*IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*
*e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 15, Issue 11 Ser. I (November 2021), PP 32-40*
*www.iosrjournals.org*

# Impacts of Times, Moisture Levels and Basic Slags on Soil Reaction and Aluminum in Acid Sulfate Soils

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***Abstract***
*Significances of basic slag (BS) under various conditions on soil reaction (pH) and Al contents in acid sulfate soils (ASSs) were studied. The BS at the rates 0, 10, 20 and 30 t ha$^{-1}$ and moisture at field capacity, saturated condition and wetting-drying cycle were considered during 30-months of incubation. The $BS_{30}$ treatments were found to be increased the soil pH by about 1.2, 1.7 and 1.2 units in Sarisabari and 1.9, 2.2 and 1.6 in Purbapukuria ASSs under the mentioned moisture conditions, respectively and followed by the trend of $BS_{30} > BS_{20} > BS_{10}$. The high contents of Al in both the ASSs were decreased strikingly by the higher doses of BS, irrespective of moisture levels and were pronounced with the early 2-5 months and then quite steady state of Al was noticed till 30-months. This study noticed that the strength of BS as a liming material will be effective not only for neutralizing acidity of ASSs for long time but also remove toxicity of Al. The application of $BS_{30}$ under saturated soil moisture condition was the most suitable practice to decrease pHs and Al contents in both the ASSs followed by moisture at field capacity and wetting-drying cycle. The contents of Al showed inverse relationship with their corresponding pH values of the ASSs and these negative relationships were stronger with the higher rates of BS treatments.*

***Keywords:*** *Acid sulfate soils; basic slags; incubation times; moisture levels; soil pH and Al.*

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Date of Submission: 06-11-2021 Date of Acceptance: 23-11-2021

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## I. Introduction

Acid sulfate soils form naturally in wetland environments when sulfate in the water is converted by bacteria to sulfide minerals, predominantly iron pyrite ($FeS_2$). Soil horizons that contain sulfides with the potential to strongly acidify to pH < 4 are called sulfidic material (Isbell 1996, Soil Survey Staff 2014) or hypersulfidic material replacing the definition of sulfidic material of Isbell 1996 by Sullivan *et al.* (2010); Isbell and National Committee on Soils and Terrain (2016), which can be environmentally damaging if exposed to air by disturbance. Exposure results in the oxidation of pyrite, with each mole of pyrite yielding 4 moles of acidity (i.e. 2 moles of sulfuric acid). This process transforms sulfidic or hypersulfidic material to sulfuric material when, on oxidation, the material develops a pH of 4 or less (Isbell 1996) and a sulfuric horizon has a pH of 3.5 or less according to Soil Survey Staff (2014). If the soil remains above pH 4 during oxidation, they are classified as hyposulfidic. When ASS become strongly acidic then acid pore water or drainage water is produced. This acid together with toxic elements that are leached from soils and sediments can kill fish and shellfish; contaminate groundwater; and can corrode concrete and steel in homes, underground pipes and foundations of buildings. These impacts can be measured in terms of a) poor water quality with loss of amenity, damage to wetland environments and reduction of wetland biodiversity, b) the need for rehabilitation of disturbed areas to improve water quality and minimize impacts, c) loss of fisheries and agricultural production, and d) additional maintenance of community infrastructure affected by acid corrosion. Other hazards associated with acid sulfate soil include (i) mobilization of metals, metalloids and non-metals, (ii) decrease in oxygen in the water column when monosulfidic materials are mobilized into the water column, and (iii) production of noxious gases. In severe cases, these risks can potentially lead to damage to the environment, and have impacts on water supplies, and human and livestock health.

Soil acidification decreases soil pH, causing adverse effects on plants and soil microorganisms. Most plants prefer soil pH between 5.5 and 6.5, and a value below this range has shown to impact plant growth (Stevens *et al.* 2010). Particularly in the subsurface of acid soil restricts plant root access to water and nutrients. Aluminum coupled with acidification can lead to disorder nutrient balance. Acid soils are well known for their ability to mobilize toxic metals resulting in increased plant uptake and subsequent transfer in food chain through plant based products and foraging animals (Blake and Goulding 2002). Soil pH is considered as a major variable controlling microbial activity in many soils. By influencing soil microbial activity, soil acidity plays a major role in soil C and N cycling (Rousk *et al.* 2010). Traditionally, lime materials are added to neutralize acidic soils and to overcome the problems associated with soil acidification, but they also influence C and N cycles, thereby affecting greenhouse gas (GHG) flux in soils. Approximately 40% of the world's arable soils are acidic and the area has been increasing in recent years (Bian *et al.* 2013). Soil acidification is a serious problem in many countries, affecting agricultural gross income (Hajkowicz and Young, 2005). More than 80 million hectares of the most productive agricultural land in Australia is categorized as acidic, of which more than 40% are highly acidic (pH < 4.0). Soil acidity has been identified by the National Land and Water Audit as the most serious land degradation issue for Australian agriculture, costing close to $AU1 billion in lost production each year (ASEC 2001; NLWRA 2002). Against these backgrounds, improvements of pH and toxicity of Al in ASSs by the application of basic slag under variable moisture regimes and incubation times were considered for this present study.

