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Soil Organic Matter, Mineral Nutrients and Heavy Metals Status of Some Selected Regions of Bangladesh

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Abstract

A study was undertaken to evaluate the status of organic matter, mineral nutrients and heavy metals content in seven different soils from fourteen selected regions of Bangladesh. The location were BAU farm, Sutiakhali, Ishardi, Lalpur, Dumuria, Kotalipara, Asasuni, Chorfasion, Kaligonj, Botiaghata, Madhupur, Tangail sadar, Chakaria and Moheskhali. Forty two surface soils (0-15 cm depth) were collected from 14 regions (3 samples from each region) of Bangladesh during November-December, 2009. The results obtained from this study showed that the organic matter of these soils very low to very high (0.65% in Madhupur to 28.24% in Dumuria) and the total N content of soil followed the same trend of organic matter ranging 0.056 to 1.638% in Madhupur and Dumuria region, respectively. The available P and S in the top of soils ranged from 3.77 $\mu g\ g^{-1}$ in Moheskhali to 17.28 $\mu g\ g^{-1}$ in BAU farm and 13.40 $\mu g\ g^{-1}$ in Madhupur to 420.32 $\mu g\ g^{-1}$ in Moheskhali, respectively. In the context of micro nutrients, the maximum available Zn, Cu, Fe and Mn were found 6.43 $\mu g\ g^{-1}$ in Dumuria, 8.06 $\mu g\ g^{-1}$ in Chakaria, 346.12 $\mu g\ g^{-1}$ in Madhupur and 83.5 $\mu g\ g^{-1}$ in Madhupur, respectively. whereas the lowest amount of these micronutrients were found 1.22 $\mu g\ g^{-1}$ in Botiaghata, 0.2 $\mu g\ g^{-1}$ in Dumuria, 7.62 $\mu g\ g^{-1}$ in Ishardi and 2.39 $\mu g\ g^{-1}$ in Lalpur, respectively. Possible contamination of the studied soils by heavy metals was not significantly observed. The OM, total N and other nutrients were found to be the dominant factors influencing not only the availability of macro and micro nutrients and heavy metals but also the quality of soil.

Keywords: Bangladesh soil, Heavy metals, Mineral nutrients, Organic matter

Introduction

Soils of Bangladesh have been formed from different kinds of parent materials occurring in various topographic and drainage conditions. They are spreaded over three major physiographic units: (i) northern and eastern hills of Tertiary formations, covering 12% of the total area, (ii) Pleistocene terraces of Madhupur and Barind tracts, covering 8% of the total area, and (iii) Recent floodplains, mainly comprising alluvial sediments of the Ganges, Brahmaputra, and Meghna river systems, and occupying 80% of the country (Saheed, 1984). Genesis and properties of soils relating to fertility vary with physiography.

The crop yield is low in Bangladesh with respect to other countries due to a number of constraints of which soil is dominant. From early sixties, soils of Bangladesh have shown deficiencies of essential elements one after another. On the other hand, organic matter content in the soils of Bangladesh is below 1% in about 60% of cultivable lands compared to an ideal minimum value of 3% (Islam, 2006). Research was concentrated on macronutrients mainly. Recently, deficiencies of micronutrients have been reported (Islam, 1992; Khan *et al.*, 1997), but comprehensive studies are still lacking.

Multiple micronutrient deficiencies (Zn, Mn, Cu, B, Mo) occur in soils of the Indo Gangetic Plains (IGP) and are becoming prevalent as cropping intensity increases. Low organic matter levels, little retention of crop residues and limited application of animal manures to soils exacerbated these deficiencies. Along with marconutrients (eg.NPK and S), deficiencies of some micronutreients (eg. Zn, B and Mo) are also reported on some soils and crops (Mondal *et al*., 1992; Jahiruddin *et al*., 1995). Badaruddin (1989) and Ahmed and Elias (1986) reported that increase in cropping intensity coupled with minimal use of fertilizers inputs are causing serious depletion of both macro and micronutrients from soils. Thus the micronutrient deficiencies (Zn, Mn, Cu etc.) are becoming more evident in the region. Jahiruddin *et al*. (1992) reported crop response to Zn and B appears to be progressively prominent. In Bangladesh about 2 million hectares of land suffer from predominantly Zn deficiency in different agro-ecological regions (SRDI, 1998).

