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IMPACT OF EARTHWORM INOCULATION ON PHYSICO-CHEMICAL PROFILE OF FLY ASH AMENDED SOIL

Sitara Jabeen and M. P. Sinha

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SITARA JABEEN AND M. P.SINHA*
Department of Zoology, Ranchi University, Ranchi - 834 008
E-mail: j.sitara@yahoo.co.in

ABSTRACT

The present work dealt with the variations in the physico-chemical profile of coal fly ash amended soil in the presence and absence of earthworm (*Drawida willsi*) for the experimentation period of 90 days. The pH of soil and fly ash amended soil at 5, 10 and 15% FA concentration showed gradual increase ranging from 5.45±0.15, 6.83±0.04, 6.92±0.02 and 7.09±0.01 to 5.81±0.16, 7.01±0.03, 7.12±0.05 and 7.41±0.05 in absence of earthworms while in presence, from 5.45±0.15, 6.83±0.04, 6.92±0.02 and 7.09±0.01 to 5.21±0.04, 6.39±0.15, 6.65±0.16 and 6.73±0.21 respectively. The conductivity in the amendments varied from 0.31±0.24, 0.47±0.32, 0.48±0.32 and 0.17±0.02 to 0.51±0.02, 0.61±0.18, 0.63±0.22 and 0.36±0.02 m Mhos/cm respectively in presence. In non availability of earthworms it ranged from 0.15±0.01, 0.31±0.45, 0.47±0.32 and 0.48±0.32 to 0.30 ±0.44, 0.45±0.21, 0.57±0.22 and 0.58±0.44 m Mhos/cm respectively in amendments. In the absence of earthworms, the organic carbon decreased in soil and the fly ash amendments whereas with earthworm the content showed a continuous increase from 0.36±0.11 to 0.48±0.03 in 5% FA amendment. The total nitrogen showed increase in soil and 5% amended soil with variation from 0.031 ±0.01 to 0.41 ±0.02 and 0.031 ±0.12 to 0.051±0.04 mg N/g soil respectively while 10 and 15% amendment showed gradual decline from 0.03±0.04 to 0.022±0.02 mg N/g soil and 0.019±0.04 mg N/g soil with earthworm whereas in their absence a decreasing trend in all three fly ash amendments with significant variation between days and concentrations were observed (F_1 = 11.45, df = 3,3, $p < 0.001$; F_2 = 6.9; df = 3,3; $p < 0.01$). Minor variations was inferred in case of phosphorous and potassium with increment in the values with earthworm inoculation. Therefore, the earthworm acted as an ameliorant enhancing the nutrient profile of the amended soil.

***Corresponding author**

INTRODUCTION

Fly ash is an amorphous mixture of ferro-alumino-silicate minerals generated from the combustion of ground or powdered coal at 400–1500ºC. The mineralogical, physical and chemical properties of fly ash depend on the nature of parent coal, conditions of combustion, type of emission control devices, storage and handling methods (Jamwal, 2003).

About 120 -150 MT of fly ash is generated annually in India (Singh, 2009) posing the problem of its disposal as well as require acres of land for the same (Pandey and Singh, 2010). In Jharkhand about 9,000 ton of fly ash is being generated everyday from the coal based thermal power plants with present generation of about 1500 MW. Fortunately, the state is utilizing over fifty percent of the fly ash through environmentally sound techniques such as abandoned mine reclamation, cement manufacturing, brick manufacturing etc. Therefore, it should not be branded as a waste product of the power plant but should get the status of a by-product. Preferably one should think of its utilization and not disposal which is not only possible but is a necessity. The quantum of generation and the methods of disposal do not lead to sustainability but may lead to serious catastrophes. Addition of FA to soil may improve the physico-chemical properties as well as nutritional quality of the soil depending upon their properties (Jabeen and Sinha, 2012) may sort out the problem. It contains most of the plant nutrients, major and minor nutrients, such as P, B, Cu etc. apart from some trace elements and radioisotopes (Satya *et al.*, 2012), along with high concentration of toxic heavy metals such as Cu, Zn, Cd, Pb, Ni, Cr etc. (Tiwari *et al.*, 2008) and quartz, mullite, aragonite, magnetite, hematite, and spinel (Kusuma , 2012) with low nitrogen and phosphorus content and pH ranged from 4.5 to 12.0 depending on the S-content of parental coal (Jabeen and Sinha, 2012). For its amelioration and increase in the usability percent a well known biological modifier, earthworm, can be incorporated as they are the natural factories, which serve as bio-catalytic agents to enhance the soil fertility through physical, chemical and biological processes. Recycling of wastes using earthworms has become an important component of substantial agriculture, which has a multi-directional impact in terms of safe disposal of wastes preventing environmental pollution besides providing nutrient rich material (Jabeen and Sinha, 2011). With this back drop, the present work was conducted to draw out the impact of earthworm inoculation on the physico-chemical profile of fly ash amended soil.