## II. Materials and Methods

Magnitudes of basic slag at different moisture levels in different acidity levels of two acid sulfate soils were studied in a laboratory of the Department of Soil, Water and Environment, University of Dhaka, Bangladesh. Surface layer (0-20 cm) of the two different ASSs were collected from the coastal plains of Cox's Bazar district. One soil was from Sarisabari consists of Cheringa series and another from Purbapukuria having Badarkhali series. These soils were air dried and grounded uniformly into <2 mm sizes. Fifty grams of each soil with respective treatments was taken in a plastic bottle (10 cm height and 4 cm diameter). The four doses of 0, 10, 20 and 30 t $ha^{-1}$ of BS were selected for this incubation study. The moisture levels were considered as moisture at field capacity (50% water); moisture at saturated condition (100% water); and wetting-drying cycle (from saturation towards field capacity). In wetting-drying cycle, the soil samples were kept open under saturated condition for the first 15 days with much care and then, the saturated soils were kept at room temperature for natural air drying towards field capacity for the next 30 days. This cycle of wetting-drying was continuously repeated within every one and a half months and maintained up to the end of the incubation period of 30 months.

The experiment was conducted under room temperatures of 25 to $30^0$C. The bottles having the treated soils were kept in aerated condition and the desired level of moisture was maintained by the addition of distilled water when required. The soils were sampled in order to analyses the element dynamics at 0, ½, $1^1/_2$, 2, 3, $3^1/_2$, $4^1/_2$, 5, 6, 9, 12, 15, 21, 27 and 30 months after incubation. And for this, there were 15 sets of bottles and each set contained 24 bottles, i.e. the numbers of total bottles were 360 for this experiment. The soils were analyzed (Tab1) for textural class (pipette method, Day 1965); pH (field, 1:2.5 water and 0.02 M $CaCl_2$, Jackson 1973), EC (1:5, Richards 1954), organic carbon (wet combustion with $K_2Cr_2O_7$, Nelson and Sommers 1982), available nitrogen (micro-Kjeldhal method, Jackson 1973), available phosphorus (0.02 N $H_2SO_4$, spectrophotometry at 440 nm wave length, Olsen et al. 1954), exchangeable cations (Jackson 1973) such as $Na^+$, $K^+$ (flame photometry), $Ca^{2+}$ and $Mg^{2+}$, $Fe^{2+}$, $Mn^{2+}$ , $Al^{2+}$ (atomic absorption spectrophotometry, Hesse 1971), CEC (Chapman 1965).

## III. Results and Discussion

**Delicacies in soil reaction (pH):** A wide and significant ($p \leq 0.05$) changes in pHs of both the ASSs at Sarisabari and Purbapukuria were attained by the BS treatments under variable moisture conditions during 30 months of incubation (Fig1). Both the ASSs were found to be reached the lower pH under the condition of moisture at field capacity as compared with those obtained from the conditions of saturated soil and wetting-drying cycles. This might be due to having more oxidized conditions in field capacity than those of the other soil conditions and the results are quite similar with the findings of Sullivan *et al.* (2010). Isbell and National Committee on Soils and Terrain (2016). As the release of acidic materials occurred from the breakdown of pyrite in more oxidized ASS, which resulting the requirements of more liming materials to neutralize more acidity in both the ASSs. The $BS_{30}$ was found to be the best dose in order of increment in soil pH than those of the other lower doses of $BS_{20}$ and $BS_{10}$. In case of control ($BS_0$), except for several initial increased trends within the first 5 months (0.1 to 0.2 units raise of pH), the almost unchanged values of soil pHs were found in both the ASSs throughout the 30 months of incubation. But the application of BS was found to be increased the soil pH linearly with their increased doses regardless of moisture contents and soil conditions. Khan *et al.* (1996, 2008) reported that the application of BS at the rate of 12 t $ha^{-1}$ in ASSs increased the soil pH from 5.3 to 7.4. The rise of soil pH in the present study also remained almost similar range, which might be due to the formation of insoluble sulfate compounds like gypsum, akaganeite, etc. (Bigham *et al.* 1990).

