Pakistan J. Sci. Ind. Res., Vol. 30, No. 4, April 1987

# STUDY OF FACTORS AFFECTING pH OF SOILS OF PAKISTAN

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(Received December 10, 1980; revised February 19, 1987)

The pH of most of the soils of Pakistan has been found to correlate in a general way with environmental factors of the parent material and climate but more specifically with the soil factors of base saturation percentage, exchangeable sodium percentage, amount and kind of salts and soil aeration. The most dominant parent material is the calcareous Alluvium of mixed mineralogy. Calcareous loess is another important parent material. The greater part of Pakistan is arid and semi-arid but some areas do have sub-humid and humid climate. The calcareousness of the parent material and aridity of the climate is responsible for the alkaline reaction (pH) of most of the soils of Pakistan. Certain soils, in the north and north-eastern hilly areas, formed in acid ingneous rocks and/or under subhumid and humid climate have acidic reaction.

*Key words.* Calcavious soils, pH of soils; Agro-ecological zone of soils.

## INTRODUCTION

Soil reaction (pH) is one of the important soil characteristics, which control the availability of many plant nutrients. Plant species differs considerably in their pH requirements, yet the range around neutrality (pH 6.5-7.5) is suitable for most of agricultural crops [2]. The pH value of Pakistan soil ranges from 4.7 to 10.5 [11]. Literature reviews show that pH of soil is generally influenced by the climate and parent material [4,10,12]. However their influence is modified by drainage and hydrologic conditions (Table 6). Ponnamperuma [7] ascribed the decrease in pH on the submergence of alkaline and calcareous soil to the $Na_2CO_3$-$H_2O$-$CO_2$ and $CaCO_3$-$H_2O$-$CO_2$ systems. The overall effect of submergence is reported to increase the pH of acid soils and to depress the pH of sodic and calca reous soils [8]. Whitney and Gardner [15] found a decrease in pH from 9.2 to 6.4 due to increase in the partial pressure of $CO_2$.

Due to the very nature of the soil survey, varieties of soil from different agro-ecological zone are analysed at our laboratories for detailed characterization. In the present study an effort has been made to find out the factors which affect the pH of soils of Pakistan.

## METHODS AND MATERIALS

Soil samples from different horizons of representative profiles of different soil series were collected by soil survey field parties during the course of soil survey of the country [11]. Various details (location, series, depth and horizon etc.) of the samples are given in the accompanying tables. These samples were air-dried, ground and passed through 2 mm sieves. The pH of these samples was determined in saturated paste with pH meter using glass electrode [14]. The pH of samples from poorly drained soils was, however, determined first in their natural saturated state and also after air-drying, like other soil samples.

## RESULTS AND DISCUSSION

The pH value of the most of the soils of Pakistan ranges from 7.7 to 8.2 [11]. However, the lowest and highest values found were 4.7 and 10.5 respectively. The extreme values are restricted to certain specific areas. The various environmental and soil factors, affecting pH of soils of Pakistan studied were (a) the nature of the parent material; (b) climate, specially precipitation; (c) base saturatin percentage; (d) amount and kind of salts; (e) exchangeable sodium percentage; and (f) drainage. These are discussed seperately under a broad grouping of environmental and soil factors.

### 1. *Environmental Factors*

(a) *Nature of parent material.* The parent material is one of the soil forming factors and has an expressing role on soil characteristics, especially when the soil is formed under low precipitation and/or in a relatively young deposit. Even under high precipitation and after a long period of time, it still maintain certain original characteristics [5].