MATERIALS AND METHODS

The fly ash for the laboratory experiment was collected from the ash pond of Patratu thermal power plant, Jharkhand and soil from the agro-fields within Ranchi university campus which was air dried, grinded and sieved using 1mm mess sieve. Air dried fly ash was mixed in the proportion of 5, 10 and 15% with the soil as one set and in the other set earthworm (*Drawida willsi*) was inoculated to observe the ameliorating effect. From each seven quadruplicate trays the amended soil sample was taken for the physico-chemical profile analysis for 90 days at an interval of a month. Following methods were followed for the analysis: The soil pH was measured by an electrical pH meter (Model PR 9405 L, Philips, India) using soil suspension (1:2 soil water ratio). Soil conductivity, by water and soil analysis kit (Model 161 E, Electronics, India) using soil suspension (1:2 soil water ratio). Organic matter was estimated according to Walkley and Black (1934) method whereas Nitrogen content of soil was estimated by Kjeldahl method of Jackson (1974). Following the method as described by Mishra (1973) potassium was precipitated as cobalt nitrate complex ($K_n Na_{3-n}$) Co $(NO_2)_6$. xH_2O. The precipitate was dissolved in 2 N sulphuric acids in presence of an excess of potassium permanganate and the remaining permanganate was back titrated with oxalic acid. Lastly, phosphorous was also analysed using the method of Mishra (1973).

RESULTS AND DISCUSSION

The physico-chemical properties of the experimental soil and fly ash are exhibited in Table 1. On estimating pH of the amendments an increasing trend was found over the 90 days experimentation at an interval of 30days without the presence of earthworms (Table 2). The value ranged from 5.45 ± 0.15 to 5.81 ± 0.16 in soil and it varied from 6.83 ± 0.04, 6.92 ± 0.02 and 7.09 ± 0.01 to 7.01 ± 0.03, 7.12 ± 0.05 and 7.41 ± 0.05 respectively in 5, 10 and 15% FA amended soil. Whereas with their incorporation in the soil fly ash mixtures, pH decreased over the days of incubation in FA amendments from 5.45 ± 0.15, 6.83 ± 0.04, 6.92 ± 0.02 and 7.09 ± 0.01 to 5.21 ± 0.04, 6.39 ± 0.15,6.65 ± 0.16 and 6.73 ± 0.21 respectively.

Two-way analysis of variance showed that the differences in pH value was highly significant ($F_1=101.6$; df=3, 7; $p<0.05$) among the various amendments in both with and without earthworms but the variation between days was not significant ($F_2=0.32$). The variation of pH with respect to days may be explained on the basis of the neutralization of H^+ by the salts present in soil as well as the solubility of basic metallic oxides of fly ash with the time interval. The shifting of pH may result in less availability of certain nutrients to plants or higher activity of metals present in fly ash imparting toxic effects to soil. With earthworm inoculation the decrease in pH of fly ash amended soil might be due to their buffering activity. The neutral pH may be generally used in amending both acidic and alkali soils (Kumar *et al.,* 1998) as in the present study the acidic soil (pH 5.81) had been amended with the slightly alkaline FA with pH 6.8. In India, FA is generally highly alkaline due to low sulfur content of coal and presence of hydroxides and carbonates of calcium and magnesium (Maiti *et al*., 2005). Jastrow *et al.* (1979) reported that while addition of fly ash improves soil pH on one hand, it simultaneously adds essential plant nutrients to the soil on the other hand. In the present study the hike in pH with increase in the FA concentrations was observed. This may be attributed to release of Ca, Na, Mg and OH ions along with other trace elements. Phung *et al*. (1979) reported that application of FA increases the pH of acidic soil inturn neutralizing it.