Micro nutrient status has become a subject of scientific interest in the two state of affairs: one is when any one of the essential elements start to limit plant growth and the other is when soil has been suspected to be polluted with heavy metals (Domingo and Kyuma, 1983). Micronutrient deficiency in Bangladesh soils is plausible in the present situation of intensive cultivation of high-yielding varieties with use of macronutrient fertilizers at higher rates. In addition, due to advance in urbanization and industrialization, soils may accumulate heavy metals.
Therefore, this study investigated the status of the organic matter, macro and micro elements as well as

heavy metals, to evaluate the conditions of fertility and environmental pollution.

Materials and Methods

Total 42 soil samples were collected during November, 2009 from 14 selected regions of Bangladesh (three samples from each region) covering 7 soil types. The collected soil samples (0-15 cm depth) were tightly sealed in labelled polythene bag as soon as possible to avoid air exposure. After collecting the soil samples, the stones, gravels, pebbles, plant roots, leaves etc. were removed and then half of the soil was air dried and rest of the soil was oven dried, mixed well and ground to pass through a 10 mesh sieve. Thereafter, the processed soil samples were analyzed for their chemical properties as per standard methods.

Wet-oxidation method was used for the analysis of organic carbon and the organic matter was calculated by multiplying the organic carbon by Van Bemmelen factor, 1.73 (Page *et al*. 1989). Semi-microkjeldahl method was used for the analysis of total nitrogen (Page *et al*. 1989). Available Phosphorus determination was carried out by Bray and Kurtz method (Bray and Kurtz 1945) as outlined by Tandon (1995). Available potassium and sulphur were analyzed by the method described by Page *et al.* (1989). Sodium and calcium were measured by ammonimum acetate extracting solution described by Peterson (2002). Determination of magnesium was done by complexometric method of titration using Na_2-EDTA as a complexing agent (Page *et al*. 1989). Zn, Fe, Cu and Mn were determined by DTPA extracting solution as outlined by Peterson (2002). Total content of arsenic, lead and cadmium were analyzed by flow injection hydride generator atomic absorption spectrophotometer using matrix-matched standards (Varian Spectra AA55B, Australia). Mono element hollow cathode lamp was employed for the determination of heavy metal of interest.

The collected data were analyzed statistically by F-test to ascertain the soil quality and ranked by Duncan's Multiple Range Test (DMRT).

Results and Discussion

Organic matter

The results on organic matter content of soil under study have been presented in Table 1. In upland soils, the organic matter content ranged from (0.65 to 28.24%) with the mean values of 3.99. The highest organic matter content in soil was found to be 28.24 in Dumuria and it was followed by Kotalipara (22.72%) and Moheskhali (4.57%) while the lowest organic matter content (0.65%) was found in Madhupur (Tangail). From the study it can be said that organic matter content was quite high in the surface layer except Madhupur soil. This is probably due to decaying of organic sunstances in top soil. According to BARC (1997) the organic matter of all the upland soils to be very low (OM< 1.00%). But an investigation showed that acid sulphate soils contain high organic matter (>5%) (Bhuiyan, 1998). The results were closely related with Khan *et al*. (2002). Organic matter has a close relation with the nutrient availability of a soil. At least 2% organic matter content is suitable for better crop production but all the studied soils did not contain organic matter up to the mark. In our soil the low level of organic matter content might be due to higher oxidation rate of plant and animal residues by relatively higher temperature. Soil organic matter status can be enriched by adding cowdung, compost and through green manuring.

