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Sustainable Management of Mine affected Area Soil through Application of Lime, Manure and Fertilizers

V. T. Shinde[1], K. N. Tiwari[2] and M. Singh[3]*

Abstract: *The present study was carried out to evaluate the effect of different fertilizer treatment combinations on amendment in mine area soil of Olidih watershed in Jharkhand state in India. Soil samples were collected from study area and analyzed for pH, EC, Available Macronutrients (N, P and K), Available Micronutrients (Cu, Zn, Fe, Mn) and heavy metals (Ni, Cr, Pb). Soil in study area was found moderately acidic and deficient in organic carbon, macronutrients and micronutrients. Pot experiment was conducted to analyze the effect of different inorganic and organic fertilizer treatments on soil chemical properties in Maize-cowpea-paddy cropping system. A randomized complete block design was employed with seven treatments and four replicates per treatment. The organic soil amendment resulted in maximum significant improvement in organic carbon of soil. Result of experiment indicated that different fertilizer treatment combinations had significant effect on pH of soil and uptake of available macronutrients. Maximum improvement in pH of soil was obtained with treatment T2 (Lime at 0.5 T/ha) and T6 (LOM_{100}). The highest uptake of Nitrogen (N) was found for the treatments T3 (Chemical fertilizer at 100% recommended dose of N, P, K), Phosphorous (P) in T4 (Organic matter at 100% recommended dose of N, P, K) and Potash (K) in T6. Results of the experiment showed that organic and inorganic fertilizers are effective in restoring the productivity of degraded soils.*

Keywords: *Coal mining; restoration; fertilizer treatments; soil analysis*

INTRODUCTION

Mining is one of the major anthropogenic activities which involves exploration and removal of minerals from the earth crust. Coal mining not only visibly disrupts the aesthetic aspect of landscapes but also disrupts soil components such as soil structure, soil microbial biomass and nutrient cycles which are crucial for a healthy ecosystem (Giammar 1997; Diels 2005). Long term mine spoil restoration requires the establishment of stable nutrient cycles from plant growth and microbial processes (Kavamura and Esposito 2010). It has been reported that every million tonne of coal extracted from surface mining methods damages surface area of about 4 ha in India (Ghose 1990). Mine sites contain materials of high Fe-oxyhydroxides, sulphates and potentially leachable contents of heavy metals (mainly Pb, Cu and Zn) due to extreme acidic conditions. Therefore, these soils have very low vegetation due to poor soil fertility. Reclamation is the process which restores the ecological integrity of disturbed mine land areas. This includes the management of all types of physical, chemical and biological disturbances of soils such as soil pH, fertility, microbial community and various soil nutrient cycles that makes the degraded land soil productive. The addition of organic amendments to contaminated mine soil is feasible, cheap and

1 Assistant Professor (Soil & Water Engg.), College of Agriculture, Navsari Agricultural University, Waghai- 394730, Gujarat, India.
2 Professor, Agricultural & Food Engineering Department, IIT Kharagpur, India-721302.
3 Assistant Professor (Soil & Water Engg.), N M College of Agriculture, Navsari Agricultural University, Navsari- 396450, Gujarat, India
* *Corresponding Author E-mail: vipulshinde123@gmail.com*

environment friendly for natural establishment of vegetation. Although there is a general consensus that efficiency of soil remediation also depends on the presence and activity of microorganisms. However the long-term ecological consequences of inorganic and organic amendments for these features have received little attention (Mench et al. 2006). Sustainable development in agriculture and yield improvement of crops can be achieved through restoration and scientific management of land productivity. The goal of this study was to evaluate the effectiveness of the remediation of contaminated mine soils by means of different inorganic and organic amendments using soil properties as indicators. This study evaluates physico-chemical properties of soils of mine affected area and suggests measures to amend soil properties based on pot experiment.

MATERIALS AND METHODS

Study area

Jharia coalfield (JCF) is one of the most important coalfields in India, located in Jharkhand state, between Latitude 23° 39' to 23° 48' N and Longitude 86° 11' to 86° 27' E. It lies in the heart of Damodar valley along the north of Damodar river. This is the most exploited coalfield because of available metallurgical grade coal reserves. Olidih watershed falling in Jharia coalfield is taken as study area to carry out this analysis. Joriya river flowing through this area, is severely affected by adjacent mining activities. Watershed covers an area of 5512 ha and has annual average rainfall of 1100 mm. Paddy is the major crop of this region, followed by maize. Mostly upland area is kept barren whereas crops are taken at lowland areas. Hence to grow crops on sustainable basis in mine affected areas, proper soil amendment measures are important. The map and location of Olidih watershed is shown in Fig. 1. About 20% area of Olidih watershed is affected by open cast mining.