The parent material of the soils of Pakistan is mainly alluvium, loess and admixture of the two. The alluvium (most extensive of all the parent material) is brought down

by rivers and torrents from the Himalayan Ranges having rocks of all kinds (sandstone, granite, limestone etc.) and containing lime is most cases. The alluvium can be broadly classified into slightly calcareous (2-3% $CaCO_3$), moderately calcareous (3-15% $CaCO_3$) and strongly calcareous, containing 15-20% and above $CaCO_3$ [13]. The slightly calcareous alluvium is deposited only by the Swat River in the northern part of N.W.F.P., the moderately calcareous alluvium is deposited by all the major rivers of Pakistan, while the strongly calcareous alluvium is deposited by torrents debouching from the western hills comprising the Sulaiman Range. The calcareous nature of the material is responsible for the alkaline reaction of soils, i.e. pH from 7.3 to 8.2 (*Table 1*), depending upon the amount of lime and organic matter content. Soils formed in the strongly calcareous piedmont alluvium of western hill ranges, have pH about 8.2 because of low organic matter and high lime content. The pH of soils which are moderately and slightly calcareous in about 7.8 and 7.3 respectively (see *Table 1*). There are, however, certain acid igneous rocks (granite group) in some parts of northern area and the soil formed in the alluvium & colluvium of these rocks is acidic in reaction with pH value of 5.1 to 6.7 [9]. A look at *Table 1* shows the though the variation in $CaCO_3$, content of various soils is quite large, the differences in pH are not proportionate. This indicates that the quantity of $CaCO_3$ matters less as compared to its mere presence.

The other important soil parent material is loess, which is mainly limited to Pothowar Upland and intermountain valleys of the lower Himalayas. This material has been blown out of broad sandy river beds and river plains of the Indus river system and deposited during the late Pleistocene [3]. This wind deposited material consists mostly of light brown (buff colour) silt size (0.02 to 0.002 mm dia) particles and contain about 15 to 20% $CaCO_3$. Due to its calcareous nature, the soils developed there upon were alkaline in reaction with pH values ranging from 7.5 to 8.2. The older soils formed in loess had been leached nearly free, but not absolutely free, of lime and the soil pH was about 7.6 [10] but the soils on young eroded surfaces contain at least moderate amounts of lime and have pH ranging between 8.2-8.2 [11].

b) Climate. The greater part of Pakistan is arid (precipitation less than 200 mm) and semi-arid precipitation 200-500 mm), but some areas in the north do have subhumid (precipitation 500-750 mm) and humid (precipitation 750 mm) conditions [1]. The climate influences almost all types of rock weathering processes/reactions and soil formation in a variety of ways. The climate, especially precipitation, had affected the reaction (pH) of soils by (i) the leaching of lime and bases, (ii) accumulation of organic matter and acidfication and (iii) accumulation of salts in the soils. The first two processes are active under humid and subhumid climate, whereas the third is typical of arid and semiarid climate.

In arid and semi-arid conditions the net movement of water in soils was upward and the soils thus remain base saturated, with pH above neutrality [12]. As the parent materials (alluvium and loess) were mostly of mixed mineralogical nature and contain lime [11], hence the soils of arid and semi-arid area of Pakistan were alkaline, with pH ranging from 7.8 to 8.2, unless affected by some processes of localized nature, i.e. salinization, sodization and poor drainage as explained later.

In the north-eastern subhumid zone of the country the precipitation had caused the leaching of lime from at least

**Table 1. Data showing effect of lime content on pH**

A. Non to slightly calcareous (Swat river and its tributries alluvium)

| S. No. | Location | Series | Horizon | Depth (cm) | CaCO % 3 | pHs |
|---|---|---|---|---|---|---|
| 1. | Swat | Chakdara | $B_2$ | 25-60 | 0.5 | 7.3 |
| 2. | ,, | ,, | $B_3$ | 60-90 | 0.5 | 7.1 |
| 3. | ,, | Kamala | $A_1$ | 0.10 | 1.0 | 6.8 |
| 4. | ,, | ,, | $B_1$ | 10-20 | 1.0 | 6.8 |
| 5. | ,, | Nimgram | Ap | 0-15 | 1.0 | 7.2 |
| 6. | ,, | ,, | $B_{2\,1}$ | 15.50 | 0.5 | 7.3 |
| 7. | ,, | ,, | $B_{2\,2}$ | 50-65 | 0.5 | 7.2 |
| 8. | ,, | ,, | $B_{2\,4}$ | 65.70 | 0.5 | 6.9 |

(Continued..... ..)