Total nitrogen (N)

The total nitrogen content of 7 different soils at 0-15 cm depth from fourteen selected areas of Bangladesh are presented in Table 1. In surface soils, the % total N content ranged from 0.056 to 1.638% with the mean values of 0.21%. The highest N content 1.638% was found in Dumuria (Khulna) and the lowest value 0.056% was found in Madhupur (Tangail). These results were very close to the findings of Portach and Islam (1984) who reported that, hundred percent soils of Bangladesh contained N below critical level (0.271-.0.36%) (BARC, 1997) whereas total N content in Dumuria (Khulna) soils were very much higher than the critical level. This might be due to higher amount of organic matter present in those peat soil. Bhuiyan (1988) reported that the total N percentage of different soil series of Bangladesh ranged from 0.05 to 0.22%.

Available phosphorus

The available phosphorus of different soils under study have been shown in Table 1. In surface soils, the available phosphorus content ranged from (3.77 to 17.28 $\mu g\ g^{-1}$) with the mean values of 11.57 $\mu g\ g^{-1}$. The highest available P was found in non-calcareous soils located BAU farm and Sutiakhali. The lowest available P was found in Moheskhali (3.77 $\mu g\ g^{-1}$). The rest of the soils were almost equal although some statistical variation existed and it ranged from 5.43 to 12.59 $\mu g\ g^{-1}$. The results showed that the phosphorus status of acid sulphate soils was quite low. The low pH might be responsible for such values of phosphorus in these soils. The phosphorus status of acid sulphate soil should be increased to maximize crop production. Portch and Islam (1984) reported that 41% soils of

Bangladesh contained phosphorus below critical level and 35% below optimum level. Bhuiyan (1988) observed that the available P of different soil series of Bangladesh ranged from 2.2 to 140 µg g^{-1} with a mean value of 21.2 µg g^{-1}.

Table 1. Organic matter, Total N, available P and S status of seven different types of soils of fourteen selected regions of Bangladesh

Soil type	Locations	OM (%)	Total N (%)	Available P (µg g^{-1})	Available S (µg g^{-1})
Non-calcareous	BAU farm, Mymensingh	1.51 g	0.183 d	17.28 a	22.43 i
	Sutiakhali, Mymensingh	1.31 h	0.155 e	16.55 b	24.81 i
Calcareous	Ishardi, Pabna	1.10 i	0.119 f	6.53 k	41.21 g
	Lalpur, Natore	1.06 i	0.118 f	7.51 j	32.33 h
Peat	Dumuria, Khulna	28.24 a	1.638 a	12.59 h	48.89 f
	Kotalipara, Gopalganj	24.72 b	1.434 b	13.04 g	55.34 e
Saline	Asasuni, Satkhira	2.29 f	0.188 d	7.78 i	44.07 g
	Chorfasion, Bhola	4.31 d	0.225 c	14.45 d	32.70 h
Alkaline	Kaligonj, Satkhira	1.63 g	0.124 f	13.62 f	64.170 d
	Botiaghata, Khulna	2.63 e	0.189 d	15.02 c	97.57 c
Acid	Madhupur, Tangail	0.65 j	0.056 g	14.21 e	13.40 j
	Tangail sadar, Tangail	1.61 g	0.151 e	14.19 e	16.33 j
Acid sulphate	Chakaria, Cox'bazar	2.28 f	0.151 e	5.43 l	325.87 b
	Moheskhali, Cox'bazar	4.57 c	0.143 e	3.77 m	420.32 a
SE (±)		0.041	0.003	0.079	1.12
CV (%)		1.78	2.79	1.19	2.20
LSD (0.01)		0.119	0.017	0.231	3.27

In a column, the figure(s) having same letter are not significantly different by DMRT.

