Bangladesh J. Sci. Res. **26**(1&2): 1-9, 2013 (December)

ASSESSMENT OF LONG-TERM EFFECTS OF BASIC SLAG IN RECLAIMING ACID SULFATE SOIL

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Abstract

A long term incubation study was carried out to ascertain the effects of basic slag on acid sulfate soil. Four treatment levels of basic slag (0, 30, 40 and 50 t/ha) were selected to find out their response on pH, EC, as well as on various water soluble and exchangeable cations (Na, K, Ca, Mg and Fe) with incubation period. In most of the cases, the results showed significant effects of basic slag on pH and cations. The highest pH and EC were recorded with the largest doses of basic slag at the final stage of incubation period. In addition, this research did not find any negative impacts concerning basic slag on the supplied soil and suggested that basic slag could be used on agricultural land.

Key words: Acid sulfate soil, basic slag, long term incubation

Introduction

Acid sulfate soils are well known as problem soils, containing iron sulfide and generating sulfuric acid. But these soils are usually harmless when stay in a waterlogged, undisturbed environment. However, when exposed to air through drainage or excavation, the iron sulfides in the soil react with oxygen and water to produce iron compounds and sulfuric acid. This acid might release with other substances including heavy metals from the soil and into the surrounding environment and waterways and helps to destroy entire natural ecological balance (Hinwood *et al.* 2006). In these circumstances, an appropriate management might be useful prior to the potential harm of acid sulfate soils and may be considered to use them for agricultural purposes (Khan 1994).

The extent of acid sulfate soils in Bangladesh is about 0.7M ha of land area and stretched across Cox's Bazar and greater Khulna district (Khan *et al.* 2000). In order to raise soil pH of strongly and moderately acid soils, different types of liming materials are applied to reduce the solubility of heavy metals as well as to improve the physical, chemical and biological properties of soils (Nessa *et al.* 2012). Usually liming materials are used to neutralize acid sulfate soils as the use of basic slag is not well known in Bangladesh. According to Dent (1986) application of basic slag from steel industry might be potential and cost effective to reduce soil acidity. In addition, the silicon from basic slag has the potentiality to decrease Mn toxicity, suppress lodging, improve insect and disease resistance power as well as increases water use capability, oxidation power of rice roots in line with the efficiency of phosphorous utilization in low pH oxisols. Moreover, the supply of Fe from the basic slag under wetland rice culture help to reduce CH_4 emissions and thus keep environment safe from global warming (Elawad and Green 1979). It has been noticed from

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short term incubation research that liming materials are able to raise pH sharply (from 4.7 to 7.8) within a month (Nessa *et al.* 2012). Since basic slag has acid neutralizing capacity, convenient and economically feasible, this might be used for long term incubation study. Khan *et al.* (2006) reported that basic slag has been used in agricultural land since 1985 and did not create any harmful effects on crops. They suggested that basic slag could be applied to reclaim acid sulfate soils. An appropriate reclamation and management practices of acid sulfate soil is necessary to reduce the leaching of base materials from soil solution as well as to decrease nutrient deficiency (Jintaridth 2006). According to Cook *et al.* (2006) increasing acidity in acid sulfate soil profile is responsible to reduce base materials and could able to do harm for aquatic and terrestrial environment. However, most of the studies aiming at reclaiming acid sulfate soils were conducted for a shorter period (Khan 1994, Khan *et al.* 1996). Therefore, the principal aim of this work was to assess the response of basic slag treatments on acid sulfate soil already incubated for a long time.

Materials and Methods

The incubation study was carried out in the laboratory of the Department of Soil, Water and Environment, University of Dhaka. It is pertinent to say that the incubation study was conducted up to 42 months earlier. Present work continued again from the period of 42 to 51 months to observe the further change of supplied soil due to long term incubation with basic slag and thus enabled to compare the data with the initial data.

In order to conduct this research, an acidic soil (0 - 30 cm) was collected from Chakaria Upazilla under Cox's Bazar district and this belonged to Cheringa series. After carrying out the soil sample, it was dried in air for three days by spreading them on a thin layer of paper.

