EFFECTS ON pH BEHAVIOUR OF EXPANSIVE AND NON EXPANSIVE SOILS CONTAMINATED WITH ACIDS AND ALKALIS

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Abstract

The acidic or alkaline characteristics of a soil sample can be quantitatively expressed by hydrogen ion-activity commonly designated as pH. The hydrogen-ion concentration of soil water solution is of interest in problems involving grouting in weak rocks, soil stabilization processes using lime and resinous materials, corrosion of metals in contact with soils and reclamation of marine soils. The pH value also helps in interpreting some of the soil chemical tests. Several factors, soil-water ratio, soluble salts concentration, Carbon dioxide pressure, exchangeable cations and temperature affect the pH value of a particular soil sample. With the dilution of soil suspension, its pH increases. Increase in salt concentration, in general, decreases the pH. A definite relationship exists between Carbon dioxide pressure of soil air and pH, for example, the pH of calcareous is reduced in proportion to the logarithm of Carbon dioxide pressure of soil air. In alkaline soils, the pH is principally influenced by exchangeable cat ions. With increase in temperature, pH decreases. In the present study Attempts were made to study the pH soils treated with optimum percent of alkalis and contaminated with one normal acids. Expansive soil Black cotton soil and non expansive soils Red Earth and Shedi soil are treated individually with optimum percent of alkalis $CaCO_3$ and $MgCO_3$ and contaminated with 1N H_2SO_4 and 1N H_3PO_4 separately. Results of the study indicate that the evaluation factors associated with soil pH therefore are based on the full consideration of the soil constituents and not on pH value alone.

Keywords: *pH, Hydrogen ion concentration, alkalization, acidification and cation exchange.*

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1. INTRODUCTION

Expansive soils are found in arid and semiarid regions of the world where the annual evaporation exceeds precipitation. Hot climate and poor drainage conditions are usually associated with the formation of these soils. The color of these soils varies from deep black to grey and sometimes even reddish to yellowish. In India, these soils are generally called black cotton soil and covers 25% of total land mass. The major mineral present is montmorillonite and composed of units made of two silica tetrahedral sheets with a central alumina octahedral sheet. The tetrahedral and octahedral sheets are combined so that the tips of the tetrahedrons of each silica sheet and one of the hydroxyl layers of the octahedral sheet form a common layer. The atoms are common to both the tetrahedral and octahedral layer become oxygens instead of hydroxyls. The layers are continuous and are stacked one above the other. Exchangeable cations occur between the silicate layers. They tend to occur in equidimensional, extremely thin flake-shaped units and are relatively readily dispersible in water down to extremely small particle sizes. Montmorillionites experience large volume changes upon exposure to climatic change and chemical contamination; they shrink upon drying accompanied by cracking and swell when water comes in contact exerting enormous pressures on the structure. Since black cotton soils cannot be avoided, their properties are altered by many ways like mechanical, thermal, chemical, Electrical or combined and other means to make acceptable or rejected on contamination. The index and engineering properties of the ground gets modified in the vicinity of the industrial pants mainly as a result of contamination by the industrial wastes disposed. The major sources are the disposal of industrial water and accidental spillage of chemicals during the course of industrial operations. The leakage of industrial effluent in to subsoil directly affects the use and stability of the supported structure. Alkali at lower concentration can cause changes to changes in the soil structure; Mitchel [1]. Also the presence of alumina along with alkali on the clay alkali interaction is unknown.

The sand or silty loam essentially forms the natural ground at Bangalore, Karnataka State, India covers 10-15% of land mass called as Red Earth. The non expansive soil has its kaolin group of minerals in which the two layered kaolinite mineral is present; however the major mineral present is quartz. The basic structure unit consists of Gibbsite series (with aluminum atoms at their centers) joined to the silica sheets through the unbalanced oxygen atoms at the apexes of the silica. The mineral thus is not readily dispersible in water into extremely small units. In general, the poorly crystallized kaolinite occurs in less distinct hexagonal flake-shaped masses than the will-crystallized variety, and the particle sizes is generally smaller.