(Table 1, Continued)

B. Moderately calcareous (Alluvium from the Indus river and its tributries)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. | Okara | Sultanpur | Ap | 0-10 | 4.0 | 7.6 |
| 2. | ,, | ,, | $B_1$ | 10-24 | 3.5 | 7.8 |
| 3. | ,, | ,, | $B_{22}$ | 40-75 | 4.0 | 7.8 |
| 4. | ,, | ,, | $B_3$ | 75-105 | 3.5 | 7.9 |
| 5. | ,, | Adilpur | $B_{21}$ | 26-51 | 4.0 | 7.9 |
| 6. | Rahimyar-Khan | Sultanpur | Ap | 0-6 | 11.0 | 7.8 |
| 7. | ,, | ,, | $B_1$ | 6-12 | 11.5 | 8.1 |
| 8. | ,, | ,, | $B_{21}$ | 12-18 | 10.0 | 8.1 |
| 9. | ,, | ,, | Ap | 0-6 | 8.0 | 7.7 |
| 10. | ,, | ,, | $B_1$ | 6-12 | 9.0 | 7.9 |

C. Strongly calcareous (Alluvium from the Sulemain Ranges)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. | Loralai | Duki | Ap | 0-12 | 34.5 | 8.1 |
| 2. | ,, | ,, | $B_{21}$ | 36-58 | 35.0 | 8.2 |
| 3. | ,, | ,, | $B_{22}$ | 58-80 | 36.0 | 8.2 |
| 4. | ,, | Shabo | $A_1$ | 0-10 | 43.0 | 8.1 |
| 5. | ,, | ,, | $B_{22}$ | 24-45 | 45.0 | 8.2 |
| 6. | ,, | Barkhan | Ap | 0-10 | 28.0 | 8.1 |
| 7. | ,, | ,, | $B_1$ | 10-22 | 27.5 | 8.1 |
| 8. | Kalat | Patki | A1 | 0-5 | 17.0 | 8.2 |
| 9. | ,, | ,, | $B_{21}$ | 5-18 | 19.5 | 8.2 |
| 10. | ,, | ,, | $B_{22}$ | 18-42 | 20.0 | 8.2 |

D. Non-calcareous (Alluvium and colluvium from acid rocks – northern area)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1. | Tarbella catch | Phagora | Ap | 0-13 | Absent | 4.7 |
| 2. | Swat | Jabar | $A_1$ | 0-18 | -do- | 5.9 |
| 3. | ,, | Nawagai | $B_2$ | 19-58 | -do- | 6.0 |
| 4. | ,, | ,, | $B_2$ | 58-81 | -do- | 6.1 |
| 5. | ,, | ,, | $C_2$ | 104-132 | -do- | 6.2 |
| 6. | ,, | Kot Killa | Ap | 0-20 | -do- | 6.3 |
| 7. | ,, | ,, | $C_2$ | 35-50 | -do- | 6.4 |
| 8. | ,, | ,, | $C_1$ | 20-35 | -do- | 6.5 |
| 9. | ,, | Guli bagh | $C_1$ | 13-23 | -do- | 6.6 |
| 10. | ,, | Galdanian | $B_1$ | 15-3o | -do- | 6.8 |

the surface horizons of soils on old Pleistocene surface [10]. The lime had been removed, but the soils still remained base saturated and thus the pH remained above neutrality though it has been lowered to a certain extent i.e. to about 7.5. The slightly alkaline reaction of these soils is partly due to the calcareous dust particles, which fell on these soils during early summer and also due to the calcareous sediments added through irrigation water [10].

In the humid northern areas, where there was enough natural vegetation, the soils have been leached free of lime and bases to varying extent by the production of carbonic acid through the respiratory activity of plant roots and their decomposition, which enhances the process of leaching. Hydrogen ions from carbonic acid displaces $Ca^{++}$ and $Mg^{++}$ from exchange complex and the $Ca^{++}$ and $Mg^{++}$ bicarbonates formed are leached down. Thus pH has been brought down, and in some cases even below neutrality. The acidity is more pronounced in soils developed on acid igneous rocks where the pH ranges from 5.1 to 7.5 (Table 1-D). The acidic soils are confined to acid ingeious rocks,

whereas the neutral or slightly alkalines soild occur on calcareous parent materials.

