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INTRINSIC PHYSICAL PROPERTIES OF KUAKATA COASTAL SOIL IN BANGLADESH

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Abstract

Herein, bulk density, particle density, pH, electrical conductivity and moisture content have been determined for 12 sampling sites of soils near Kuakata sea beach with Geographic Positioning System (GPS) positions. Excellent porosity has been observed for all soil samples ranging from 36 to 66 % with reasonable pH range. A good range (12 to 24%) of moisture contents together with remarkable soil aerations provides the favorable conditions for plant growth.

Keywords: Bulk density, Particle density, Porosity, Plant growth, Soil aeration.

Introduction

Bangladesh is a country that is blessed with many natural sea beaches. Among them, Kuakata sea beach is one of the best beaches and a rare scenic beauty spot on the southernmost edge of Bangladesh. Both the sunrise and sunset can be viewed around the beach and this uniqueness attracts thousands of tourists from home and abroad every year. This panoramic sea beach is locally known as Shagor Konnya (Daughter of the Sea). It is located at Patuakhali district, some 320 kilometers from the capital city of Dhaka (Rahman *et al*., 2013). Due to its importance on tourism and national economy, it, as well, draws attention of researchers too. Several research works have been conducted on different features of Kuakata like, study on the beach materials of the Kuakata coast (Rahman *et al.,* 1999), environmental radiation on sand and soil samples from Kuakata sea beach (Islam *et al*., 2013a), the potentiality of Kuakata beach for tourism business and economic development, the stability of Kuakata coast using remote sensing techniques (Islam *et al*., 2013b), investigation on erosion of Kuakata sea beach and its protection design (Rahman *et al.*, 2013).

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Soil bulk density is a basic soil property influenced by some soil physical and chemical properties. Bulk density of soil is influenced by the amount of organic matter, their texture, constituent minerals and porosity. Knowledge of soil bulk density is essential for soil management, and information about it is important in soil compaction as well as in the planning of modern farming techniques. A soil's porosity and pore size distribution characterize its pore space, that portion of the soil's volume that is not occupied by or isolated by solid material. The basic character of the pore space affects and is affected by critical aspects of almost everything that occurs in the soil: the movement of water, air, and other fluids; the transport and the reaction of chemicals; and the residence of roots and other biota. Porosity ϕ is the fraction of the total soil volume that is taken up by the pore space. Thus it is a single-value quantification of the amount of space available to fluid within a specific body of soil. Particle density is unaffected by aggregation or compaction of soil particles, in other words, the particle density is not affected by soil porosity, but interrelated with porosity, bulk density, air-space and rate of sedimentation of particles in fluids. Soil moisture content or amount of water present or retained in the soil is indispensable to know as it ultimately affects the growth and better production of plants. Measurement of changes in soil moisture storage with time is also important to learn for suitable scheduling of irrigation, estimating evapotranspiration and estimating the amount of water to apply as irrigation. The importance of this dynamic property of soil in relation to plant growth has resulted in the development of many methods for measuring soil moisture. pH is one of the most important physico-chemical parameters which define the characteristics of soil. Some soils possess a preponderance of hydrogen over hydroxyl ions and, therefore, are acids. Some show the reverse, and are alkaline; while others, which have an equal concentration of hydrogen and hydroxyl ions, are neutral in reaction. Soil pH influences availability of nutrients to plants, activity of useful and parasitic soil organisms, potency of toxic substances present in soil. Electrical conductivity commonly represented as EC is reciprocal of resistance and is measured for salinity appraisal. It is based on the principle that pure water is a very poor conductor of electric current, whereas water containing dissolved salts ordinarily found in soils conducts current approximately in proportion to the amount of salt present. But there is no literature has yet been evaluated on the physiochemical properties of soils near Kuakata beach in Bangladesh. This research intends to give baseline information about physico-chemical properties like pH, electrical conductivity (EC) and some physical properties such as bulk density, particle density and moisture content as well as porosity of soils for sampling areas at Kuakata in Bangladesh.