Laterites (Shedi soil deposits) are the ferruginous deposit of vesicular unstratified structure, occurring not far below the surface and have long been known in India where they occupy large areas of Deccan Peninsula. They are the products of intense sub aerial rock weathering whose Fe and /or Al content is higher and Si content is lower than in many kaolinised parent rocks. They consist predominantly of mineral assemblage of goethite, aluminum hydroxide, kaolinite minerals and quartz. Their upper stratum can be converted into lateritic soils by soils forming process. A laterite formation in general consists of top hardened vesicular layer followed by Lithomarge clay layer over the weathered residual soil and parent rock.

Extensive damage to the floors, pavements and foundations of a light industrial building in a fertilizer plant in Kerala State was reported by Sridharan [2], Rao and Sridharan [3]. Severe damage occurred to the interconnecting pipes of a Phosphoric acid tank in particular and also to the adjacent building due to differential movements between pump and acid tank foundations of fertilizer plant in Calgary, Canada was reported by Joshi [4]. Decrease in shear strength of Black cotton soil on account of reduction in diffuse layer thickness due to increase in electrolyte concentration is reported by Sivapullaiah [5]. A similar case of accidental spillage of highly concentrated caustic soda solution as a result of spillage from cracked drains in an industrial establishment in Tema, Ghana caused considerable structural damage to a light industrial building in the factory, in addition to localized subsidence of the affected area is reported by Kumapley and Ishola [6]. The effect of hydroxides on the properties some soils is well known: Ingles [7] [10].

Anand J Puppala, [8] in his investigation on sulfate heave mechanisms in chemical treated kaolinitc and illitic clay observed that the increase in curing temperature enhanced the unconfined compressive strength properties of lime and cement treated soils. A strength decrement of 82% changing the limestone rich soil into a weak soil due to splash from a Sulphuric acid($pH<1$) manufacturing factory in Al-Kaim of North western Iraq was reported by Raid R. AL-Omari [9].

In this investigation an attempt is made to study the effect of acids and alkalis separately on variation of pH behaviour of a Black cotton soil, Red Earth and Shedi soil individually contaminated with acids.

2. MATERIALS USED

The Black Cotton soil is obtained from Davanagere district in Karnataka state of India. This is a residual soil and is collected at a depth of one meter below the natural ground surface. The soil was air dried and passed through IS sieve 425 microns and oven dried before being used for investigation. It is classified as "CH" group as per IS classification (1970). The physical and chemical properties of Black Cotton soil have been listed in table 1 and 2 respectively.

Table -1 Physical Properties of Black Cotton Soil

Color	Black
Specific gravity	2.64
Fine sand	9%
Silt	31%
Clay	60%
Liquid limit	77%
Plastic limit	30.75%
Plasticity Index	49.85%
Shrinkage Limit	8.3%
Optimum moisture Content	33.7%
Maximum dry density	13.8 kPa
Unconfined Compressive strength	299 kPa
Coefficient of permeability	$1.796X10^{-9}$m/sec
Free swell Index	86%
Coefficient of Consolidation Cv	$1.2X10^{-2}mm^2$/sec
Compression Index Cc	0.09 cm^2 /kg

Table -2: Chemical Analysis of Black Cotton soil

Chemical composition	**Percentage**
Silica (SiO_2)	52.85
Alumina(Al_2O_3)	12.24
Ferric Oxide(Fe_2O_3)	8.04
Calcium Oxide(CaO)	6.01
Magnesium Oxide(Mgo)	2.94
Titanium Dioxide(Ti O_2)	0.24
Potassium Oxide (K_2O)	0.48
Sodium Oxide (N_2O)	0.26
Loss of ignition	16.18

The Red Earth was collected at a depth of 1.5 meters at a test pit dug for the proposed Bio-park at the Bangalore University campus, Jnanabharathi. It was air dried and the soil sample for the studies were taken from the collected soil by quartering to ensure uniformity and pulverized and sieved through IS 425 micron sieve before using. The soil is a typical non-expansive clayey soil. The Physical Properties of Red Earth are shown in Table 3. Also the chemical composition of oven dried Red earth was analyzed as per the standards methods and is presented in table 4.