Available sulphur

Results presented in Table 1 showed that the available S varies from location to location vary widely. It varied from 13.40 to 420.32 µg g^{-1} with the mean value of 88.53 µg g^{-1}. The highest available S was found in Moheskhali (420.32 µg g^{-1}) was significantly higher over all other soils. It was followed by Chakaria (325.88 µg g^{-1}) and Botiaghata (97.57 µg g^{-1}). The status of Kaligonj (64.1 µg g^{-1}), Kotalipara (55.3 µg g^{-1}4) and Dumuria were significantly higher than Ishardi (41.22 µg g^{-1}) and Asasuni (44.07 µg g^{-1}) which were again statistically equal. Next to these soils were Chorfasion (32.70 µg g^{-1}) and Lalpur (32.33 µg g^{-1}) which were again statistically equal and significantly lower than Sutiakhali (24.81 µg g^{-1}) and BAU farm (22.43 µg g^{-1}) which were again statistically identical. The lowest available S was found to be 13.40 µg g^{-1} in Madhupur which was statistically similar with Tangail sadar (16.88 µg g^{-1}). The high content of sulphur in acid sulphate soils is possibly due to the oxidation of pyrite minerals resulting in the formation of ferrous sulphate ions. This high level of S may be toxic for some of the crops. Khan *et al.* (2002) stated that the high sulphur content in the surface soil suggests the use of acid sulphate soils as sulfidic fertilizers or acidic materials especially for S-deficient or calcareous soils. These findings are in agreement with Islam (1992) who reported that the S deficiency in Bangladesh soils is becoming widespread and acute except the acid sulphate soils of Bangladesh. Portch and Islam (1984) reported that 68% soils of Bangladesh contained sulphur below critical level and 14% below optimum level.

Exchangeable sodium

The results on exchangeable Na content of soils under study have been presented in Table 2. In surface soils, the exchangeable Na content ranged from 0.44 to 7.83 meq/100 g soil with the mean values of 3.25 me/100 g soil. A strong variation in exchangeable Na content was found between the soils (Table 2). In general, the alkaline and saline soils showed superiority over other soils. The soils of Kaligonj (7.83 meq/100 g soil) showed a strong significant superiority over the other soils. The Na content of Chorfasion (6.25 meq/100 g soil) and Asasuni (6.14 meq/100 g soil) soils was next to Kaligonj and dominated over Dumuria (4.89 meq/100 g soil) and Botiaghata (4.26 meq/100 g soil) soils. The status of Kotalipara (3.87 meq/100 g soil), Chakaria (3.31 meq/100 g soil) and Moheskhali (2.73 meq/100 g soil) soils had almost equal and lower than Dumuria and Botiaghata. The lowest Na content (0.44 meq/ 100 g soil) was observed in Madhupur (Tangail). Other soils varied between 0.56 to 1.98 meq/100 g soil. Sodium concentration of saline and alkaline soils was much higher possibly due to the intrusion of saline water from the sea and capillary rise of saline water from the underground.

Table 2. Exchangeable Na, K, Ca and Mg values of seven different types of soils of fourteen selected regions of Bangladesh

Soil type	Locations	Ex. Na (meq/100g soil)	Ex. K (meq/100g soil)	Ex. Ca (meq/100g soil)	Ex. Mg (meq/100g soil)
Non-calcareous	BAU farm, Mymensingh	0.75 k	0.149 j	5.41 h	2.51 c
	Sutiakhali, Mymensingh	0.61 l	0.111 k	4.68 i	3.16 a
Calcareous	Ishardhi, Pabna	1.98 i	0.114 k	22.57 a	1.49 e
	Lalpur, Natore	1.90 j	0.078 l	23.83 b	1.45 e
Peat	Dumuria, Khulna	4.89 d	0.473 d	13.75 c	0.76 g
	Kotalipara, Gopalganj	3.87 f	0.197 h	13.44 d	0.67 h
Saline	Asasuni, Satkhira	6.14 c	0.346 f	9.75 e	0.34 i
	Chorfasion, Bhola	6.25 b	0.952 a	6.26 f	0.27 ij
Alkaline	Kaligonj, Satkhira	7.83 a	0.764 b	2.30 l	0.16 k
	Botiaghata, Khulna	4.26 e	0.649 c	3.87 j	0.26 j
Acid	Madhupur, Tangail	0.44 m	0.190 h	3.42 k	2.26 d
	Tangail sadar, Tangail	0.56 l	0.169 i	3.67 j	2.76 b
Acid sulphate	Chakaria, Cox'bazar	3.13 g	0.323 g	5.26 h	1.13 f
	Moheskhali, Cox'bazar	2.73 h	0.365 e	5.81 g	1.45 e
SE (±)		0.026	0.005	0.078	.0.027
CV (%)		1.37	2.65	1.46	3.25
LSD (0.01)		0.075	0.017	0.225	0.075

In a column, the figure(s) having same letter are not significantly different by DMRT.