Experimental details

Mine affected locations in the study area were chosen to carry out further analysis. Surface soil (0-25 cm) from the mine affected arable land of study

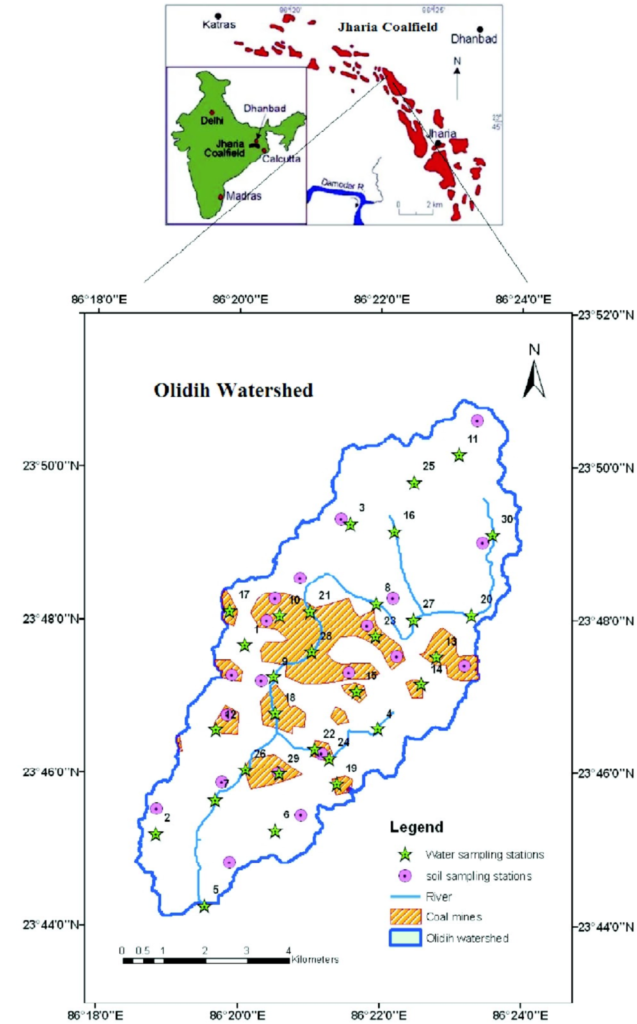

Figure 1: Location of Jharia coalfield and Olidih Watershed

area was collected by following standard procedures. The soil was cleaned for foreign materials and then air dried. The collected soil is then analyzed for pH, EC, OC, Available macronutrients (N, P, K), micronutrients (Cu, Zn, Fe, Mn) and heavy metals (Ni, Cr, Pb) in the Soil Chemical Analysis Laboratory of Agricultural and Food Engineering Department of IIT, Kharagpur. The analysis results revealed that the soils in mine affected areas were moderately acidic and deficient in organic carbon, macro- and micro- nutrients. Further, the pot experiment was conducted to analyze the effect of different inorganic and organic fertilizer treatments on soil chemical properties in maize-cowpea-paddy cropping system. Soils from mine affected area of study watershed were used in pot experiment. A randomized complete block design was employed with seven treatments and four replicates. Each experimental unit was a ten litre pot (10 L) filled with 10 kg top soil. Maize and cowpea crops are moistened to the required soil moisture content of field capacity (15-20%) determined gravimetrically (Kramer 1983; Abayomi 1996). In case of paddy, soil was kept under saturated condition. The cropping pattern during experiment was Maize (December 2011 – April 2012), Cowpea (May – June 2012) and Paddy (July – October 2012). Various treatments selected for pot experiment in this study are given in table 1.