Materials and Methods

Study area

Twelve soil samples were collected from Kuakata, southern part of Bangladesh for analyzing some intrinsic properties (*viz*. pH, EC, moisture content, bulk density, particle density and porosity). Detailed information about the locations and samples collected from those sites are given below in Table 1.

Table 1. Sample number with corresponding location details.

Location	Sample no.	Latitude	Longitude
1	S-1, S-2, S-3, S-4	21^o49'11" N	90^o07'10" E
2	S-5	21^o49'02" N	90^o07'18" E
3	S-6, S-7, S-8, S-9	21^o50'25" N	90^o07'32" E
4	S-10	21^o50'24" N	90^o07'34" E
5	S-11	21^o50'23" N	90^o07'42" E
6	S-12	21^o49'31" N	90^o07'14" E

Collection and preparation of soil samples

Soil samples were collected from five different locations in April, 2016. Before sampling, existing plants and vegetation were removed with the help of spade. Then, an aluminum core was inserted to take a topsoil sample for bulk density analysis and after that a composite sample of about 2.0 kg was taken into a polythene bag with proper labeling for further analysis and was carried out to the laboratory. Sub-soil sample at a depth of 15 cm was also taken from the same site for analyzing the above stated parameters. The samples, except for pH measurement, were brought to the laboratory and left for air-drying. After that, the larger aggregates are broken down gently and are passed through a 2.00 mm sieve. The sieved samples were then weighed and collected in a plastic container for the further analysis.

All the parameters were measured using standard procedures (Black, 1965 and Jackson, 1973) in the soil laboratory at department of Soil and Environmental Sciences, University of Barisal.

Measurement of pH and Electrical Conductivity

Ten grams of soil and 25 ml distilled water (at a ratio of 1:2.5) was taken into a 100 ml beaker and stirred for 30 minutes. After that pH reading was taken using pH meter (Model: Adwa AD1000 and AD1020) and EC was measured using EC meter (Model: Adwa AD32) from the extract of soil where the soil and water ratio was also 1:5.

Measurement of Bulk density

Soil bulk or apparent density was measured by using Core method. A cylindrical metal core sampler of known height and diameter was driven into the soil to the desired depth and was carefully removed. Each end of the sample holder was trimmed and flushed with a sharp spatula to establish the soil sample volume same as the volume of the core. Bulk density was then calculated using the following equation:

$$\rho_b = m_s/V_t \qquad (1)$$

Where, ρ_b is the bulk density of the soil in Mgm^{-3}; m_s is the oven-dry weight (Mg) of the soil; and V_t is the volume of the soil (m^3) filled in the core sampler.

Volume of soil or core sampler (V_t) was calculated using the equation given below:

$$V_t = \pi r^2 h \qquad (2)$$

Where, r is the radius of the core sampler and h is the height of the sampler.

Measurement of particle density

Particle density determination of a soil sample by pycnometer method is calculated from two measured quantities, namely, mass of the sample and its volume. A clean and dry pycnometer was weighed with its lid and then certain amount of oven-dry sample was poured into it and weighed again. Next to that, cool, distilled water was poured into the soil inside the pycnometer and weighed again. Finally, the pycnometer was washed thoroughly and filled with only distilled water and weight was recorded along with the room temperature. All the collected data were used in the following equation to determine particle density of the soil sample.

$$\rho_s = \rho w \times (Ws - W)/\{ ((Ws - W) - (Wsw - Ww)\} \qquad (3)$$

Where, ρ_s is the particle density of the soil to be calculated in gcm^{-3}; ρw is the density of water (gcm^{-3}) at observed temperature; Ws is the weight of pycnometer + soil sample corrected to oven-dry condition; W is the weight of empty pycnometer; Wsw is the weight of pycnometer + soil + water; and Ww is the weight of pycnometer + water at observed temperature.