Exchangeable potassium

In surface soils, the exchangeable K content ranged from (0.078 to 0.952 meq/100 g soil) with the mean values of 0.349. The highest value of exchangeable K was found to be 0.952 meq/100 g soil in Chorfasion which was followed by Kaligonj (0.764 meq/100 g soil) and Botiaghata (0.649 meq/100 g soil). The status of Dumuria (0.473 meq/100 g soil), Moheskhali (0.365 meq/100 g soil), Asasuni (0.346 meq/100 g soil) and Chakaria (0.323 meq/100 g soil) although significantly varied from Kaligonj and Botiaghata, these were more close to Kaligonj and Botiaghata than others. The lowest amount of exchangeable K was found 0.078 meq/100 g soil in Lalpur. Ghelani (1985) also found the similar results. In most of the values of K were above the critical level except Lalpur soil which was below critical level. The reasons of such variation in exchangeable

K content of the soil is not clearly understood. However, original deposition and fertilizer management of soil probably responsible for the variation.

Available calcium

The results on exchangeable Ca content of soils at 0-15 cm depth from fourteen selected areas of Bangladesh have been shown in Table 2. It varied from (2.30 to 22.57 meq/100 g soil) with the mean values of 9.22. There was wide variation in exchangeable Ca content between the soils ranging from 2.30 meq/100 g soil to as high as 22.57 meq/100 g soil where the highest and lowest amount were found in Ishardi (22.57 meq/100 g soil) and Kaligonj (2.30 meq/100 g soil) soils respectively. The content of Lalpur (23.83 meq/100 g soil) and Dumuria (13.75 meq/100 g soil) were close to each other and significantly lower than Ishardi soils. A significant variations was also observed between Kotalipara (13.44 meq/100 g soil) and Asasuni (9.75 meq/100 g soil). Except Kaligonj the status of the rest of the soils ranged between 3.42 to 6.26 meq/100 g soil where again the highest and lowest value were found in Chorfasion (6.26 meq/100 g soil) and Madhuupur (3.42 meq/100 g soil). This result is very close to the findings of Zaman and Nuruzzaman (1995). These results were above the critical level of 2.0 meq/100 g soil (Table 2). The amount of exchangeable Ca content in different soil depths did not vary widely but decreased with the soil depth.

Exchangeable Magnesium

The results on exchangeable Mg content of soils have been presented in Table 2. It ranged from (0.16 to 3.16 meq/ 100 g soil) with the mean values of 1.33. The highest amount of exchangeable Mg was found to be 3.16 meq/ 100 g soil in Sutiakhali which was followed by Madhupur (2.76 meq/ 100 g soil) and BAU farm (2.51 meq/ 100 g soil). Next to these soils was Tangail sadar (2.26 meq/ 100 g soil) which was significantly lower than Sutiakhali soil. The status of Ishardi (1.49 meq/ 100 g soil), Lalpur (1.4 meq/100 g soil 5) and Moheskhali (1.45 meq/ 100 g soil) were statistically identical and significantly superior to the rest of the soils under study. The lowest value was obtained (0.16 meq/100 g soil) in Kaligonj followed by Botiaghata (0.26 meq/100 g soil). The rest of the soils ranged from 0.27 to 0.76 meq/ 100 g soil.

Available Zn

The available Zn content of seven different soil types were presented in Table 3. The available Zn content of different soil types varied from one location to another. It varied from 1.22 to 6.43 µg g^{-1} with the mean values of 2.28 µg g^{-1}. The highest available Zn was obtained in Dumuria (Khulna) 6.43 µg g^{-1} which was followed by kotalipara 4.50 µg g^{-1} and then Asasuni 2.61 µg g^{-1}. Next to these soils was Madhupur 2.32 µg g^{-1} which was again higher than that of Dumuria soils. The status of Kaligonj 1.78 µg g^{-1}, Tangail sadar 1.77 µg g^{-1} and Moheskhali were statistically same and significantly lower than Madhupur soil. The lowest available Zn (1.22 µg g^{-1}) was found in BAU farm (Mymensingh) which was statistically similar with Ishardi soil (1.22 µg g^{-1} Zn). These results were around the medium to optimum level. Hence the status of Zn in surface soil is much higher for crop production.