The saturated conditions in both the ASSs might protect the pyrite from more oxidation and resulting less acidity, which ultimately required less amount of BS to be neutralized as well as induced more increment of soil pH than those of the low moisture content of the ASSs. The maximum values of soil pHs were determined in Sarisabari soils where the soil pHs ranged from 4.1 to 4.7, 4.1 to 5.1 and 4.1 to 4.6 by the $BS_{30}$ treatment under the moisture at field capacity, saturated soil condition and wetting-drying cycle, respectively (Fig. 1). In Purbapukuria soil, the values of soil pHs were ranged from 4.7 to 5.5, 4.7 to 5.8 and 4.7 to 5.2 by the same $BS_{30}$ treatment under the same moisture conditions as in Sarisabari ASS. In comparison to the initial ASSs (pH 3.5 for Sarisabari and 3.7 for Purbapukuria ASSs at 0 month) with the 30 months of incubation, the pH values were found to be increased by about 1.2, 1.7 and 1.2 units in Sarisabari ASSs and 1.9, 2.2 and 1.6 units in Purbapukuria ASSs

**Table 1.** Selected properties of the soils (0-15 cm depth) used for the study

| Soil properties | Sarisabari ASSs | Purbapukuria ASSs |
|---|---|---|
| Texture | Silty clay loam | Silty clay loam |
| Bulk density (g/cc) | 1.08 | 1.16 |
| Moisture at field condition (vol. %) | 50 | 48 |
| Soil pH (Field) | 4.0 | 4.2 |
| Soil pH (Soil:Water = 1: 2.5) | 3.7 | 4.0 |
| Soil pH (Soil:0.02 M $CaCl_2$ = 1:2.5) | 3.5 | 3.7 |
| [#]Pyrite content (%) | 7.5 | 6.6 |
| Electrical Conductivity (1:5 dS $m^{-1}$) | 17.3 | 18.4 |
| Organic matter (Wet oxidation, g $kg^{-1}$) | 29.4 | 21.2 |
| Available nitrogen (1.3 M KCl, mM $kg^{-1}$) | 3.2 | 2.8 |
| Available phosphorus (0.02N $H_2SO_4$, mM $kg^{-1}$) | 0.09 | 0.10 |
| CEC (1 M $NH_4Cl$: cmol $kg^{-1}$, at pH 7.0) | 18.3 | 19.3 |
| Exchangeable ions (1M $NH_4Cl$ : cmol $kg^{-1}$) | | |
| Aluminum | 7.11 | 7.23 |
| Iron | 1.45 | 1.25 |
| Sodium | 2.23 | 2.31 |
| Potassium | 0.26 | 0.31 |
| Calcium | 0.34 | 0.37 |
| Magnesium | 0.98 | 1.09 |
| Water-soluble ions (cmol $kg^{-1}$) | | |
| Sodium (Flame photometry) | 2.98 | 3.1 |
| Potassium (Flame photometry) | 0.20 | 0.22 |
| Calcium (*AAS) | 0.38 | 0.41 |
| Magnesium (AAS) | 2.31 | 2.45 |
| Iron (AAS) | 0.37 | 0.32 |
| Aluminum (ASS) | 1.90 | 1.7 |
| Sulfate ($BaCl_2$) | 3.98 | 3.47 |

both received $BS_{30}$ under the condition of field capacity, saturated soil and wetting-drying cycle, respectively and followed by the trend of $BS_{30} > BS_{20} > BS_{10}$ (Fig1). In wetting-drying cycle, the soil pH was found to be increased through wetting while decreased during drying period of incubation in both the ASSs. The higher values of soil pHs were found in Purbapukuria ASS than those of Sarisabari ASS, which might be due to the initial contents of the lower amounts of potential acidity as compared with Sarisabari ASS (Table 1). The neutralizing capacity of BS by releasing basic elements in the acid soil solution was found to be the best after 2 months of incubation in each of the moisture condition and treatments under both the ASSs. After that, the pH values were found to be decreased again up to 6 months of incubation and later on those values of soil pHs were found to be remained almost same with the passes of time. The initial increments of soil pHs might be due to the quick release of soluble basic ions which reacted with the amount of acids formed from the ASSs that resulted the increment of the soil pH after neutralization. With the passes of time, the production of acids were being proceeded and reacted with the slow released basic ions from the BS and holds the steady increments of soil pHs. This incubation study noticed that the strength of BS as a liming material will be effective for neutralizing the acidity of ASSs for long time. To maintain a reasonably good conditioned soil for growing crops, the soils should be amended by the application of $BS_{30}$ before 2 months of cultivation at saturated soil condition. The BS was also reported to be effective in increasing soil pH as well as maintained favorable soil condition (Anderson *et al.* 1987 and Khan *et al.* 2008).

**Water soluble Aluminum:** The availability of aluminum is highly pH dependent, *i.e.* Al is available at the lower pH value of <4.5 and the higher pH of >10 (Donahue *et al.* 1987). With the amendments through BS, the pHs of Purbapukuria and Sarisabari ASSs were found to be increased strikingly as compared with their initial