Measurement of moisture content

Soil moisture content was measured by gravimetric method. According to this method, soil water consists of measuring the moist and dry soil and is determined by weighing the sample as it is at the time of sampling, and the dry weight was obtained after drying the sample to a constant weight in an oven at 100-105^{o}C for 24 hours. An empty aluminum can was weighed and 40g soil was taken into the can and weighed again immediately. Then, the can with soil was placed into an oven for 24 hours at 105^{o}C for drying. Finally, the oven-dry weight was measured and moisture percentage was determined using the following equation:

$$\text{\% Moisture in the sample} = \frac{W1-W2}{W2-W3} \times 100 \tag{4}$$

Where, W_1 is the weight of wet soil + can; W_2 is the weight of oven-dry soil + can; and W_3 is the weight of the empty soil moisture can.

Measurement of Soil Porosity

Porosity can be calculated from measurements of particle density ρ_s and bulk density ρ_b From the definitions of ρ_b as the solid mass per total volume of soil and ρ_s as the solid mass per solid volume, their ratio ρ_b/ρ_s is the complement of ϕ, so that

$$\phi = 1-\rho_b/\rho_s \tag{5}$$

Often the critical source of error is in the determination of total soil volume, which is harder to measure than the mass. This measurement can be based on the dimensions of a minimally disturbed sample in a regular geometric shape, usually a cylinder. Significant error can result from irregularities in the actual shape and from unavoidable compaction (Nimmo, 2004).

Statistical Analysis

Different properties of soils were statistically analyzed to determine the relation among them. The Pearson’s correlations were conducted among the parameters.

Results and Discussion

As we discussed earlier that the physico-chemical properties of soils have influenced availability of nutrients to plants, activity of useful and parasitic soil organisms, potency of toxic substances. Table 2 provides us the pH and electrical conductivity (EC) of twelve sampling sites of Kuakata soils at observed temperature. The pH of soil samples (S-1 to S-12) ranges from 5.82 to 7.80 *i.e.* the soil samples are neither strongly acidic nor basic in nature. The observed values are within very good range for the plant growth as well as microbial growth. These results are coincided with the values found by Anwar (1993) who showed that the pH of Patuakhali and Barguna Districts of Bangladesh varied from 6.21 to 7.88. On the other hand, the observed EC values lie between 0.48-0.67 $mScm^{-1}$ indicating the soil samples are not saline or problematic.

The moisture content, bulk density, particle density and porosity of the soil samples are shown in Table 3. For moisture content, the collected soil samples are within the good range of having 10 to 24%. The actual soil moisture content at field capacity varies with soil texture, typically ranging from 15 to 45% by volume. Plant can easily extract water from a soil when its moisture is at or near field capacity. At this view, the soils were almost suitable for related crop production. Ranges of bulk density (ρ_b) in soils were 1.0 to 1.7 gcm^{-3} while particle density (ρ_s) is almost double of it *i.e.*, 2.0 to 3.3 gcm^{-3} which denoted near about the ideal condition of soils. As bulk density is indicator of root penetration in soil it indicates the favorable condition of plant growth of the sampling area in Kuakata.

Table 2. Soil pH and electrical conductivity of the sampling sites.

Sample no.	pH	EC (μScm^{-1})	Temperature (^oC)
S-1	7.19	0.52	31.7
S-2	6.28	0.49	31.7
S-3	6.77	0.52	31.5
S-4	6.47	0.67	32.1
S-5	6.22	0.42	31.7
S-6	5.94	0.49	31.0
S-7	5.86	0.52	31.7
S-8	6.68	0.56	31.6
S-9	5.86	0.60	31.7
S-10	5.98	0.64	31.3
S-11	5.82	0.64	31.3
S-12	7.80	0.48	31.4

The percentages of measured porosity of Kuakata soils presented in table 3 are one of the remarkable findings of present studies which showed excellent range (36 to 66%) of porosity of that samples termed as ‘highly porous soil’ (porosity 25-40%) for only soil sample S-11 and ‘extremely porous soil’ (porosity>40%) for the rest samples according to the micromorphometric method (Pagliai, 1988) as because a total macroporosity of 10% is considered to be the lower limit for good soil and a high percentage of this type of pore (above 70-80%) in soils is usually an index of poor soil structure, especially in relation to plant growth (Marcello and Vignozzi, 2002) .

