it should be consulted the separate insert on soil lead levels.

Arsenic is extremely toxic to both plants and animals. It is naturally present in soils at safely low levels (less than 1 ppm). Industrial discharges of arsenic, however, often cause municipal sewage sludge to contain elevated levels of arsenic. Composted sludges are often used as soil amendments. Although safe upper limits of arsenic for both plants and animals have not been established, monitoring soil arsenic levels helps to avoid excess when such materials are used. Unless the arsenic in the soil exceeds 1 ppm it is not reported.

Total Organic Matter and Total Organic Carbon

Total Organic Matter and Total Organic Carbon such as those used on roads to promote melting and those present in many commercial (and some natural) fertilizers, can cause severe water stress and nutritional imbalances in plants. Generally, seedlings are more sensitive than established plants to elevated TOC and TOM levels and great variation exists between plant species. Most soils have values between 0.5 and 1.3. Values higher than 0.60 may cause damage to sensitive plants (such as onions, etc.). A TOC and TOM level can change rapidly in the soil due to leaching (washing out), so evaluating its significance must consider the effects of time and growing conditions. Excessive TOC and TOM levels can often be corrected by leaching with liberal amounts (2 to 4 inches) of fresh water.

Iron

The iron is essential to plants, but required in very small amounts. In most properly limed soils they are available in sufficient quantities. The values of iron lie between 0.1% to 1.24 %.

CONCLUSION

With increasing awareness in the field of soil quality, it is expected that the approach described in this work will be proved a useful tool in evaluating the quality of soil to be utilized for various beneficial uses. From the results, the quality of soils in and around Chennai region, most of the Soil Samples are in the Permissible Limit except in some places. In Velachery, Nandambakkam, Ambattur and Guindy the soil quality is in polluted condition which is only due to the industrialization. Hence, it is recommended that suitable soil quality management is essential to avoid any further contamination.

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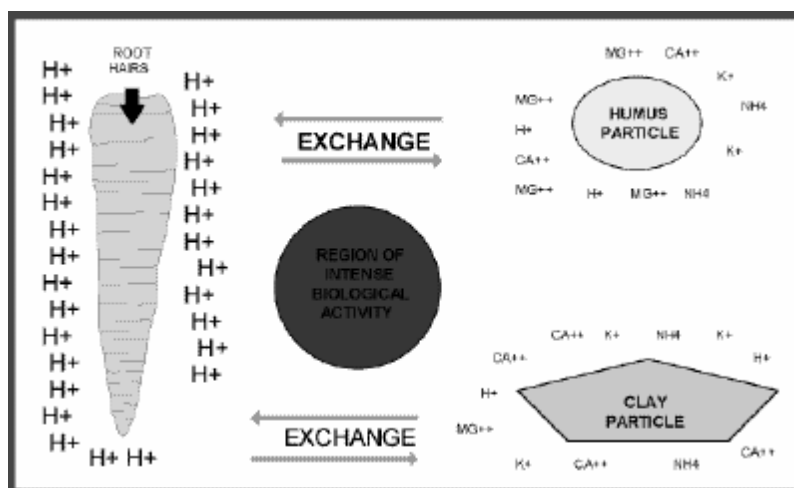