II. *Soil Factors*

(a) *Base saturation percentage.* The processes which encouraged the maintenance or build-up of exchangeable bases contributed towards the increase in pH. Moreover, the conditions which permitted the exchangeable bases to remain high in the soils encouraged high pH values. In the process of organic matter decomposition, which was mainly limited to humid areas of the northern part of Pakistan

Table 2. Data showing effect of lime leaching on pH.

| S. No. | Location | Series | Horizon | Depth (cm) | CaCO % 3 | pHs |
|---|---|---|---|---|---|---|
| 1. | Hare Basin | Dosera | $A_1$ | 0-10 | 1.0 | 7.30 |
| 2. | ,, | ,, | $B_1$ | 10-22 | 0.5 | 6.95 |
| 3. | ,, | ,, | $B_{21}$ | 22-48 | 0.5 | 6.80 |
| 4. | ,, | ,, | $B_{22}$ | 48-70 | 0.5 | 6.85 |
| 5. | ,, | ,, | $B_{23}$ ca | 70-100 | 10.5 | 8.00 |
| 6. | ,, | ,, | $B_3$ ca | 100-130 | 11.5 | 8.0 |
| 7. | Sheikhupura | Pindorian | Ap | 0-15 | 0.5 | 6.69 |
| 8. | ,, | ,, | $B_1$ | 15-75 | 0.5 | 6.30 |
| 9. | ,, | ,, | $B_{21}$ | 75-100 | 0.5 | 6.60 |
| 10. | ,, | ,, | $B_{22}$ | 100-120 | 1.5 | 7.20 |

Table 3. Data showing the effect of base saturation percentage (B.S.P) on pH.

| S. No. | Series | Area | Horizon | Depth cm | B.S.P. | pH | Org. matter (%) | Parent material |
|---|---|---|---|---|---|---|---|---|
| 1. c/ | Phagora | Tarbella Water shed | Ap | 0-13 | 26.31 | 4.7 | 1.1 | Non-calcareous slates and phyllite |
| 2. a/ | Ayubia | Haro Basin | $B_1$ | 10-21 | 46.02 | 5.7 | 5.7 | Non-calcareous slates |
| 3. c/f | Dosera | -do- | $B_1$ | 10-22 | 50.81 | 6.95 | 2.5 | Non-calcareous losses |
| 4. b/ | Shahi | Dir | $A_1$ | 0-8 | 54.72 | 5.7 | 11.7 | Non-calcareous losses |
| 5. d/ | Besham | Tarbella Water-shed | A | 0-13 | 54.74 | 6.9 | 4.5 | Non-calcareous quartizite and sandstone. |
| 6. b/ | Balimang | Swat | Ap | 0-15 | 56.75 | 6.5 | 2.0 | Mic-sil-phylitic shicst |
| 7. a/ | Bara Gali | Haro Basin | Ap | 0-18 | 56.79 | 6.3 | 7.9 | Non-calcareous shales |
| 8. d/f | Palam | Swat | Ap | 0-14 | 66.00 | 6.5 | 1.4 | Non-calcareous amphibolite |
| 9. d/ | Usho | Swat | 02 | 6-0 | 76.85 | 6.2 | 22.7 | Non-calcareous mic. quartizite and schist. |
| 10. c/f | Birot | Haro Basin | $A_1$ | 0-8 | 80.56 | 7.6 | 2.5 | V. slightly calcareous shales and sandstone |
| 11. e/f | Bhalwal | Sheikhupura | $B_3$ | 125-165 | 99.30 | 8.0 | 0.6 | Calcareous river alluvium |
| 12. e/f | Bhalwal | Sheikhupura | $C_2$ | $180^+$ | 97.6 | 7.9 | 0.5 | Calcareous river alluvium |

a/ Humid temperate, pine-fir with undergrowth grasses, excessive drainage.
b/ Sub-humid, temperate; conifer/grass; excessive drainage.
c/ Humid, Subtropical; & crubs, & sattered pine with undergrowth grasses; well to excessive drainage.
d/ Sub-humid, subtropical; scattered pine trees with grasses/deodara; excessively drained.
e/ Semi-arid subtropical, well drained.
f/ Arable.