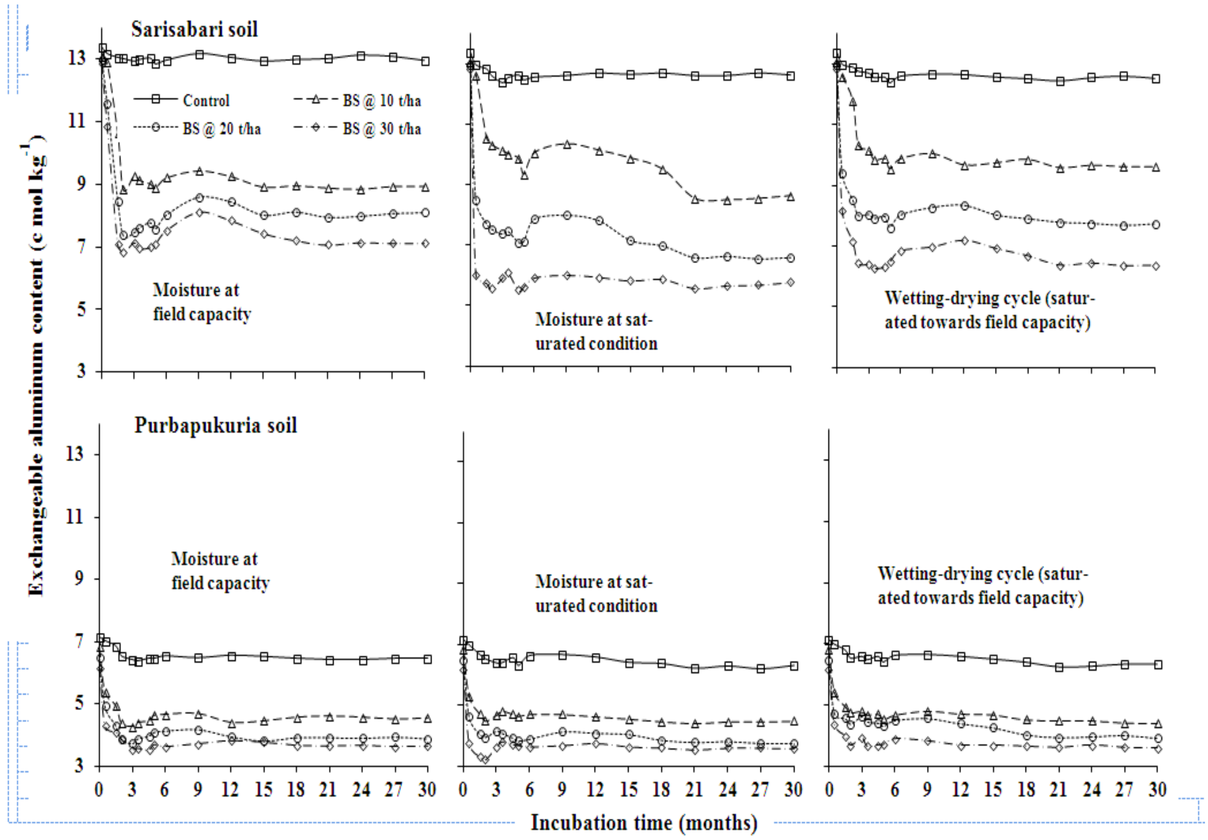


**Fig. 1.** Effects of basic slag on exchangeable aluminum under various moisture contents in acid sulfate soils of Cox's Bazar, Bangladesh

pHs, which resulted the low availability of Al. The amounts of water soluble Al in both the ASS were found to be decreased significantly ($p \leq 0.05$) at saturated soil condition (Tab2). The lowest amounts of water soluble Al were determined after 2 months by the highest dose of $BS_{30}$ in both the ASSs and the values were 0.86, 0.71 and 1.03 at Purbapukuria and 1.57, 1.26 and 1.62 cmol $kg^{-1}$ at Sarisabari ASSs under the moisture conditions of field capacity, saturated soil and wetting-drying cycle, respectively. After 2 months, the availability of Al increased a little which was due to decrease in soil pHs from the increased levels and then the Al status was remained almost steady state up to the end of incubation period. The amounts of water soluble Al within the 2 to 30 months of incubation ranged from 0.86 to 1.04, 0.71 to 0.96 and 1.03 to 1.16 cmol $kg^{-1}$ at Purbapukuria and 1.57 to 1.88, 1.26 to 1.45 and 1.60 to 1.78 cmol $kg^{-1}$ at Sarisabari ASSs by the same dose of $BS_{30}$ under the set moisture conditions. Sarisabari ASS was found to be contained more Al, which might be due to their initial high potential acidity as compared with Purbapukuria ASS (Table 1). Application of $BS_{30}$ and $BS_{20}$ were found to be effective in decreasing Al contents in both the ASSs regardless of moisture levels. The $BS_{30}$ exerted more negative effect regarding the availability of Al, which reduced to almost half of the amounts of its initial content of Al in both the ASSs (Table 2). The concentration of Al at pH 3.5 was 0.26 cmol $kg^{-1}$ as reported by Ponnamperuma (1972). Khan *et al.* (2008) reported that the concentrations of 0.1 to 0.2 cmol $L^{-1}$ Al are toxic to most crops and approximately 0.2 cmol $L^{-1}$ Al is toxic to rice. Fishes are most susceptible and fish deaths occur at 0.05 cmol $L^{-1}$ Al. If the soil pH raised to pH 4.8, even then the Al concentrations were found to drop to 0.004 cmol $kg^{-1}$ (Khan and Adachi, 1999). The present results have similarities with the findings of Allbrook (1973) who reported that the soluble Al in ASSs of North-West Malaya ranged from 0.0 to 8.5 c mol $kg^{-1}$ with pH of 4.2 to 3.2. Besides that, van Breemen (1993) reported that aluminum activity was inversely related to pH, increasing roughly 10 folds per unit pH decrease.