Visible roots and debris were removed from the soil and discarded. After air drying, a portion of larger and massive soil aggregates were crushed gently with the help of a wooden hammer. Ground samples were then screened to pass through a 2 mm stainless steel sieve. After that the sieved samples were mixed thoroughly to make a composite sample. Some physical and chemical properties of studied soil were analyzed according to the method of Huq and Alam (2005) (Table 1). Soil samples were then preserved in plastic bags and labeled properly for incubation study.

Basic slag was collected from Chittagong Steel Mills Corporation, Chittagong, Bangladesh and then grounded to less than 1 mm sizes. The composition of basic slag (%): SiO_2 (12.8), Ca (20.8), Mg (9.8), Fe (11.3), Mn (0.04), PO_4 (0.3) and others (44.96). It was mixed thoroughly as per treatment.

In order to observe the effects of basic slag on acid sulfate soil an incubation study was conducted at room temperature in the laboratory of the Department of Soil, Water and Environment. 50 gm of soils were put into 12 plastic bottles of 10 cm height and 4 cm diameter. Soils were then treated with basic slag at the rate of 0, 30, 40 and 50 t/ha coded as BS_0, BS_1, BS_2 and BS_3, respectively. Soils were mixed properly with corresponding rate of basic slag. The soil, incubated for initial 42 months (T_0) was further incubated for 3 months (T_1), 6 months (T_2) and 9 months (T_3). Treatment combinations for the incubation study with their corresponding symbol are shown in Table 2.

Table 1. Physical and chemical properties of soil series.

Property	Findings
Textural class	Silty clay loam
Bulk density (g/cm)	1.03
Structure	Massive to moderate coarse and medium angular blocky
Color	Dark grayish brown with yellowish brown mottles
Moisture under field condition (vol. %)	49.00
Organic carbon (g/kg)	23.40
Soil pH (soil : water 1 : 2.5)	3.9
Electrical conductivity (soil : water 1 : 5) (mS/cm)	3.0
Water soluble ion (cmol/kg):	
Sodium	4.84
Potassium	0.21
Calcium	0.27
Magnesium	1.34
Iron	0.33
Exchangeable ion (cmol/kg):	
Sodium	4.30
Potassium	0.29
Calcium	0.44
Magnesium	1.53
Iron	1.29

Table 2. Treatment levels for incubation study with their corresponding symbol.

Treatment		Symbol
Time (T)	Basic slag (BS)	
T_0	BS_0	T_0BS_0
	BS_1	T_0BS_1
	BS_2	T_0BS_2
	BS_3	T_0BS_3
T_1	BS_0	T_1BS_0
	BS_1	T_1BS_1
	BS_2	T_1BS_2
	BS_3	T_1BS_3
T_2	BS_0	T_2BS_0
	BS_1	T_2BS_1
	BS_2	T_2BS_2
	BS_3	T_2BS_3
T_3	BS_0	T_3BS_0
	BS_1	T_3BS_1
	BS_2	T_3BS_2
	BS_3	T_3BS_3

Different chemical parameters of the incubated soils were analyzed in the laboratory following the procedures illustrated by Huq and Alam (2005). Both the initial and incubated water soluble and exchangeable nutrients were analyzed by prescribed methods as well. The results given were the mean of triplicate determination. After obtaining the result statistical analyses were done by ANOVA using the software Minitab 13.

Results and Discussion

The soil was analyzed to find out the changes of different chemical parameters (pH and EC) and water soluble and exchangeable cations at different incubation period.