Available Cu

The data on available Cu of surface soils were presented in Table 3. It varied from 0.20 to 6.69 µg g^{-1} with the mean values of 2.18 µg g^{-1}. The highest available Cu content (8.1 µg g^{-1}) was found in Chakaria (Cox'sbazar) which was significantly higher over all other soils. It was followed by Moheskhali (7.70 µg g^{-1} Cu) and BAU farm soils (6.69 µg g^{-1} Cu). The available Cu of Sutiakhali (5.66 µg g^{-1}) which was significantly higher than that of Tangail sadar (3.29 µg g^{-1}). The status of Chorfasion (2.84 µg g^{-1}) and Madhupur (2.94 µg g^{-1}) was statistically equal and significantly higher than Kaligonj (1.85 µg g^{-1}) and Botiaghata (1.71 µg g^{-1}). Among the soils studied the available Cu content of Dumuria (Khulna) soil was the lowest followed by Ishardi (0.56 µg g^{-1}) and Lalpur (0.53 µg g^{-1}). Other soils were almost similar although some statistical variation existed (Table 3). The results were very close to that of Khan *et al.* (1997) and Razzaque *et al.* (1998). However, the available Cu contents in the study areas were very high and in most of the cases it ranged from medium to optimum level. The acid sulphate soils of chakaria contained the highest amount of copper. Sarker (1995) also reported that available Cu content of acid sulphate soil was much higher than any other soils of Bangladesh.

Available Fe

The results on available Fe content of soils at 0-15 cm depth from fourteen selected areas of Bangladesh have been shown in Table 3. It varied from 7.62 to 346.12 µg g^{-1} Fe with the mean value of 115.66 µg g^{-1} Fe. The highest value of available Fe was found to be 346.12 µg g^{-1} in Madhupur (Tangail) which was followed by Tangail sadar (315.09 µg g^{-1}) and Kotalipara (173.14 µg g^{-1}). The available Fe of Dumuria (164.29 µg g^{-1}), Moheskhali (135.00 µg g^{-1}), Botiaghata (101.05 µg g^{-1}) and Kaligonj (97.00 µg g^{-1}) although significantly lower from Tangail sadar and Kotalipara but statistically higher than others.

The lowest available Fe (7.62 µg g^{-1}) was found in Ishardi (Pabna). It was observed that Fe contents in the study soils were at optimum level except Ishardi (Pabna) & Lalpur (Natore) soils. The highest available Fe in Madhupur (Tangail) soils might be due to comparatively low pH in surface layer. The activity of Fe decreases with increase in soil pH (Lindsay, 1974). Liming generally decrease the availability of this nutrient in soil.

Table 3. Micronutrient status of seven different types of soils of fourteen selected regions of Bangladesh

Soil type	Locations	Available Zn (µg g^{-1})	Available Cu (µg g^{-1})	Available Fe (µg g^{-1})	Available Mn (µg g^{-1})
Non-calcareous	BAU farm, Mymensingh	1.22 j	6.69 c	74.23i	48.48 c
	Sutiakhali, Mymensingh	1.63 h	5.66 d	68.02 j	43.25 d
Calcareous	Ishardi, Pabna	1.22 j	0.56 j	7.62 n	2.67 k
	Lalpur, Natore	1.50 i	0.53 j	11.12 m	2.39 k
Peat	Dumuria, Khulna	6.43 a	0.20 k	164.29 d	7.68 j
	Kotalipara, Gopalganj	4.50 b	0.89 i	173.14 c	7.51 j
Saline	Asasuni, Satkhira	2.61 c	1.10 h	14.12 l	12.76 h
	Chorfasion, Bhola	2.05 e	2.84 f	30.25 k	9.42 i
Alkaline	Kaligonj, Satkhira	1.78 g	1.85 g	97.00 g	27.85 g
	Botiaghata, Khulna	1.22 j	1.71 g	101.05 f	27.61 g
Acid	Madhupur, Tangail	2.32 d	2.94 f	346.12 a	83.58 a
	Tangail sadar, Tangail	1.77 g	3.29 e	315.09 b	77.47 b
Acid sulphate	Chakaria, Cox'bazar	1.88 f	8.06 a	81.53 h	32.16 f
	Moheskhali, Cox'bazar	1.75 g	7.70 b	135.00 e	37.34 e
SE (±)		0.022		0.047	0.160
CV (%)		1.46	2.76	0.91	0.92
LSD (0.01)		0.053	0.140	1.78	0.466