Table -3: Physical Properties of Red Earth

Color	Brick Red
Specific gravity	2.39
Fine sand ()	29 %
Silt ()	23 %
Clay (	48 %
Liquid limit	44.1%
Plastic limit	20.69 %
Plasticity Index	23.41%
Shrinkage Limit (%)	14.3%
Optimum moisture Content	22..5%
Maximum dry density	16.6kPa
Unconfined Compressive strength	237.35kPa
Coefficient of permeability	2.4X10-7 cm/sec
Free swell Index (modified)	1.2cc/g
Coefficient of Consolidation Cv	0.001887mm2/sec
Compression Index Cc	0.0029 m2/KN

Table -4 Chemical analysis of Red Earth

Chemical composition	Percentage
Silicon dioxide	60.4
Alumina	15.05
Iron –oxide	6.6
Titanium dioxide	0.2
Calcium oxide	6.9
Magnesium oxide	1.7
Potassium oxide	0.4
Loss on ignition	8.4
Sodium oxide	0.3

Table -5: Physical Properties of Shedi Soil

Color	Light Pink
Specific gravity	2.43
Gravel fraction (%)	0.00
Sand fraction (%)	85.00
Silt and Clay fraction (%)	15.00
Liquid Limit	26.5
Plastic Limit	16.7
Shrinkage Limit	21.19
Optimum Moisture content (%)	14.5
Maximum Dry Density (KN/cum)	17.7
Free swell Index (cc/g)	0.00
Coe-efficient Permeability (mm/s)	$3.652X10^{-6}$
Coefficient of Consolidation Cv (mm^2/s)	$70.8\ X10^{-3}$
Compression Index Cc (mm^2/s)	$1.69\ X10^{-3}$
Unconfined Compressive Strength (kPa)	220.78

Table -6 Chemical analysis of Shedi Soil

Chemical Parameters		Percentage %
pH		5.42
Calcium (%)		0.002
Sodium (%)		0.039
Potassium (%)		0.000
Chloride (%)		0.008
Sulphate	As SO_4	0.004
	As SO_3	0.003

The Shedi soil used for the present study has been obtained from shedi gudda from a depth of 2 meter below natural ground level, Mangalore, Karnataka state, India. It was dried and sieved through a sieve of 4.75 mm to eliminate grave fraction if any.

Chemicals used in the study are Calcium Carbonate ($CaCO_{3)}$, Magnesium Carbonate ($MgCO_3$), Sulphuric acid (H_2SO_4) and Orthophosporic acid (H_3PO_4).These chemicals have been obtained from Qualigens Fine Chemicals and Sd Fine Chemicals Pvt. Limited, Mumbai India. The Calcium Carbonate and Magnesium Carbonate are in white powder form and insoluble in water but reacts with constituents of any soil. The strength of the acids was reduced to one normal solution. Properties of $CaCO_3$ and $MgCO_3$ are listed table 7.

3. RESULTS AND DISCUSSIONS

3.1 Effect of $CaCO_3$ and $MgCO_3$ on Black Cotton Soil

Increase with the various percentages of Calcium Carbonate and Magnesium Carbonate has successively increased the pH of the Black Cotton soil. However the increase in pH with the increase in percentage Magnesium Carbonate is more compared to increase with percentage Calcium Carbonate due to soil alkali interaction in the presence of water in which hydrogen ion concentration increases significantly. The variations are shown in figures 1 and 2.

Table -7 Properties of Chemicals used

Properties	$CaCO_3$	$MgCO_3$
Molecular Weight	100.1	84.3
Color	White	White
Crystal Symmetry	Rhombic	Trigonal
Refractive Index n_D	1.681	1.51
Density	2.71g/cc	3.05g/cc
Melting Point	825˚C	990˚C
Solubility in 100 parts solvent	0.013g/100ml@ 20˚C,soluble in acids	0.01g/100ml@ 20˚C,soluble in acids
Assay	85%	95%

3.2 Effect of 1N H_2SO_4 and 1N H_3PO_4 on Black Cotton soil

Alkalis treated soils contaminated with 1N H_2SO_4 and1N H_3PO_4 showed drastic decrease in pH. However the decrease in pH by 1N H_2SO_4 is observed more than that with1N H_3PO_4. The decrease in pH indicates the higher acidification of soil and due to increase in Hydrogen ion concentration in soil-alkali-acid mixture followed with immediate soil-alkali-acid interaction. Black Cotton soil alone contaminated with 1N H_2SO_4 and1N H_3PO_4 showed further decrease in pH. The decrease with 1N H_2SO_4 more compared to decrease in pH with 1N H_3PO_4 the variations are shown in figure 3.