Table 4.Data showing the effect of electrolyte on soil pH

| Sr. No. | Area | Series | Horizon | Depth (cm) | EC (mmhos/cm | pH | $CaCO_3$(%) |
|---|---|---|---|---|---|---|---|
| 1. | Lesbela | Khamra | $B_2$ | 26-87 | 132.0 | 6.6 | 30.5 |
| 2. | ,, | ,, | $B_{23}$ ca | 87-100 | 152.9 | 6.7 | 31.0 |
| 3. | Sangar | Bahali ki | A | 0-6 | 154.0 | 6.8 | 11.0 |
| 4. | Lesbela | Kunar | $B_{21}$ | 12-77 | 99.0 | 6.9 | 21.0 |
| 5. | Lesbela | Ghazab | $B_{21}$ | 12-42 | 82.5 | 7.1 | 22.5 |
| 6. | Lesbela | Jorai | $C_2$ | 30-74 | 41.8 | 7.1 | 16.0 |
| 7. | Lesbela | Landhi | $B_{21}$ | 8-38 | 121.0 | 7.1 | 47.0 |
| 8. | Lesbela | Langra | $B_{22}$ ca | $35^+$ | 64.9 | 7.2 | 50.0 |
| 9. | Lesbela | | $B_{21}$ ca | 4-35 | 77.0 | 7.2 | 40.0 |

The differential influence of EC on soil pH may be attributed to variation in clay (buffering), lime and chloride/sulphate of calcium.

Table 5.Data showing effect of exchangeable sodium percentage (E.S.P) on pH

| S. No. | Series | Area | Horizon | Depth (cm) | E.S.P | pH | $EC_e$x103 | $CO_3$ (me1/1) | $HCO_3$ (meq/1) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Gagu (B) | Rawalpindi | $A_1$ | 0-4 | 38.0 | 8.70 | 30.8 | 0.9 | 5.0 |
| 2. | Gagu (B) | Rawalpindi | $B_1$ | 18-18 | 65.6 | 9.90 | 13.3 | 7.0 | 10.0 |
| 3. | ,, | ,, | $B_2$ | 18-52 | 62.3 | 10.10 | 14.1 | 24.0 | 26.4 |
| 4. | Gagu (A) | ,, | $A_1$ | 0-12 | 98.1 | 10.15 | 77.0 | 94.0 | 99.0 |
| 5. | ,, | ,, | $C_2$ | 108-138 | 45.7 | 10.15 | 6.0 | 10.0 | 18.0 |
| 6. | ,, | ,, | $B_2$ | 22-85 | 94.7 | 10.30 | 37.4 | 90.0 | 95.0 |
| 7. | Satghara | Sheikhupura | B | 45.90 | 55.8 | 10.50 | 6.8 | 60.8 | 71.2 |
| 8. | ,, | Thal | $B_1$ | 8-30 | 71.8 | 10.50 | 13.5 | 76.0 | 57.0 |
| 9. | Chandra | ,, | Ap | 0-15 | 92.6 | 10.50 | 37.4 | 243.0 | 167.0 |
| 10. | ,, | Thal | Ap | 0-8 | 91.1 | 10.60 | 53.9 | 235.2 | 114.8 |

The somewhat differential influence of ESP on soil pH could be accounted for variations in clay (buffering) and carbonates content.