Fig.- 1: Schematic diagram for **Cation Exchange**

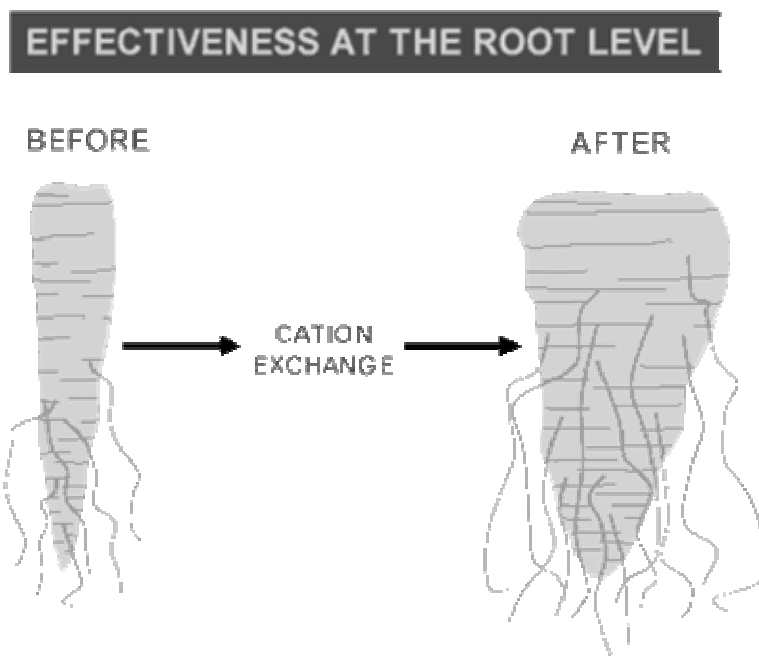


Fig.-2: Cation Exchange after and before effectiveness

Table-1: Locations of collected soil samples

S.No	Sample identification	Soil sample collected area	Location
1	S1	Tondiyarpeta	Back side of the Aksthya theatre
2	S2	Old Wahermanpet	On the way of the Thiruvottiyur highway
3	S3	George down	Near to the bridge
4	S4	Royahpettah	Front of the Government Hospital
5	S5	Manali	Nearer to IOCL
6	S6	Ponneri	Nearer to Bus-stand
7	S7	Ambattur	Nearer to Ambattur Clothing Company
8	S8	Saidapet	Near to the river of Koovam down to the bridge
9	S9	Guindy	Inside the industrial area and nearer to the CIPET
10	S10	Nandampakkam	Nearer to the Trade Center
11	S11	Porur	Nearer to the Junction
12	S12	Ponnamalli	Nearer to the Bus-stand
13	S13	West Mambalam	Nearer to the Park
14	S14	T.Nagar	Nearer to the Market
15	S15	Adyar	In Kamarajar 2 nd Street
16	S16	Kottur	Behind to the Railway Station
17	S17	Taramani	Nearer to Bus-stand

18	S18	Velachery	Velacherry–Taramani Highway
19	S19	Rajaannamalaipuram	Nearer to the Hotel Sherington
20	S20	Mandaveli	Behind the Bridge
21	S21	Mylapore	Nearer to the Palace
22	S22	Kodampakkam	Nearer to the Railway Station
23	S23	Ashok Nagar	Near to the Pillar
24	S24	Vadapalani	Nearer to Tata Consultancy Services
25	S25	Anna Nagar west	Nearer to Bus-stand
26	S26	ICF Colony	Nearer to the Railway Station
27	S27	Nungampakkam	Nearer to the Railway Station
28	S28	Chetpet	Industrial Area
29	S29	Egmore	Nearer to the Railway Station
30	S30	Pudupet	In the Market
31	S31	Sindadaripet	Nearer to Railway Station
32	S32	Meenampakkam	In the Highway, nearer to Airport
33	S33	Pallavaram	Industrial area of Pallavaram
34	S34	Tambaram	Nearer to the Government Hospital

Table-2: The methods involved in the preparation of the soil samples for physicochemical analysis (Drying / Pulverization/ Protocol⁷ of Soil samples)

S.No.	Test	Type – Temperature – Duration of drying	Amount of soil sample required for test	Degree of pulverization passing IS sieve size	REF to Part of IS:2720
1	Total Organic Carbon & Total Organic Matter	Air drying	100 g	2 mm	Part 22
2	Calcium as Ca & Magnesium as Mg	Oven, 105 – 110°C, 24 h	5 g	--	Part 23
3	pH	Oven, 105 – 110°C, 24 h	30 g	425 micron	Part 26
4	Electrical Conductivity	As received basis	10 g	--	IS 14767:2000
5	Cation Exchange Capacity	Oven, 105 – 110°C, 24 h	80 – 130 g	--	Part 24
6	Water Content	Oven, 24 h	50 g	2 mm	Part 2
7	Permeability	Oven, 105 – 110°C, 24 h	2.5 Kg (100 mm dia)/ 5 Kg (200 mm dia)	9.5 mm	Part 17

8	Bulk Density	Oven, 105 – 110°C, 24 h	1 Kg	2 mm	Part 29
9	Distribution Texture	Oven, 105 – 110°C, 24 h	1000 g	2 mm	Ref: Methods of Soil Analysis, Tamilnadu Agricultural University
10	Sodium & Potassium	Oven, 105 – 110°C, 24h	100 g	2 mm	Using Flame photometer
11	Total Phosphate as PO ₄ ³⁻	Oven, 105 – 110°C, 24 h	100 g	2 mm	Ref: Methods of Soil analysis, Tamilnadu Agricultural University
12	Sodium Absorption Ratio	Oven, 105 – 110°C, 24 h	100 g	2 mm	Using Flame photometer
13	Total iron as Fe	Oven, 105 – 110°C, 24 h	100 g	2 mm	Ref: Methods of Soil analysis, Tamilnadu Agricultural University
14	Arsenic & Mercury	Oven, 105 – 110°C, 24 h	100 g	2 mm	By Atomic Absorption Spectrophotometer