Table 1
The details of treatments for pot experiment

Treatment	*Name of treatment*	*Description*
T_1	Control	Without any fertilizer application
T_2	Lime	Application of lime at the rate of 0.5 t/ha
T_3	CF_{100}	Chemical fertilizers (CF) at 100% recommended dose of N, P_2O_5 and K_2O
T_4	OM_{100}	Organic matter (OM)-FYM 10 t ha^{-1}
T_5	$L+CF_{100}$	Lime + CF_{100}
T_6	$L+OM_{100}$	Lime + OM_{100}
T_7	$L+CF_{50}+OM_{50}$	Lime + CF at 50% recommended dose of N, P_2O_5 and K_2O + OM FYM 5 t ha^{-}

For lime treatment, the quantity of lime requirement was calculated using Shoemaker method (Shoemaker et al. 1961). The estimated lime requirement was 0.5 t $CaCO_3$ ha^{-1} which was applied to soil during the experimentation. The recommended doses of CF N: P_2O_5: K_2O as 120:60:60, 25: 75: 60 and 80:40:20 kg ha^{-1} for maize, cowpea and paddy respectively, were used. The nutrients N, P and K were supplied through urea, single super phosphate (SSP) and mutate of potash (MOP) respectively. For OM_{100} treatment, the dose of organic manure (FYM) 10 t ha^{-1} for maize, cowpea and paddy were used. In case of combined treatment $LCF_{50}OM_{50}$ half dose of chemical fertilizer and organic manure were applied. All the lime, organic matter and fertilizers were mixed with the pot soils. The seeds of maize and cowpea were sown in pots manually and seedlings of paddy were transplanted in pots at the age of 23 days with four seedlings per pot. The duration of maize, cowpea and paddy were 110, 60 and 120 days, respectively. In the control pot fertilizer and chemicals were not added; however the soil preparation was done in the same manner as those of other soil treatments. Weeding was done manually to keep the pot weed free. No plant protection measures were taken as there was no incidence of major pest and diseases.

Soil analysis

Physico-chemical properties of soil samples from the pots were analyzed to estimate the effect of different fertilizer treatment combinations. The soil samples were collected and were analyzed at regular interval i.e., 60 days after sowing of maize, 110 days (at harvesting of maize), after harvesting of cowpea (60 days after sowing), 60 days after transplanting of paddy seedlings and at the time of paddy harvesting (120 days).

RESULTS AND DISCUSSION

Soil chemical properties

pH

Soil acidity plays a major role in plant nutrient bioavailability and the growth and activity of micro-organisms due to which the amount of nutrients being recycled by soil micro-organisms gets reduced. In the current investigation it was observed that application of lime and organic manure improved the soil pH (Fig. 2). The lime treatment resulted in soil pH increase from 5.8 to 7.1 which is safe limit for better crop growth. There was quite good improvement in soil pH with treatment

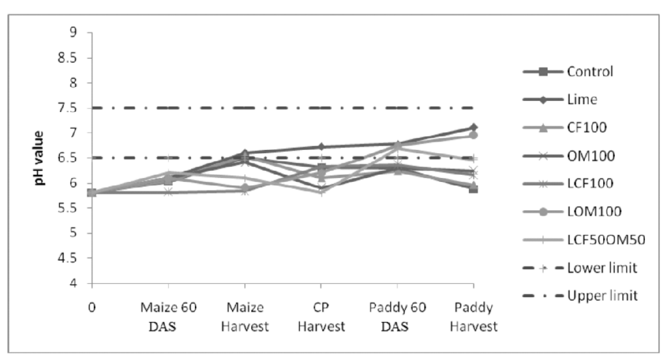

Figure 2: Effect of various treatments on soil pH

LOM_{100} (6.9) and $LCF_{50}OM_{50}$ (6.5) which are slightly acidic but not very harmful for crop growth. The increase of pH with manure application agrees with the findings of Egball (2002) and Mucheru (2003) who reported that addition of organic manures to acid soils lead to an increase in soil pH, decrease of Al ions in soil solution and thereby improve soil conditions for plant growth. The change in soil pH with time concurs with the findings by Fageria (2001) who reported that significant chemical changes could take place within 4-6 weeks after applying liming materials if a soil has sufficient moisture. In this investigation it was noticed that application of chemical fertilizers also increased the soil pH over the control. Use of mineral fertilizers in agriculture increases inputs of nutrients to soils, and the form in which the nutrients are applied and their fate in the soil-plant system determine the overall effects on soil pH. In general, lime treatment revealed its superiority over other treatments when tested statistically in respect to improve soil pH was concern.

Soil organic carbon (SOC)

Organic carbon is an index of soil productivity and the amount of carbon broken down from plants and animals that stored in soil (Dekka *et al.* 2008). Organic carbon levels greater than 0.75% is rated as good quality of soil or dump and less than 0.5% is rated as low quality of dump for crop production (Ghosh *et al.* 1983). In this study, application of lime plus organic manure improved the SOC from 0.39% to 0.74%, likewise application organic manure alone had improved the SOC to 0.72% (Fig. 3).