Table 6.Data showing effect of waterlogging on soil pH

| S. No. | Series | Area | Horizon | Depth (cm) | pH Saturated* | Arid dried** | Date of sampling |
|---|---|---|---|---|---|---|---|
| 1. | Raiwin | Lahore | $B_{22}$ ca | 36-42 | 8.80 | 9.45 | March, 80 |
| 2. | Khuriawala | ,, | $B_{23}$ ca | 42-50 | 8.70 | 9.40 | -do- |
| 3. | ,, | ,, | $C_1$ | 50-70 | 8.70 | 9.25 | -do- |
| 4. | ,, | ,, | $C_2$ | $70^+$ | 8.40 | 9.25 | -do- |
| 5. | ,, | ,, | $B_{22}$ | 30-60 | 8.10 | 9.10 | February, 80 |
| 6. | ,, | ,, | $B_3$ ca | 60-80 | 8.30 | 9.50 | January, 80 |
| 7. | ,, | ,, | $C_1$ | 80+90 | 7.80 | 9.20 | -do- |
| 8. | ,, | ,, | $C_2$ | $90^+$ | 7.40 | 8.95 | -do- |

*The soil under natural condition was saturated and its pH was determined in its natural state.

** After these samples were air dried and again saturated a paste was prepared and its pH measured.

having sufficient natural vegetation, both organic and inorganic acids were formed which helped to replace the exchangeable bases with $H^+$ which releases from organic acids and in conditions which were favourable for leaching (i.e. high precipitation and free drainage) the pH was brought down below neutrality. It must be pointed out that a close correlation between base saturation status and pH exists if the soils are formed in the same parent material and resemble in texture and organic matter content (Table 3).

(b) *Nature and amount of soluble salts.* The total amounts of salts and their component ions affect the pH of soils to a varying degree depending upon the buffering capacity of the soil. The presence of excessive amounts of soluble salts (NaCI, $Na_2SO_4$, $CaCI_2$ and $CaSO_4$ etc.) had in general a depressive effect on the pH of alkaline soils by lowering it to near neutrality (Table 4)

In saline soils were chorides and sulphates, especially if calcium chloride dominated, the depressive effect, stated above, was quite pronounced. The pH of such soils was even brought down below neutrality (6.6 – 6.9) in spite of the presence of lime. The pH of these soils was possibly being controlled by the ionization of $Cacl_2$ and $CaSO_4$ suppressing of the activity of $HCO_3$ ions. Moreover the aridity of climate could be another possible reason limiting chemical reactions.

(c) *Exchangeable sodium percentage.* In the salt affected soils, where sodium had dominated the exchange complex (Table 5) the pH had gone to the strongly alkaline range. This exchangeable sodium on hydrolysis gives rise to the formation of sodium carbonates, which raises the pH and causes the precipitation of calcium from solution according to the following equation;

$$[\text{Colloid}]^{Na}_{Na} + HOH \rightleftharpoons [\text{Colloid}]^{H}_{H} +$$

$$^{2}NaOH + HCO_3 \rightleftharpoons Na_2CO_3 + H_2O$$

The increase in pH, to a certain extent, was proportional to the amount of sodium carbonate present (Table 5). The appearance or $Na_2CO_3$ is almost concurrent with the precipitation of $Ca^{2+}$ as $CaCO_3$ which was almost inert under strongly alkaline conditions (pH more than 8.5). Such sodic or saline-sodic soils occured as scattered patches in the semi arid and arid parts of the country [11].

(d) *Drainage.* In waterlogged soils, anaerobic (reducing) conditions prevail and the partial pressure of $CO_2$ increases, so the pH of the soils naturally was decreased due to the acids, especially the carbonic acid formed and/or to Fe $(OH)_3$-$Fe^{++}$ and/or $Na_2CO_3$-$H_2O$-$CO_2$ and $CaCO_3$-$HO_2$ $CO_2$ systems as pointed out by Ponnamperuma *et al* [7]. The data on waterlogged soils, although limited, conform to the above statement (Table 6).

## CONCLUSION

These were a few factors recognized during the course of the study on the pH of soils of Pakistan. The accompanying Tables (1-6) contains the selective but reelvant analytical data on soil samples taken from soil series throughout Pakistan. It may be concluded than nature of the parent material and climate (conditioned by hydrogeology of the area) had dominant influence on the pH of soils of Pakistan.

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