**Exchangeable aluminum:** The lowest values of 3.22 and 5.51 cmol $kg^{-1}$ $Al^{3+}$ were recorded by the highest rate of $BS_{30}$ at Purbapukuria and Sarisabari ASSs, respectively under the moisture at saturated condition. The second lowest contents of $Al^{3+}$ were obtained from the saturated soil (6.55 cmol $kg^{-1}$) condition followed by the field capacity (6.83 cmol $kg^{-1}$) and wetting-drying cycle (6.27 cmol $kg^{-1}$) for Sarisabari ASS and 3.31 at saturated condition followed by 3.51 at field capacity and 3.58 cmol $kg^{-1}$ at wetting-drying cycle for Purbapukuria ASS having the same $BS_{30}$ treatment. The maximum decrements of exchangeable $Al^{3+}$ contents were recorded within 2 to 5 months of incubation by the higher rates of BS with a few exceptions for the saturated moisture conditions in both the ASSs at the later part, i.e. 21 to 30 months of incubation (Fig2). During 6 to 30 months of incubation, the amounts of exchangeable $Al^{3+}$ were ranged from 3.62 to 3.81, 3.54 to 3.75 and 3.58 to 3.89 cmol $kg^{-1}$ for Purbapukuria ASSs and 7.07 to 7.85, 5.58 to 6.02 and 6.36 to 7.20 cmol $kg^{-1}$ for Sarisabari ASSs which received $BS_{30}$ under soil moisture conditions of field capacity, saturated and wetting-drying cycle, respectively (Fig2). The contents of exchangeable $Al^{+3}$ in the studied ASSs were found to be decreased (decrease over initial month) by about 4, 6 and 7% in control; 32, 35 and 27% by $BS_{10}$; 43, 50 and 41% by $BS_{20}$; and 47, 57 and 51%

**Table 2.** Typical responses of basic slag (BS) on pH and water soluble Al contents under various moisture levels during 30 months of incubation in two acid sulfate soils of the coastal plains of Bangladesh.

| **Treatments** | **Water soluble Al during 30 months of incubation** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **0** | **2.0** | **3.5** | **5.0** | **9.0** | **21** | **27** | **30** |
| **Sarisabari acid sulfate soil:** LSD (5%) for the Al = 0.23 at all incubation times and moisture levels. | | | | | | | | |
| ***Moisture at field capacity:*** | | | | | | | | |
| Control | 2.82 a | 2.71 a | 2.65 a | 2.69 a | 2.71 a | 2.67 a | 2.69 a | 2.69 a |
| $BS_{10}$ | 2.49 b | 2.06 b | 2.18 b | 2.12 b | 2.24 b | 2.14 b | 2.24 b | 2.24 b |