In this study, the SOC increased significantly due to application of organic manures; a similar finding was reported by Hao et al. (2003). This effect was further enhanced when OM was applied with lime. Because lime reduced the soil acidity might have improved the microbial growth and activities in turn they acted upon added organic material and restore the SOC through mineralization (Haynes 1984). Apart from direct addition of organic matter to soil, application of manure indirectly increases soil organic matter because of higher crop growth and the amount of residues returned to the soil. OM

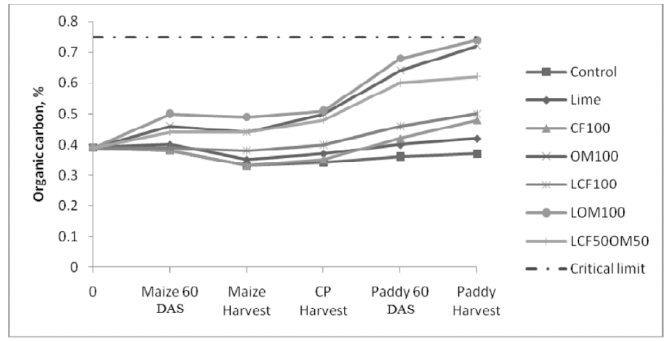

Fig 3. Effect of various treatments on soil organic carbon

contains well-decomposed organic matter, which likely becomes part of the SOC, and more plant residues are returned to the soil with application of organic materials (Haynes and Naidu 1998). Fertilizer application also increased the SOC concentration appreciably in this experiment, probably because nutrients released from chemical fertilizers boosted the yield of crops (Liu et al. 2001) and then crop residues in the form of roots and stubble in turn increased the SOC concentration, which was in agreement with Whalen and Chang (2002).

Available N, P, K

Application of organic manure improved the available N, P and K status (Fig. 4) of mine soil. Organic matter acts as a reservoir of nutrients and these nutrients are slowly released to soil for long period through mineralization and decomposition of organic matter (Bhandari *et al.* 2002) and also due to smaller losses of mineral N from manure. This might have improved the soil available nutrients.

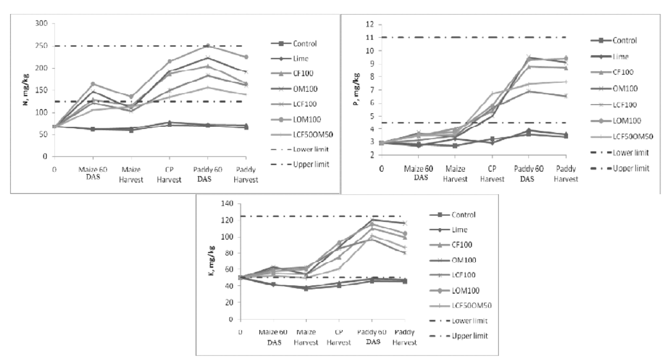

Figure 4: Effect of various treatments on available N, P and K of soil

Haynes and Molokobate (2001) also reported that the application of organic residues decreased exchangeable acidity and increased the available P of acidic soils. The increase of soil organic matter resulted in decrease K fixation and subsequent increase K availability (Olk *et al.* 1993). Application of chemical fertilizers also improved available nutrient status of soil. Singh *et al.* (2001) reported that prolonged use of mineral fertilizers, manure, compost and other ameliorants increases the potassium content in the soil. Because of high amount of K in organic amendments that increases CEC, the K amount rises in soil. Those results agree with findings of Khoshgoftarmanesh and Kalbasi (2002). Application of lime did not show any improvement in soil available N, P, K because of poor native organic matter and deficiency of these nutrients. Therefore to improve crop growth and yield in these soils along with lime OM or CF should be applied.

DTPA extractable micronutrients

The experimental soil was rich in respect to DTPA extractable micronutrients like Fe, Mn, Zn and Cu. However after harvest of three crops the available content of these micronutrients were declined (Fig. 5). It might be due to higher uptake of these micronutrients by the crops grown in this experiment. Also application of various amendments like lime, manure and chemical fertilizers showed significant reduction of all these micronutrient elements in the current investigation. This might be due to higher plant growth assisted uptake of these nutrient by better crop growth and yield in these treatments, modification of soil pH particularly lime and OM applied treatments, fixation of these nutrient elements to insoluble forms. Elevated levels of heavy metals in soils may lead to their uptake by plants, which depends not only on heavy metal contents in soils but is also determined by soil pH value, organic matter and clay contents are influenced by the fertilization (Fytianos *et al.* 2001). The above mentioned parameters can significantly affect their bioavailability (Ge *et al.* 2000).