3.3 Effect of $CaCO_3$ and $MgCO_3$ on Red Earth

Increase with the various percentages of Calcium Carbonate and Magnesium Carbonate has successively increased the pH of the Red Earth. However the increase in pH with the increase in percentage Magnesium Carbonate is more compared to increase with percentage Calcium Carbonate due to soil alkali interaction in the presence of water in which hydrogen ion concentration increases significantly. The variations are shown in figures 3 and 4.

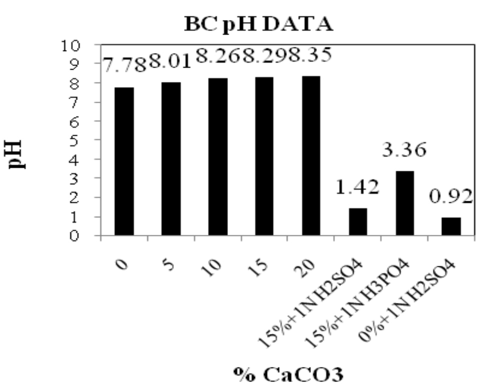

Chart 1 Variation of pH with % of $CaCO_3$ and 1N acids

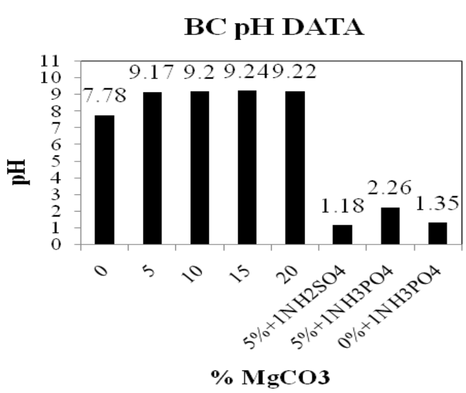

Chart 2 Variation of pH with % of $MgCO_3$ and 1N acids

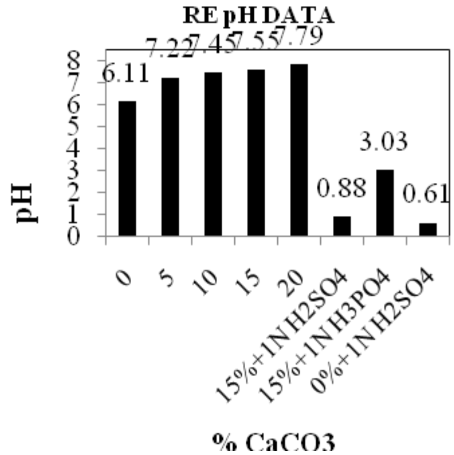

Chart 3 Variation of pH with % of $CaCO_3$ and 1N acids

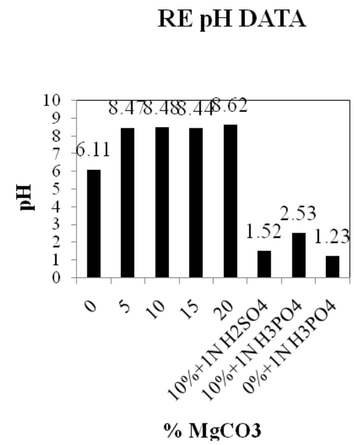

Chart 4 Variation of pH with % of $MgCO_3$ and 1N acids

3.4 Effect of 1N H_2SO_4 and 1N H_3PO_4 on Red Earth

Alkalis treated Red Earth contaminated with 1N H_2SO_4 and1N H_3PO_4 showed drastic decrease in pH. However the decrease in pH by 1N H_2SO_4 is observed more than that with1N H_3PO_4. The decrease in pH indicates the higher acidification of soil due to increase in Hydrogen ion concentration in soil-alkali-acid mixture followed with immediate soil-alkali-acid interaction in which formation of sulphate compounds takes the role of increasing the Hydrogen ion concentration. Red Earth alone contaminated with 1N H_2SO_4 and1N H_3PO_4 showed further decrease in pH. The decrease with 1N H_2SO_4 more compared to decrease in pH with 1N H_3PO_4. 1N H_2SO_4 is the strong acid compared to 1N H_3PO_4 and hence the highest decrease in pH is noticed. The variations are shown in figures 3 and 4.