Conductivity: Table 2 showed that conductivity in the three graded levels of FA amendments in soil increased with increasing FA content throughout the experiment in both with and without earthworms' inoculation. But comparatively higher increase in conductivity was observed in their presence. The conductivity of the amended soil at different concentration of FA amendments and soil in presence of earthworms varied from 0.31 ± 0.24, 0.47 ± 0.32, 0.48 ± 0.32 and 0.17 ± 0.11 to $0.51\pm$ 0.02, 0.61 ± 0.18, 0.63 ± 0.22 and 0.36 ± 0.02 m Mhos/cm respectively in 5, 10 and 15% FA amended soil and soil alone. In non availability of earthworms the value showed a variation from 0.15 ± 0.01, 0.31 ± 0.45, 0.47 ± 0.32 and 0.48 ± 0.32 to 0.30 ± 0.44, 0.45 ± 0.21, 0.57 ± 0.22 and 0.58 ± 0.44 m Mhos/cm respectively in amendments. The increase in conductivity might be due to the availability of more cations and anions. Increase in electrical conductivity of soil with FA application has also been observed by Kumar (2004); Kishore *et al*. (2009). Similar results were obtained with increasing availability of soluble salts (Pitchel and Hayes, 1990) which might have detrimental effects on microbial respiration, enzyme activity and soil N cycling etc. It was also reported that at low application rate, FA amended soil shows improvement in agronomic properties such as water holding capacity (WHC), bulk density and conductivity (Chang *et al*., 1977). The conductivity increase in presence of earthworms in the FA amended soil can be attributed to the active mineralization process by soil organisms resulting in greater availability of soluble salts. Addition of un-weathered FA results in increased EC of soil there by increasing the availability of soluble salts.

The two way ANOVA revealed the significant role of both the concentration of fly ash and the days on soil conductivity variance in both with and without earthworm inoculation ($F_1=198.84$; df=3,7; $p<0.01$; F2= 94.32; df =3, 7; $p<0.01$).

Organic carbon: The organic carbon percentage value was found to be lower in amended FA than the soil as shown in the table 2. with increase in fly ash concentration from 5 to 15% the OC decreased gradually. In soil the value was 0.41 ± 0.12 on the 1st day of incubation and decreased to 0.31 ± 0.005 on the 90th day in absence of earthworm. Whereas in presence of earthworm the value increased from 0.41 ± 0.02 to 0.63 ± 0.15 over the experimental days.

In absence of earthworms the OC declined gradually with the incubation period in the three FA amendments *i.e.* 5, 10 and 15% respectively from 0.36 ± 0.11, 0.35 ± 0.02 and 0.29 ± 0.15 to 0.32 ± 0.15, 0.29 ± 0.04 and 0.13 ± 0.02. Among the concentrations maximum OC was observed at 5% FA concentration. Sharp decline was observed in the 15% FA amendment.

With inoculation of *Drawida willsi* in the fly ash amended soil the carbon content showed a continuous increasing trend from 0.36 ± 0.11 to 0.48 ± 0.03 in 5% FA amendment whereas in 10 and 15% amendment the value increased till 30th day from 0.36 ± 0.02 and 0.29 ± 0.15 to 0.38 ± 0.02 and 0.3 ± 0.02 and then declined to 0.29 ± 0.04 and 0.2 ± 0.04 respectively on the 90th day of experiment. The organic matter in soil is highly dependent on the activity of animals in the soil, the rate of microbial activity as well as the process of humification. Addition of fly ash enhances the humification in the amended soil (Amontte, 2003). Thus, an estimate of organic matter can indirectly assess the status of microbial activity in the soil.

The change in the organic carbon content with FA proportion

Table 1: Physico-chemical characterization of soil and fly ash

Parameters	Soil	Fly ash
pH	5.81±0.1	6.85±0.31
O. C (g %)	0.31±0.21	0.12±0.11
O.M (g %)	0.54±1.1	0.21±0.3
Nitrogen	0.078±0.41	0.175±0.22
Phosphorus	0.0279±0.17	0.13±0.23
Potassium	1.48±0.41	1.9±0.14
EC(mMhos/cm)	0.23±0.04	0.56±0.21

was in agreement to earlier works (Kene and Matte, 1995; Lal *et al*., 1996). With increase in the FA concentration the organic carbon percent value declined gradually which might be due to the lower concentration of OC in fly ash in comparison to soil. Without the earthworm the OC declined with the incubation period but in presence of earthworms it increased in soil and 5% FA which might be due to the activity of the microbes in comparison to those in their absence. Earthworm enhances the value of OC due to their humification process which in turn positively affects the soil organisms (Kene and Matte, 1995). With increase in the FA concentration to 10 and 15% led to decline might be due to the toxicological impact of the heavy metal concentration in the FA and at low concentration increase the availability of nutrients *i.e.* C, N, P, S, Ca and K (Lubbers *et al*., 2010). The variation in organic carbon content wasn't significant between days but significant between the FA concentrations in presence of earthworms (F_1=0.54; F_2=9.42;df=3,3;p<0.001) and without earthworm inoculation both FA concentration and days played significant role on the organic carbon content (F_1=10.86;df=3,3; p<0.001; F_2=33.52; df=3,3; p<0.1).