| $BS_{20}$ | 2.38 ab | 1.81 bc | 1.89 c | 1.85 c | 2.03 bc | 1.87 c | 1.94 c | 1.94 c |
| $BS_{30}$ | 2.23 c | 1.57 c | 1.78 cd | 1.75 cd | 1.88 c | 1.68 cd | 1.75 cd | 1.75 cd |
| ***Moisture at saturation:*** | | | | | | | | |
| Control | 2.82 a | 2.69 a | 2.62 a | 2.65 a | 2.67 a | 2.63 a | 2.65 a | 2.63 a |
| $BS_{10}$ | 2.49 b | 2.16 b | 2.22 b | 2.12 b | 2.35 b | 2.10 b | 2.14 b | 2.18 b |
| $BS_{20}$ | 2.38 ab | 1.73 c | 1.83 c | 1.81 c | 1.95 c | 1.58 c | 1.56 c | 1.64 c |
| $BS_{30}$ | 2.23 c | 1.26 d | 1.45 d | 1.37 d | 1.45 d | 1.30 d | 1.40 d | 1.42 d |
| ***Moisture at wetting and drying cycle:*** | | | | | | | | |
| Control | 2.82 a | 2.67 a | 2.63 a | 2.61 a | 2.71 a | 2.67 a | 2.69 a | 2.67 a |
| $BS_{10}$ | 2.49 b | 2.18 b | 2.11 b | 2.15 b | 2.33 b | 2.16 b | 2.16 b | 2.18 b |
| $BS_{20}$ | 2.38 ab | 1.83 c | 1.86 c | 1.88 c | 2.05 c | 1.85 c | 1.80 c | 1.83 c |
| $BS_{30}$ | 2.23 c | 1.62 d | 1.60 d | 1.62 d | 1.78 d | 1.60 d | 1.62 d | 1.62 d |
| **Purbapukuria acid sulfate soil:** LSD (5%) for the Al = 0.17 at all incubation times and moisture levels. | | | | | | | | |
| ***Moisture at field capacity:*** | | | | | | | | |
| Control | 1.95 a | 1.73 a | 1.75 a | 1.80 a | 1.84 a | 1.84 a | 1.86 a | 1.86 a |
| $BS_{10}$ | 1.83 ab | 1.28 b | 1.39 b | 1.41 b | 1.39 b | 1.39 b | 1.34 b | 1.34 b |
| $BS_{20}$ | 1.67 b | 1.07 c | 1.18 c | 1.27 c | 1.29 bc | 1.23 c | 1.23 bc | 1.27 bc |
| $BS_{30}$ | 1.51 bc | 0.86 d | 1.04 d | 0.98 d | 0.98 c | 0.98 d | 1.00 c | 1.00 c |
| ***Moisture at saturation:*** | | | | | | | | |
| Control | 1.95 a | 1.62 a | 1.66 a | 1.75 a | 1.84 a | 1.74 a | 1.76 a | 1.78 a |
| $BS_{10}$ | 1.83 ab | 1.32 b | 1.48 b | 1.41 b | 1.48 b | 1.41 b | 1.39 b | 1.39 b |
| $BS_{20}$ | 1.67 b | 1.03 c | 1.23 c | 1.16 c | 1.27 c | 1.18 c | 1.18 c | 1.18 c |
| $BS_{30}$ | 1.51 bc | 0.71 d | 0.82 d | 0.92 d | 0.96 d | 0.92 d | 0.96 d | 0.96 d |
| ***Moisture at wetting and drying cycle:*** | | | | | | | | |
| Control | 1.95 a | 1.65 a | 1.62 a | 1.68 a | 1.80 a | 1.76 a | 1.80 a | 1.80 a |
| $BS_{10}$ | 1.83 ab | 1.37 b | 1.44 b | 1.44 b | 1.51 b | 1.48 b | 1.43 b | 1.43 b |
| $BS_{20}$ | 1.67 b | 1.16 c | 1.27 c | 1.25 c | 1.37 c | 1.27 c | 1.29 bc | 1.27 c |
| $BS_{30}$ | 1.51 bc | 1.03 d | 1.09 d | 1.05 d | 1.16 d | 1.14 cd | 1.12 c | 1.12 cd |