3.5 Effect of $CaCO_3$ and $MgCO_3$ on Shedi soil

Increase with the various percentages of Calcium Carbonate and Magnesium Carbonate has successively increased the pH of the Shed soil. However the increase in pH with the increase in percentage Magnesium Carbonate is more compared to increase in pH with percentage Calcium Carbonate due to soil alkali interaction in the presence of water in which hydrogen ion concentration increases significantly. The variations are shown in figures 5 and 6.

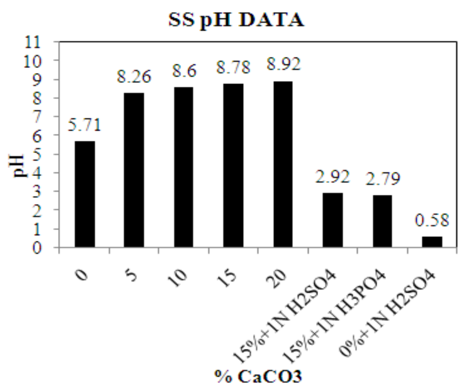

Chart 5 Variation of pH with % of $CaCO_3$ and 1N acids

3.6 Effect of 1N H_2SO_4 and 1N H_3PO_4 on Shedi soil

Alkalis treated soils contaminated with 1N H_3PO_4 and 1N H_2SO_4 respectively showed drastic decrease in pH. However the decrease in pH by 1N H_2SO_4 for $CaCO_3$ treated soil is observed more than that for MgCO3 treated Shedi soil contaminated with1N H_3PO_4. The decrease in pH indicates the higher acidification of soil due to increase in Hydrogen ion concentration in soil- alkali-acid mixture followed with immediate soil-alkali-acid interaction in which formation of sulphate compounds takes the role of increasing the Hydrogen ion concentration. Shedi soil alone contaminated with 1N H_2SO_4 and1N H_3PO_4 showed significant decrease in pH. The decrease with 1N H_2SO_4 more is compared to decrease in pH with 1N H_3PO_4. 1N H_2SO_4 is the strong acid compared to 1N H_3PO_4 and hence the maximum decrease in pH is noticed. The variations are shown in figures 5 and 6.

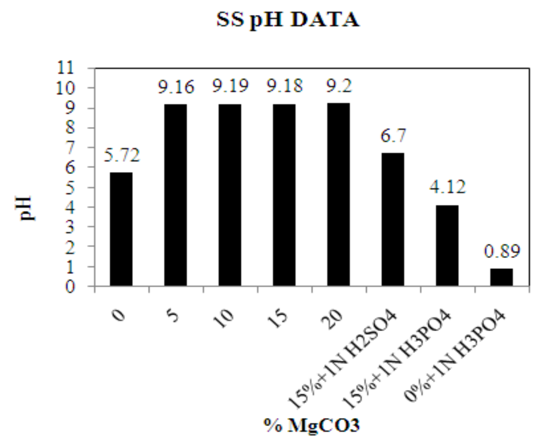

Chart 6 Variation of pH with % of $MgCO_3$ and 1N acids

4. CONCLUSIONS

1. Magnesium carbonate has resulted in more alkalization of Black cotton soil and Shedi soil equally, compared to alkalization of Red Earth indicating high pH.
2. The cation exchange phenomena is more with increase in Magnesium Carbonate at all percentages compared to increase in Calcium Carbonate at all percentages for all the three soils inferring more hydrogen ion activity .
3. The increase or decrease in pH for soil alone treated with $CaCO_3$ and $MgCO_3$ separately and again for the soil alone contaminated with 1N H_2SO_4 and 1N H_3PO_4 are due to Physical properties and chemical analysis of the individual soil
4. Significant acidification is resulted in all the three soils due to 1N H_2SO_4 contamination rather than contamination due to 1N H_3PO_4 indicating sudden low pH.
5. Acidic Soils showing the pH value between 1 to 2 in pH Scale determines the amount of lime to be added to raise its pH for any Engineering applications.

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