Total nitrogen content: The total nitrogen content showed decrease with increase in FA content from 1st till 90th day of incubation in the absence of earthworms (Table 2). It ranged from 0.031±0.01, 0.031±0.12, 0.03±0.04 and 0.03±0.13 to 0.0190±0.34.029±0.32, 0.02±0.004 and 0.017±0.21 mg N/g soil respectively in soil and FA amended soil. In their presence the total nitrogen showed increase in soil and 5% amended soil with variation from 0.031±0.01 to 0.41 ±0.02 and 0.031 ±0.12 to 0.051±0.04 mg N/g soil while in 10 and 15% amendment gradual decrease from 0.03±0.04 to 0.022±0.02 and 0.019±0.04 mg N/g soil respectively was observed. The decrease in N content with increase in FA concentration in soil might have been due to the low level of nitrogen content in fly ash. Carbon and nitrogen are usually present in negligible quantities as they are likely to be oxidized into gaseous forms during combustion (Sadasivan *et al*., 1993). The result was in accordance to the work by Punjwani *et al.* (2011). The further decrease with increase in incubation period might be due to release of gaseous nitrogen to the atmosphere by the microbial activity. Increase in nitrogen content with earthworm inoculation was due to the high rate of mineralization in presence of worms and also may be due to the release of nitrogenous products of earthworm metabolism through the urine, excreta (cast) and mucoproteins (Padmavathiamma *et al*., 2008). In presence of earthworms both amendments and days were not significant (F_1=1.09; F_2=0.9) but in their absence the decrease in the nitrogen was significant between FA amendments and days (F_1=11.45; df=3, 3; p<0.001; F_2=6.91, df=3, 3; p<0.01).

Phosphorus content: The phosphorus content showed a steady decrease in the absence of earthworms in all three concentration of fly ash along with the soil (Table 2) varying from 0.142±0.13, 0.157±0.33, 0.15±0.01 and 0.021± 0.01 to 0.06±0.001, 0.07±0.04, 0.109±0.03 and 0.009±0.11 mg P/g soil respectively. In the presence of earthworm it increased from 0.021±0.01 and 0.142±0.13 to 0.071±0.02 and 0.164±0.11 mg P/g soil respectively in soil and 5% amendment. In 10 and 15% fly ash soil mixture

Table 2: Physico-chemical characterization of fly ash amended soil with and without earthworm (*Drawida willsi*) inoculation

Parameters	Days	Soil	Soil+E	5%FA	5%F A + E	10%FA	10%FA+ E	15% FA	15%FA+E
pH	1	5.45±0.15	5.45±0.15	6.83±0.04	6.83±0.04	6.92±0.02	6.92±0.02	7.12±0.02	7.09±0.01
	30	5.69±0.18	5.33±0.11	6.91±0.05	6.79±0.02	7.02±0.1	6.81±0.12	7.27±0.16	6.98±0.21
	60	5.74±0.19	5.25±0.1	6.94±0.02	6.57±0.04	7.06±0.22	6.76±0.15	7.39±0.11	6.82±0.02
	90	5.81±0.16	5.21±0.04	7.01±0.03	6.39±0.15	7.12±0.05	6.65±0.16	7.41±0.05	6.73±0.21
EC	1	0.15±0.01	0.17±0.11	0.31±0.14	0.31±0.04	0.47±0.13	0.47±0.12	0.48±0.02	0.48±0.02
	30	0.19±0.22	0.24±0.03	0.37±0.05	0.38±0.14	0.52±0.17	0.54±0.04	0.50±0.04	0.53±0.16
	60	0.27±0.03	0.29±0.15	0.41±0.18	0.46±0.02	0.53±0.04	0.59±0.2	0.54±0.03	0.57±0.11
	90	0.30±0.14	0.36±0.02	0.45±0.21	0.51±0.02	0.57±0.16	0.61±0.18	0.58±0.04	0.63±0.01
OC	1	0.41±0.12	0.41±0.02	0.36±0.11	0.36±0.114	0.35±0.02	0.36±0.02	0.29±0.15	0.29±0.15
	30	0.4±0.02	0.43±0.11	0.38±0.03	0.39±0.04	0.33±0.02	0.38±0.02	0.25±0.02	0.3±0.02
	60	0.37±0.013	0.51±0.16	0.35±0.01	0.42±0.19	0.31±0.12	0.35±0.12	0.18±0.11	0.23±0.12
	90	0.31±0.05	0.63±0.15	0.32±0.15	0.48±0.03	0.29±0.04	0.33±0.02	0.13±0.03	0.21±0.04
N	1	0.031±0.001	0.031±0.001	0.031±0.001	0.031±0.012	0.03±0.004	0.03±0.004	0.03±0.013	0.03±0.013
	30	0.027±0.012	0.035±0.003	0.031±0.002	0.039±0.002	0.025±0.002	0.029±0.011	0.027±0.003	0.028±0.002
	60	0.023±0.002	0.038±0.004	0.0313±0.004	0.045±0.013	0.023±0.014	0.027±0.001	0.021±0.011	0.022±0.011
	90	0.019±0.003	0.41±0.002	0.029±0.003	0.051±0.004	0.02±0.004	0.022±0.002	0.017±0.001	0.019±0.004
P	1	0.021±0.001	0.021±0.001	0.142±0.013	0.142±0.013	0.157±0.013	0.157±0.013	0.15±0.001	0.15±0.001
	30	0.017±0.004	0.039±0.011	0.12±0.004	0.146±0.002	0.139±0.001	0.161±0.012	0.142±0.004	0.146±0.013
	60	0.013±0.021	0.058±0.003	0.10±0.002	0.154±0.014	0.111±0.002	0.133±0.003	0.127±0.011	0.139±0.001
	90	0.009±0.011	0.071±0.002	0.06±0.001	0.164±0.011	0.07±0.004	0.12±0.002	0.109±0.003	0.115±0.004
K	1	0.19±0.01	0.19±0.01	0.23±0.05	0.23±0.02	0.31±0.11	0.31±0.11	0.34±0.02	0.34±0.03
	30	0.20±0.02	0.24±0.0	0.25±0.01	0.29±0.03	0.33±0.02	0.35±0.004	0.36±0.05	0.37±0.02
	60	0.23±0.03	0.27±0.04	0.27±0.04	0.31±0.001	0.36±0.01	0.39±0.002	0.37±0.01	0.41±0.05
	90	0.24±0.11	0.31±0.002	0.30±0.11	0.37±0.02	0.38±0.03	0.41±0.03	0.39±0.002	0.43±0.15