Table-3. Normal Range of CEC Values for Common Color/Texture Soil Groups

S.No	Soil Groups	CEC in meq/100g
1	Light colored sands	3 – 5
2	Dark colored sands	10 – 20
3	Light colored loams and silt loams	10 – 20
4	Dark colored loams and silt loams	15 – 25
5	Dark colored silty clay	30 – 40
6	Loams and silty clays	50 – 100

Table-4: The Soil Quality Parameters of the various soil samples

S. No.	Test Parameter	Protocol	Result									
			S1	S2	S3	S4	S5	S6	S7	S8	S9	
1	pH	IS 2720: Part 26 – 1987	5.46	5.24	6.06	6.05	5.58	6.58	6.11	6.12	6.02	
2	Electrical Conductivity, μ mhos/cm	IS 14767: 2000	71	77	76	74	83	89	68	72	71	
3	Distribution Texture, %	International Pipette method	%Sand	92	88	87	94	55	94	87	91	90
			%Clay	6	8	10	4	37	4	10	8	8
			%Silt	2	4	3	2	8	2	3	1	2
4	Sodium as Na, mg/kg	By Flame photometer	798	681	744	778	814	1047	916	548	458	
5	Potassium as K, mg/kg	By Flame photometer	200	194	149	194	153	150	102	100	102	
6	Total Organic Matter, (% w/v)	IS 2720: Part 22 – 1972	0.5127	0.5159	0.5145	0.5127	0.5070	0.5180	0.5233	0.5188	0.5271	
7	Total Organic Carbon, (%w/v)	IS 2720: Part 22 – 1972	0.2974	0.2992	0.2984	0.2974	0.2941	0.3005	0.3035	0.3009	0.3057	
8	Cation Exchange Capacity,	IS 2720: Part XXIV – 1976	11.92	15.57	10.76	11.53	10.49	15.08	15.26	10.42	10.75	

	me/100g												
9	Calcium as Ca, (% w/v)	By Complexometric titration	0.08	0.12	0.13	0.12	0.15	0.13	0.34	0.15	0.17		
10	Magnesium as Mg, (% w/v)	By complexometric titration	0.13	0.24	0.17	0.20	0.23	0.36	0.19	0.19	0.27		
11	Total phosphate as PO ₄ ³⁻ , mg/kg	By Colorimetry	92	115	205	103	76	70	83	116	106		
12	Sodium absorption ratio	By Flame photometer	40	26	32	32	31	34	31	22	16		
13	Bulk density, g/cc	IS 2720: Part XXXIV – 1972	1.51	1.47	1.47	1.43	1.31	1.58	1.52	1.50	1.45		
14	Total iron as Fe, (% w/v)	By Colorimetry	0.68	0.43	0.19	0.70	0.80	0.79	1.24	0.20	0.17		
15	Arsenic as As, mg/kg	By Atomic Absorption Spectrophotometer	2.36	3.58	0.36	0.69	2.36	0.29	0.39	2.15	0.58		
16	Lead as Pb, mg/kg	By Atomic Absorption Spectrophotometer	0.56	0.29	5.32	2.36	6.98	2.47	2.36	2.36	3.65		
17	Moisture, (% w/w)	IS 2720 : Part 2 – 1973	5.36	2.58	6.35	5.32	27	3.01	9.21	9.21	6.95		

Table-5: The Soil Quality Parameters of the various soil samples (continuation)