by $BS_{30}$ treatments under soil moisture at field capacity, saturated condition and wetting-drying cycle, respectively in Sarisabari ASSs. While these decrements were 11, 12 and 12% in control; 37, 35 and 35% by $BS_{10}$; 42, 42 and 39% by $BS_{20}$; and 43, 48 and 42% by $BS_{30}$ treatments for Purbapukuria ASSs under the specified moisture levels, respectively (Fig. 2).

The maintenance of saturated soil moisture condition was found to be the most suitable practice in order of decrement in the contents of exchangeable $Al^{3+}$ in both the ASSs followed by moisture at field capacity and wetting-drying cycle. The amount of exchangeable $Al^{3+}$ was very high in Sarisabari ASS as compared with

Purbapukuria ASS, which might be due to the variation in their corresponding pH levels. However, the application of $BS_{30}$ was found to be reduced the content of exchangeable $Al^{3+}$ to about 42 to 57%, followed by 39 to 50% at $BS_{20}$ and 27 to 37% by $BS_{10}$ during 30 months of incubation. These results are in harmony with the findings of Anderson *et al.* (1987) and Khan, *et al.* (2008). They revealed that the basic slag is most effective in reducing the

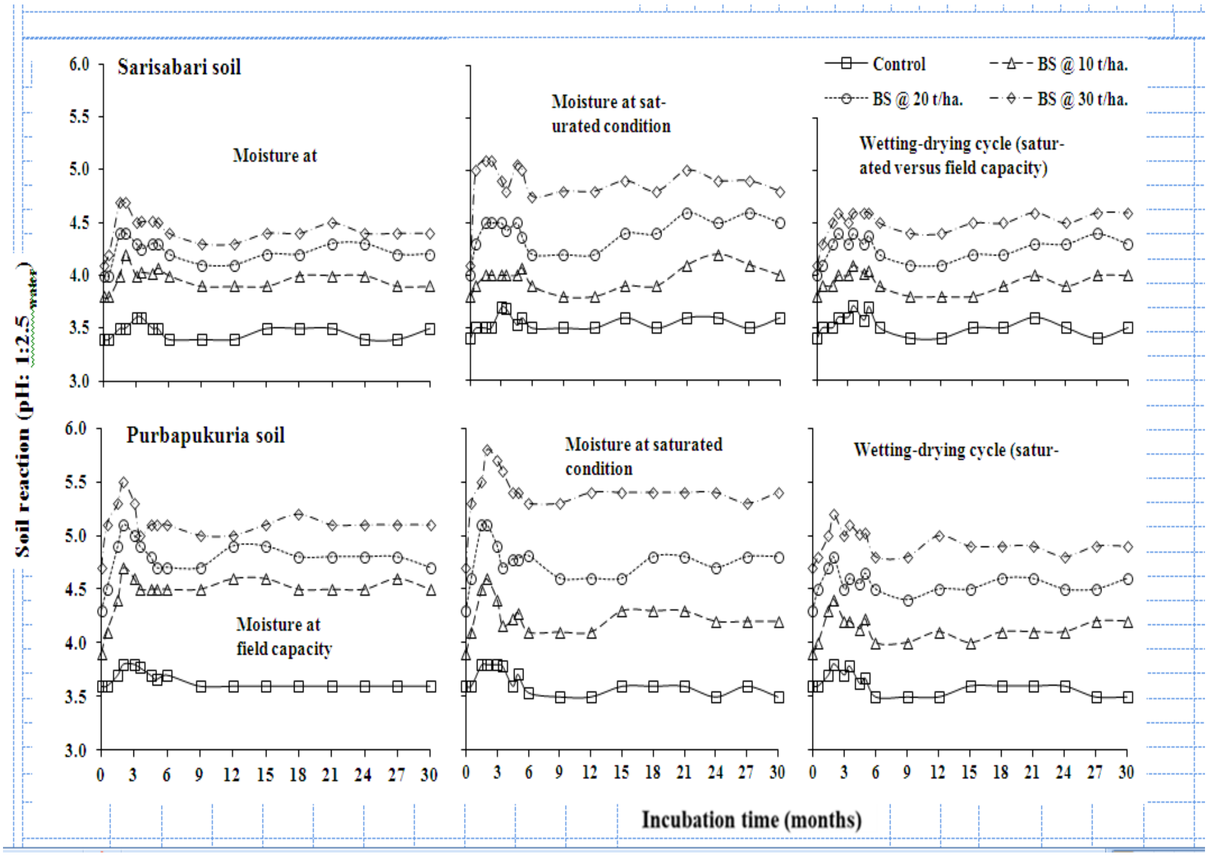


**Fig. 2.** Effects of basic slag on soil reaction (pH) under various moisture contents in acid sulfate soils of Cox's Bazar, Bangladesh

toxicity of $Al^{3+}$ in ASSs. But its application rate should be further studied under variable soil conditions. It was noticed that the exchangeable $Al^{3+}$ of ASSs fell steeply as soon as the pH rose above 4.0 (Gotoh and Patrick, 1974).

Correlation studies between the selected parameters and the data obtained during 30 months of experiment demonstrated that the soil pH was found to have strong positive relationship with time and the effect was more pronounced with Sarisabari ASS. While the Al contents showed strong negative relationship with the corresponding pHs of the ASSs and these effects were more pronounced with Sarisabari ASS (Fig. 3). The strong negative correlations and the trends of relationships between soil reaction (pH) and exchangeable $Al^{3+}$ contents of the ASSs also confirmed by the correlation equations and $R^2$ values as shown in the table 3. Moreover, van Breemen (1973 and 1976) has shown that aluminum activity was inversely related to pH, increasing roughly 10 folds per unit pH decrease. These indicate that the amelioration of acid sulfate soils by the application of basic slag is a sustainable reclamation and improvement measures regarding Al toxicity of the soils.

## IV. Conclusion

The present results concluded that the application of BS in ASSs were found to be increased the soil pH by about 1.2 to 2.2 units irrespective of moisture conditions and followed the order of increment of soil pH is $BS_{30}$