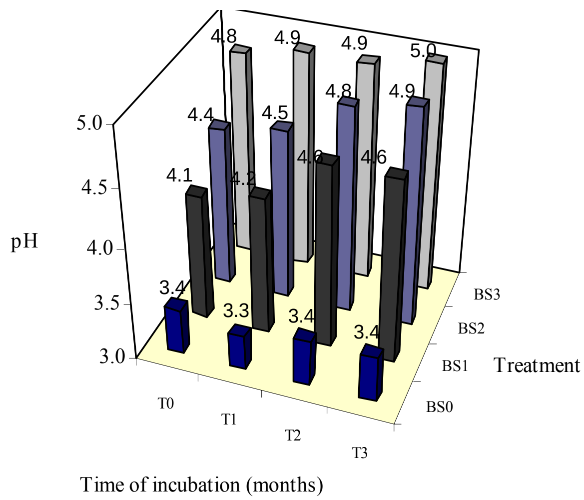

Fig. 1. Changes in soil pH on incubation with basic slag.

Fig. 1 shows significant ($p \leq 0.05$) positive increase in pH with the increased rate of basic slag application in the soil compared with the control where no basic slag was applied. The initial low pH of the soil was increased with the highest dose of basic slag and the effect was more pronounced with the final period of incubation. The pH rose from 3.4 to 5.0 after 51 months of incubation which revealed a wide and significant change in soil pH made by the application of basic slag (Fig. 1). It is noticeable from the figure that a gradual increasing trend of pH was observed in the overall incubation months but the initial lower pH value (3.4) was not changed with the incubation time in the control treatment (BS_o), except T_1 where the lowest pH of the supplied soil was recorded as 3.3. The increase of pH was owing to the higher base materials (like Ca, Mg) in basic slag. These results partially agree well with the findings of Khan *et al.* (1993 and 1996).They reported that the application of basic slag at the rate of 12 t/ha on acid sulfate soils increased the soil pH from 5.3 to 7.4. The rise of pH in the present study also remained almost similar range, which might be due to the washout of soluble sulfate and /or in the formation of insoluble sulfate compounds like gypsum, akaganeite (Bigham *et al.* 1990). Throughout the incubation period, it was noticed that the potentiality of basic slag as a liming material will be effective for reducing the acidity of acid sulfate soil for long time. Abbaspour *et al.* (2004); Alves *et al.* (2006) and Khan *et al.* (2006) reported that the basic slag was also effective in increasing soil pH as well as maintained favorable soil conditions.

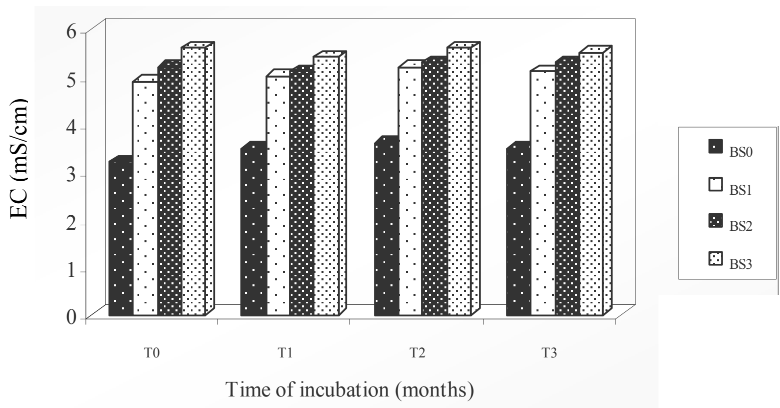

Fig. 2. Changes in soil pH on incubation with basic slag.

The effects of basic slag and duration of incubation time on the changes in EC of supplied acid sulfate soil is represented in Fig. 2. The application of basic slag and incubation time showed significant ($p = 0.030$) influence on EC values of the supplied soil although the trend of EC increase was very slow. The rise of EC values could be attributed to the initial high salt contents of the soil, which was released with time during incubation. The maximum increase of EC (5.6 ms/cm) was observed while highest treatment (BS_3) was applied. This might be due to the maximum solubility of the applied basic slag in presence of high acidity resulting in high EC in the soils. This is likely to have the EC value of an acid soil sulfate 10-20 mS/cm (Khan *et al.* 2000 and Marius 1992). Therefore, the maximum EC (5.6 mS/cm) resulted from present work may not hinder the role of treatment as well as crop growth while considered for field study.