In a column, the figure(s) having same letter are not significantly different by DMRT.

Available Mn

The data on available Mn content of soils have been presented in Table 3. It varied from 2.39 to 83.58 µg g^{-1} with the mean value of 30.01 µg g^{-1}. The highest available Mn (83.58 µg g^{-1}) was obtained in Madhupur (Tangail) and it was followed by Tangail sadar (77.47 µg g^{-1}) and BAU farm (48.48 µg g^{-1}). Sutiakhali (43.25 µg g^{-1}), Moheskhali (37.34 µg g^{-1}) and Chakaria (32.16 µg g^{-1}) were very close to one another and dominated over rest of the soils for available Mn. Next to these soils the available Mn of Kaligonj (27.85 µg g^{-1}) and Botiaghata (27.61 µg g^{-1}) were statistically equal and significantly lower than Asasuni (12.76 µg g^{-1}). The lowest available Mn (2.39 µg g^{-1}) was found in Lalpur (Natore) which was statistically similar to Ishardi (2.67 µg g^{-1}). These results were higher than the critical level for successful crop production. The results were close to that of Razzaque *et al.* (1998). Sarker (1995) studied that in Harirampur soil of Bangladeah, the highest Mn content was 38.37 ppm. The present investigation showed that the Mn content of acid sulphate soils were generally high.

Arsenic (As) content in soils

The levels of arsenic (As) content of soil at different regions have been presented in Table 4. It appears that all the 14 samples were contaminated with arsenic though their concentration varies from soil to soil. The average arsenic content was 8.81 µg g^{-1} (Table 4) with a range of 1.07 to 21.28 µg g^{-1} at 0-15 cm depth. The maximum acceptable limit of As for agricultural soils are 20 µg g^{-1} (Pendias and Pendias, 1992). With this consideration, the present average concentration (8.81 µg g^{-1}) at different soil types was safe against the hazards and contamination of arsenic.

The highest total As content (21.28 µg g^{-1}) was found in Kotalipara (Gopalganj) and it was followed by Dumuria (19.53 µg g^{-1}), and Chakaria (13.2 µg g^{-1}). The lowest As content (1.07 µg g^{-1}) was found in BAU farm (Mymensingh). The rest of the soils were found almost similar with respect to As content. All the soil samples without Kotalipara (Gopalganj) can be called uncontaminated. Arsenic varies soil to soil, depending on their capacity to adsorb arsenic. The adsorption capacity of soils is also dependent on many factors viz. texture, redox potential, pH, changes in cation coordination, isomorphism substitution and crystallinity of the colloidal materials, carbonate minerals, Fe-oxide/hydroxide, Al-oxide/hydroxides (Sadiq, 1997).