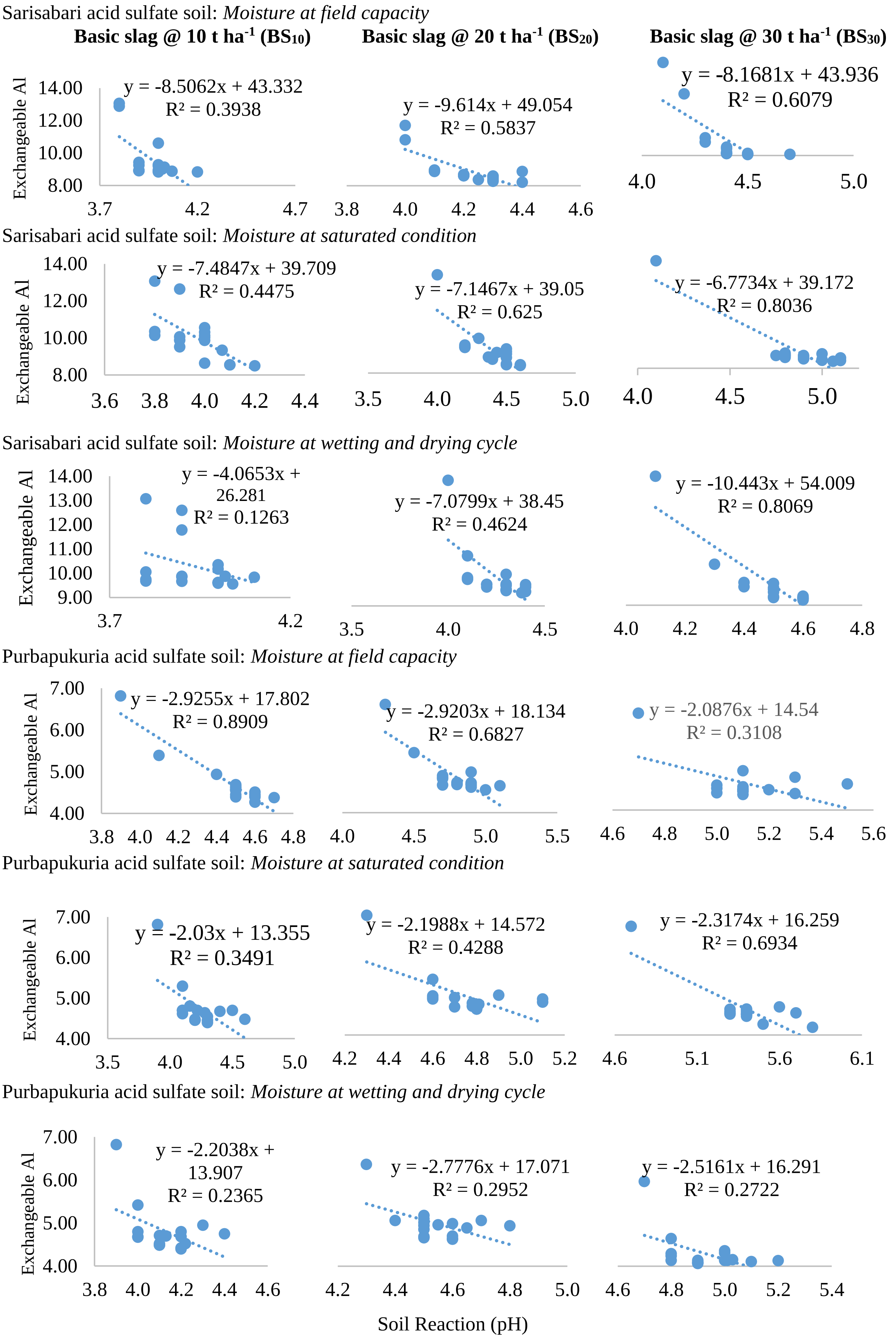


**Fig. 3.** Relationships between soil pHs and exchangeable Al contents in two acid sulfate soils during 30 months of incubation with different rates of basic slag under various moisture levels.

**Table 3.** Pearson correlation coefficient (r) and probability (p) values between pH and exchangeable Al contents in two acid sulfate soils during 30 months of incubation under various moisture conditions.

| Treatment Denotation | Moisture at field capacity | | Moisture at saturation | | Moist. at wetting-drying cycle | |
|---|---|---|---|---|---|---|
| | **r value** | **p value** | **r value** | **p value** | **r value** | **p value** |
| **Sarisabari acid sulfate soil** | | | | | | |
| #BS10 | -0.6275** | 0.0070 | -0.6690** | 0.0033 | -0.3553NS | 0.1616 |
| BS20 | -0.7640*** | 0.0004 | -0.7906*** | 0.0002 | -0.6800** | 0.0027 |
| BS30 | -0.7797*** | 0.0002 | -0.8964*** | 0.0001 | -0.8983*** | 0.0001 |
| **Purbapukuria acid sulfate soil** | | | | | | |
| BS10 | -0.9439*** | 0.0001 | -0.5909* | 0.0125 | -0.4863* | 0.0478 |
| BS20 | -0.8263*** | 0.0001 | -0.6548** | 0.0043 | -0.5433* | 0.0242 |
| BS30 | -0.5575* | 0.0201 | -0.8327*** | 0.0001 | -0.5217* | 0.0317 |

#BS = Basic slag, applied at rates of 10, 20 and 30 t $ha^{-1}$.

> $BS_{20}$ > $BS_{10}$. The high contents of Al in the ASSs were decreased strikingly by the higher doses of BS and were pronounced with the first 2-5 months and then almost steady state of Al was identified till 30 months. This suggested that the strength of BS will be effective not only for neutralizing the acidity of ASSs but also remove toxicity of Al and effects were pronounced within early months. The application of $BS_{30}$ under saturated soil moisture condition was the most suitable practice to decrease pHs and Al contents in both the ASSs followed by moisture at field capacity and wetting-drying cycle.

## Acknowledgements

This study was carried out under the financial and technical supports of the Volkswagen and the Alexander von Humboldt foundations, respectively of FR-Germany. We are also grateful to the Project staffs, MS students of Bangladesh and FR-Germany and especial acknowledgement to the German academic exchange service (DAAD) for providing Sandwich Scholarships for Sylvia Warneke, MS Student (Inst. for Plant Nutrition and Soil Science, Univ. of Kiel) and for the PhD programs of S. M. Kabir and M. M. A. Bhuiyan (SWED, DU).

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Md. H. R. Khan. 'Impacts of Times, Moisture Levels and Basic Slags on Soil Reaction and Aluminum in Acid Sulfate Soils'. *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 15(11), (2021): pp 32-40.