The amount of water soluble ions depend on their solubility in water in soil matrix. Some parts of adsorbed cations and anions are easily dissolved in water but the portions absorbed by soils are comparatively difficult to dissolve. Nevertheless, plant nutrient availability depends largely on water soluble elements present in soil. This research enabled to find out the changes in water soluble ions at different incubation periods and showed their response with different treatment levels.

The present work followed a sharp decrease in sodium solubility with basic slag application and different incubation periods. The Table 3 reveals that the initial amount of water soluble sodium was 3.11 cmol/kg where no treatment (T_0BS_0) was applied. The minimum water soluble sodium was recorded at the last incubation stages (T_3BS_0) and it was 1.76 cmol/kg. Bhuiyan (2004) reported that basic slag application on acid sulfate soils increase the solubility of sodium up to 32 months and slowed dramatically thereafter. Present results coincide with his report. The influence of basic slag on water soluble sodium on incubation time was highly significant (p = 0.002).

Table 3. Effects of basic slag on water soluble cations at different periods of incubation.

Treatment	Water soluble Na (cmol/kg)	Water soluble K (cmol/kg)	Water soluble Ca (cmol/kg)	Water soluble Mg (cmol/kg)	Water soluble Fe (cmol/kg)
T_0 BS_0	3.11	0.26	0.31	1.35	0.21
T_0 BS_1	3.16	0.39	0.99	2.74	0.13
T_0 BS_2	3.16	0.42	1.11	3.82	0.11
T_0 BS_3	3.13	0.44	2.75	4.42	0.08
T_1 BS_0	2.88	0.25	0.32	1.36	0.27
T_1 BS_1	2.95	0.40	1.03	2.77	0.16
T_1 BS_2	2.99	0.41	1.14	3.86	0.13
T_1 BS_3	2.84	0.45	2.77	4.45	0.12
T_2 BS_0	2.23	0.27	0.31	1.36	0.20
T_2 BS_1	2.16	0.44	1.08	2.71	0.14
T_2 BS_2	2.15	0.45	1.18	3.68	0.10
T_2 BS_3	2.16	0.51	2.82	4.44	0.08
T_3 BS_0	1.76	0.27	0.32	1.35	0.21
T_3 BS_1	1.80	0.45	1.10	2.62	0.15
T_3 BS_2	1.78	0.48	1.19	3.51	0.08
T_3 BS_3	1.87	0.51	2.81	4.23	0.07

Meanwhile a reverse trend was noticed for potassium solubility with basic slag application. A significant (p = 0.000) and steady increase of potassium solubility recorded from this study. The amount of potassium solubility reached from 0.26 to 0.51 cmol/kg at the end of incubation period.

Both water soluble calcium and magnesium followed an increasing trend with basic slag application at different incubation periods. In addition, these two cations showed highest level of significance (p = 0.000) with treatments. It has been noticed from the Table 3 that both the minimum and maximum calcium concentration was found at T_2 incubation period. The highest amount of water soluble calcium recorded at T_2BS_3 (2.82 cmol/kg). Meanwhile the highest amount of magnesium (4.45 cmol/kg) noticed at T_1BS_3 treatment level. The increase in calcium and magnesium concentration in the supplied soil might be due to the addition of calcium and magnesium from basic slag undergoing dissolution. Thus basic slag application helped develop the availability of calcium and magnesium cations and preparing the soils more suitable for crop production. The application of basic slag was found to be the best among the individual treatments in order to the increase in calcium contents, and support the findings of Anderson *et al.* (1987) and Gashcho (1977).

Iron is mostly a pH dependent element. The high amount of water soluble iron content was found in control treatment (BS_0). But the content of iron was decreased with the addition of different rates of basic slag (Table 3). Basic slag at the rate of 50 t/ha was found more effective to decrease the iron concentration. The amount of water soluble iron was low throughout the incubation time and the quantity was found to be decreased with the increase of pH as compared with the control. The steepest fall in the concentration of iron were observed with the application of lime (Khan *et al.* 1996). They also reported that the concentration of K, Ca, and Mg were increased while the concentration of Fe and Mn decreased in the acid sulfate soil. The influence of basic slag on water soluble iron was highly significant ($p = 0.000$).