Test Parameter	Result													
	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	
pH	7.05	6.41	5.29	6.29	6.65	7.73	6.64	6.62	7.18	6.49	6.48	8.06	8.47	
Electrical Conductivity, μmhos/cm	148	81	92	74	80	95	77	93	89	101	75	200	150	
Distribution Texture, %	%Sand	92	81	89	84	85	86	91	70	95	92	86	84	96
	%Clay	6	14	8	12	11	10	6	24	4	6	10	10	3
	%Silt	2	5	3	4	4	4	3	6	1	2	4	6	1
Sodium as Na, mg/kg	1346	1119	1196	1402	1246	1201	1197	1404	847	1351	441	1595	1221	
Potassium as K, mg/kg	249	203	199	200	150	150	149	150	100	150	147	199	203	
Total Organic Matter, (% w/v)	0.522 3	0.523 6	0.514 9	0.518 3	0.509 7	0.51 40	0.5066	0.518 4	0.509 8	0.518 8	0.513 3	0.509 1	0.512 8	
Total Organic Carbon, (% w/v)	0.303 5	0.303 7	0.298 7	0.300 6	0.295 6	0.29 81	0.2938	0.300 7	0.295 7	0.300 9	0.297 7	0.295 3	0.297 4	
Cation Exchange Capacity, me/100g	17.55	13.40	12.96	19.90	19.20	16.2 2	14.70	20.69	19.60	20.97	23.01	23.00	21.48	
Calcium as Ca, (% w/v)	0.11	0.13	0.29	1.75	0.85	0.24	0.83	0.22	0.20	0.18	0.38	0.39	0.20	
Magnesium as Mg, (% w/v)	0.16	0.20	0.41	1.06	0.16	0.30	0.45	0.32	0.34	0.30	0.33	0.26	0.20	
Total phosphate as PO ₄ ³⁻ , mg/kg	62	119	145	64	85	59	66	1096	97	56	144	42	51	
Sodium absorption ratio	60	45	33	21	32	39	26	45	27	45	13	48	46	
Bulk density, g/cc	1.54	1.64	1.51	1.45	1.58	1.48	1.59	1.21	1.60	1.51	1.40	1.45	1.49	
Total iron as Fe, (% w/v)	0.62	0.61	0.48	0.60	0.60	0.62	0.59	0.25	0.60	0.10	0.63	0.86	0.44	
Arsenic as As, mg/kg	0.23	0.25	0.58	0.56	2.36	0.87	0.58	2.36	0.26	0.25	0.23	0.58	0.23	
Lead as Pb,	0.59	0.89	0.69	0.89	5.21	2.47	0.69	2.24	0.32	0.69	0.68	0.69	0.56	

mg/kg													
Moisture, (% w/w)	4.23	10.24	6.89	11.02	9.65	9.23	5.21	11	3.02	4.52	8.25	7.89	1.02

Table-6. The Soil Quality Parameters of the various soil samples (continuation)

Test Parameter	Result												
	S23	S24	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	
pH	7.65	6.12	6.09	7.45	6.86	6.28	7.10	6.86	5.89	5.62	5.43	6.20	
Electrical Conductivity, $\mu\text{mhos/cm}$	250	137	115	99	86	131	248	85	75	98	131	111	
Distribution Texture, %	%Sand	93	17	18	12	93	74	85	90	30	28	94	66
	%Clay	5	65	60	70	5	22	9	8	54	60	4	27
	%Silt	2	18	22	18	2	4	6	2	16	12	2	7
Sodium as Na, mg/kg	1156	588	1417	2050	712	814	506	814	759	712	356	150	
Potassium as K, mg/kg	151	254	303	586	305	305	202	204	253	305	204	150	
Total Organic Matter, (% w/v)	0.5140	1.2933	1.2823	1.3022	0.5172	0.5190	0.5154	0.5159	0.5158	0.5158	0.5094	0.5187	
Total Organic Carbon, (% w/v)	0.2981	0.7502	0.7438	0.7553	0.3000	0.3010	0.2989	0.2992	0.2992	0.2992	0.2955	0.3009	
Cation Exchange Capacity, me/100g	25.36	23.86	29.42	26.47	20.47	23.37	22.73	18.73	24.22	21.83	14.11	19.97	
Calcium as Ca, (% w/v)	0.43	0.44	0.95	0.32	0.16	0.39	0.39	0.79	0.15	0.34	0.10	0.09	
Magnesium as Mg, (% w/v)	0.26	0.35	0.34	0.22	0.19	0.19	0.22	0.20	0.23	0.23	0.08	0.07	
Total phosphate as PO_4^{3-} , mg/kg	43	10	1212	91	77	104	70	51	53	51	43	104	
Sodium absorption ratio	34	16	32	68	28	27	16	21	29	23	20	9	
Bulk density, g/cc	1.65	1.38	1.20	1.04	1.48	1.40	1.49	1.61	1.19	1.15	1.60	1.59	
Total iron as Fe, (% w/v)	0.51	0.76	0.31	0.26	0.85	0.86	0.86	0.86	0.85	0.56	0.07	0.70	
Arsenic as As, mg/kg	2.39	2.35	0.56	0.23	0.23	0.56	2.25	0.28	0.23	0.89	0.89	1.23	
Lead as Pb, mg/kg	5.21	5.32	0.87	0.98	0.58	0.98	3.41	0.65	0.56	0.45	0.23	0.56	
Moisture, (% w/w)	1.28	68	55	72	4	9	8	8	27	32	3	11	

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