Table 3. Physical properties of the soil samples.

Sample no.	Moisture content (w, %)	Particle density (ρ_s, gcm^{-3})	Bulk density (ρ_b, gcm^{-3})	Porosity (ϕ, %)
S-1	11.59	3.00	1.42	52.76
S-2	12.18	2.99	1.49	49.39
S-3	9.69	2.91	1.45	50.17
S-4	17.97	2.86	1.16	59.34
S-5	12.05	3.11	1.07	65.74
S-6	22.80	2.60	1.32	49.12
S-7	18.31	2.43	1.15	52.67
S-8	10.14	2.22	1.01	54.32
S-9	12.49	2.35	1.14	51.34
S-10	20.15	2.59	1.35	47.98
S-11	23.05	2.62	1.66	36.48
S-12	15.78	3.30	1.16	64.96

As soil porosity is the index of penetration resistance (Carter, 1990), knowledge of their range for root response plus their interrelationships to soil strength which is indicated by bulk density and particle density (Carter, 1990) allows a cumulative description of soil physical quality. The ‘ideal’ soil would hold sufficient air and water to meet the needs of plants with enough pore space for easy root penetration (Chaudhari *et al*., 2013).

Two types of pores are responsible for the total porosity of soil such as "storage pores (micropores)", *i.e*. the pores that store water and are very important because they determine the amount of water availability to plants and for micro-organisms and "transmission pores (macropores)" in which the movements of water are important for plants, and, moreover, they are the pores needed by feeding roots to grow into (Marcello and Vignozzi, 2002). The present research clearly shows the good physical quality of soil in relation to plant growth as because on one hand the determined moisture contents of the soil samples express the presence of storage pores and on the other hand, high percentage of porosity as well as the ideal range of bulk density and particle density of soils represent that there may be large amount of transmission pore characterizing the easy penetration of root and movement of water and nutrients. Therefore, porosity is one of the physical properties of soil on which a healthy soil environment is dependent.

The statistical study amongst the measured properties of the samples was carried out and the values of correlation coefficient (r) are presented in table 4 in which the bolded value represents the significant correlation coefficient (r = -0.762) which is negatively significant at 1%level.

Table 4. Simple correlation coefficients (r) among soil properties.

Properties	Particle density	Porosity	Moisture content	pH	EC
Bulk density	0.185	-0.762*	0.302	0.221	0.192
Particle density		0.492	-0.183	0.242	-0.473
Porosity			-0.418	0.544	-0.481
Moisture content				-0.257	0.391
pH					-0.316
EC					

*Significant at 1% level.

This statistical analysis indicates a high negative correlation between bulk density and porosity which implies that the higher the bulk density, the lower the porosity and vice-versa (Chaudhari *et al*., 2013). This might be due to the fact that the bulk density indirectly provides a measure of the soil porosity (equation 6). Soil porosity is the ratio of the volume of soil pores to the total soil volume. The linear equation developed by the two negatively correlated properties is as follows:

$$y = 39.72\,x + 1.95 \qquad (6)$$

Conclusion

From the above discussion, we may conclude that the ideal porosity is nearly attained among the soils of sampling areas in Kuakata. The equilibrium of the moisture and aeration properties in soils readily provides the favorable conditions for plants, microbial community growth and ease of root penetration, which may exemplary for the scientific points of view. The particle size analyses and other chemical investigations

(OM, N, P, K, etc.) for such soils samples are now underway for future prospect of findings.

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