Generally heavy metals availability is impacted by soil pH, when soil is acidic the mobility and

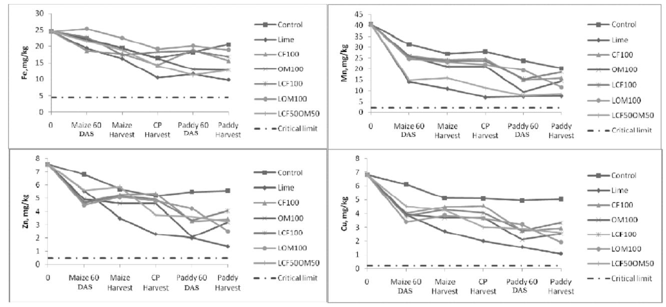

Figure 5: Effect of various treatments on DTPA extractable micronutrients of soil

availability of these micronutrient elements increase. In this experiment, application of various amendments increased the soil pH which resulted in decrement of DTPA extractable micronutrients in soil. The similar results was observed by Karalic et al. (2013) who reported that application of lime decreased the bioavailability of these metals by forming insoluble carbonate compounds. The addition of amendments into soils precipitates or increases metal sorption, therefore decreasing the proportion of the total element in soil solution (Brown et al. 2005). Also application of organic manures decreased these micronutrients. This might be due to higher solubility of these metals by forming chelation which increased the uptake of these nutrient elements by crops resulted in decrement of DTPA extractable elements. Regardless of fertilization applied, microelement concentrations in the soil solution are sufficient for fulfilling nutritional needs of plants cultivated during the trial.

Heavy metals (Ni, Pb, Cr)

In the current experiment, it was observed that available heavy metals significantly decreased after the application soil amendments particularly lime and organic manures (Fig. 6).

Liming treatments resulted in trend of heavy metals availability decrement. Similar results were reported by many researchers (Popovic et al. 2009; Karalic et al. 2013). They claimed that heavy metal availability was pH dependent, and addition of lime increased the soil pH resulted in increase metal adsorption and precipitation. All these processes mediated to reduction heavy metal availability. Soil organic matter has the tendency of transition metal

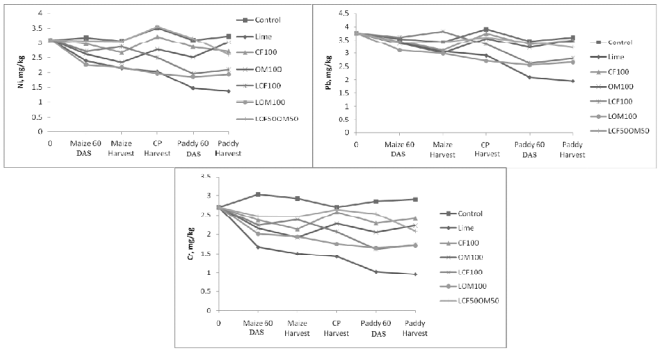

Figure 6: Effect of various treatments on Heavy metal content of soil

cations to form stable complexes with organic ligands (Elliott et al. 1986). Application of organic manure was found to be effective in reducing heavy metals availability in soils (Wong and Lau 1985; Ye et al. 1999). Because the addition of organic matter can significantly improve the physical characteristics and the nutrient status of mine soil (Ye et al. 1999). In addition, fertilizers are an essential ingredient for successful restoration of mine wastes (Bradshaw and Chadwick 1980) because they improve plant growth and yields that resulted in restoration of HMs polluted soils.

CONCLUSIONS

Restoration of abandoned coal mine land is a very complex process. Once the restoration plan is complete and vegetation has established, some assessment should be made to determine how closely the reclaimed site functions as an ecosystem compared to similar undisturbed sites. In this study an attempt was made to evaluate the effect of different fertilizer treatment combinations on amendment in soil and their response to crop production in mine affected area. Results indicated that the additions of organic and inorganic fertilizers with lime are effective in restoring the productivity of degraded soils in open cast mine areas.

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