Table 4. Heavy metals such as Arsenic (As), Cadmium (Cd) and Lead (Pb) status of seven different types of soils of fourteen selected regions of Bangladesh

Soil type	Locations	Arsenic (As) (µg g^{-1})	Cadmium (Cd) (µg g^{-1})	Lead (Pb) (µg g^{-1})
Non-calcareous	BAU farm, Mymensingh	1.07 n	2.09 ef	23.86 m
	Sutiakhali, Mymensingh	3.93 k	2.25 de	28.20 k
Calcareous	Ishardi, Pabna	5.53 j	2.58 c	43.67 e
	Lalpur, Natore	5.77 i	2.39 cd	26.19 l
Peat	Dumuria, Khulna	19.53 b	2.46 cd	60.9 a
	Kotalipara, Gopalganj	21.28 a	1.94 f	42.25 f
Saline	Asasuni, Satkhira	10.81 e	2.43 cd	38.41 h
	Chorfasion, Bhola	11.82 d	3.15 a	54.09 b
Alkaline	Kaligonj, Satkhira	10.55 f	2.89 b	48.22 d
	Botiaghata, Khulna	6.23 g	1.51 h	51.82 c
Acid	Madhupur, Tangail	3.76 l	1.64 gh	40.68 g
	Tangail sadar, Tangail	3.63 m	1.38 h	28.82 j
Acid sulphate	Chakaria, Cox'bazar	13.23 c	1.81 fg	36.88 i
	Moheskhali, Cox'bazar	6.16 h	2.08 ef	43.37 e
SE (±)		0.022	0.09	0.158
CV (%)		1.43	7.15	2.67
LSD (0.01)		0.0531	0.260	0.457

In a column, the figure(s) having same letter are not significantly different by DMRT.

Cadmium (Cd) content in soils

The data on total Cd content of soils have been presented in Table 4. It varied from 1.38 to 3.15 µg g^{-1} with a mean value of 2.19. The highest total Cd was found to be 3.15 µg g^{-1} in Chorfasion (Bhola) and it was followed by Ishardi (5.23 µg g^{-1}), and Kaligonj (2.89 µg g^{-1}). The Cd of Lalpur (2.39 µg g^{-1}), Dumuria (2.4 µg g^{-1} 5) and Asasuni (2.43 µg g^{-1}) was statistically same and signiificantly higher than Chakaria (2.08 µg g^{-1}), BAU farm (2.08 µg g^{-1}) and Sutiakhali (2.25 µg g^{-1}). The lowest Cd value was found 1.38 µg g^{-1} in Tangail sadar (Tangail) which was identical to Botiaghata (1.51 µg g^{-1}) and Madhupur (1.64 µg g^{-1}). The acceptable level of Cd in agricultural soil is around 3.0 µg g^{-1} (Cicek and Koparal, 2004). Furthermore, accumulation of Cd in the plants increases with increasing salinity in the soil (Norvell *et al.*; 2000) and here in the present study we found higher Cd content in saline soils which needs to be addressed in future research.

Lead (Pb) content in soils

The results on total Pb content of soils at 0-15 cm depth from fourteen selected areas of Bangladesh have been presented in Table 4. It varied from 23.86 to 60.99 µg g^{-1} with the mean value of 40.53. The highest total Pb content was found to be 60.99 µg g^{-1}

in Dumuria (Khulna) was significantly higher over all other soils. The Pb status of Chorfasion (54.09 µg g^{-1}) and Botiaghata (51.82 µg g^{-1}) were significantly lower than Dumuria soil. Next to these soils was Kaligonj (48.22 µg g^{-1}) which was again significantly superior to rest of the soils under study. The lowest Pb content was found in BAU farm (Mymensingh) (23.86 µg g^{-1}) soils. Sattar and Blume (2000) reported Pb content of 3.6 to 53.4 mg kg^{-1} in some soils of Bangladesh and results presented here within their published range.

Conclusions

From the present study, it may be concluded that total contents of organic matter, N, P, K, S, Fe, Cu, Mn, Zn, Ca, Mg, Na, As, Pb, and Cd in Bangladesh soils were affected more or less by physiography on which soils are distributed. Trace element contents were generally lower for terrace soils than for floodplain soils, and the variation element concentration was prominent with physiography. No deficiency of available Fe and Cu was found, but occurrence of Cu deficiency in near future is possible. About half and almost all soils were deficient in Mn and Zn, respectively. A single good indicator for different elements studied could not be assessed. The soils studied in the experiment did not show marked contamination of elements studied except salinity in some soils.

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