Table 4. Effects of basic slag on exchangeable cations in the soil with incubation time.

Treatment	Exchangeable Na (cmol/kg)	Exchangeable K (cmol/kg)	Exchangeable Ca (cmol/kg)	Exchangeable Mg (cmol/kg)	Exchangeable Fe (cmol/kg)
T_0 BS_0	4.65	0.41	0.55	1.59	1.31
T_0 BS_1	4.85	0.65	1.35	3.41	0.98
T_0 BS_2	5.30	0.71	1.88	5.02	0.86
T_0 BS_3	5.42	0.85	3.78	5.98	0.76
T_1 BS_0	4.57	0.40	0.52	1.62	1.25
T_1 BS_1	4.78	0.63	1.36	3.52	1.02
T_1 BS_2	5.24	0.68	1.84	5.32	0.98
T_1 BS_3	5.34	0.84	3.71	6.21	0.77
T_2 BS_0	4.51	0.36	0.47	1.67	1.29
T_2 BS_1	4.71	0.61	1.24	3.61	1.12
T_2 BS_2	5.16	0.65	1.65	5.42	1.02
T_2 BS_3	5.23	0.82	3.41	6.11	0.85
T_3 BS_0	4.35	0.38	0.44	1.61	1.21
T_3 BS_1	4.63	0.63	1.26	3.54	1.10
T_3 BS_2	4.99	0.65	1.70	5.36	0.87
T_3 BS_3	5.12	0.85	3.48	6.08	0.81

From the Table 4 it has been observed that the influence of basic slag showed a significant ($p = 0.000$) rise for both the exchangeable sodium and potassium concentration of Cheringa soil. It is noticeable from this research that the increase of exchangeable cations concentration is true for each separate incubation period. However, the effects of basic slag on four different incubation periods followed a significant decrease trend from initial to final incubation stage. For example, Table 4 revealed that in T_0BS_0, the sodium content was 4.65 cmol/kg and raised up to 5.42 cmol/kg at T_0BS_3 treatment level, although the same treatment (BS_3) reduced to 5.12 cmol/kg at the final incubation (T_3) stage. The amount of potassium content due to basic slag application remained same at both T_0BS_3 and T_3BS_3 (0.85cmol/kg). The tendency of exchangeable cations to reduce from initial to final incubation period might due to the leaching loss of soluble ions over long incubation periods.

A decrease of exchangeable calcium concentration noticed from the Table 4 although basic slag influences calcium concentration significantly ($p = 0.000$) over the incubation period. The highest amount of exchangeable calcium was 3.78 cmol/kg at T_0BS_3.

From the Table 4 a reverse condition observed in exchangeable magnesium concentration. The effects of treatment, time and their interaction have found to have highly significant ($p = 0.000$) throughout the incubation period. Here, magnesium concentration did not follow any regular trend and the changes in ion content were not pronounced.

The result showed (Table 4) that the content of exchangeable iron remarkably decreased with time as compared with the control. The lowest concentration of iron was determined by the highest dose of basic slag (50 t/ha) where the corresponding pH rises at highest level. The influence of basic slag showed a significant ($p = 0.000$) rise for the exchangeable iron content of the soil.

Conclusion

This research attempted to evaluate the long term effects of basic slag treatments on acid sulfate soil at different incubation periods. In most of the cases the results showed significant response of treatments on pH, EC as well as various water soluble and exchangeable cations throughout the incubation periods. In addition, the results did not show any negative impacts concerning basic slag and encouraged basic slag's application to agricultural land. Nevertheless, further research is recommended regarding the presence of manganese or other metallaloids contained in basic slag and their behavior on soil in order to evaluate possible harmful effects due to basic slag application for agricultural use purposes and to avoid their possible negative environmental impacts.

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(Manuscript received on 30 May, 2013; revised on 21 July, 2013)