EC - Conductivity; OC - Organic carbon; N - Total Nitrogen; P- Phosphorus; K - Potassium the phosphorus content showed a difference from 0.157±0.33 to 0.12±0.02 mg P/g soil and 0.15±0.01 to 0.115±0.04 mg P/g soil respectively. The increase in phosphorous content with increase in FA in the present study may be attributed to the available phosphorus present in CFA which was found to be higher in comparison to the experimental soil. The increase may due to the hydrolysis of iron, aluminium and magnesium compounds in CFA and released inorganic acids by CFA. The liberated acids help in the release of available phosphate from the unavailable form without affecting the pH as organic matter present in the soil has a buffering capacity in maintaining the pH. The increase of extractable phosphorus by 2.5 to 4.5 fold has also been documented (Pathan *et al.,* 2003).

The decrease in phosphorous content with days in absence of earthworms might be due to hindrance in phosphorylation activity. But in presence of earthworms an increasing trend of phosphorous with days were observed which indicates increase in inorganic P replaced by mineralization of organic P by the phosphatase activity in worm casts (Tiwari *et al.*, 1989). Therefore, the earthworms acted as an ameliorant of amended fly ash which helps to enhance the phosphorous content.

The increase in phosphorous content in presence of earthworms were significant between amendments ($F = 24.25$; $df = 3, 3$; $p < 0.0001$) and not between days ($F = 0.075$). In absence of earthworms the steady decrease was significant ($F_1 = 47.79$, $df = 3, 3$, $p < 0.1$; $F_2 = 9.71$, $df = 3, 3$, $p < 0.001$) between amendments and days in FA amended soil.

Potassium content

The potassium content increased with increasing amendments of FA and in both presence and absence of earthworms (Table 2). In earthworm inoculated soil and soil FA mixtures, it varied from 0.19±0.01, 0.23±0.15, 0.31±0.11 and 0.43±0.21 to 0.31±0.002, 0.37±0.02, 0.41±0.03 and 0.43±0.15 mg K/g soil respectively. In the absence of earthworms phosphorus content ranged from 0.19±0.01, 0.23±0.15, 0.31±0.11 and 0.43±0.21 to 0.24±0.11, 0.30±0.11, 0.38±0.03 and 0.39±0.002mg K/g soil respectively. The present investigation showed increase in potassium content with increase in the FA concentration in the soil. This has been documented by Basker *et al.* (1993) who also found increase in the potassium with higher level of FA amendment. The potassium content showed significant variation between days and amendments ($F_1 = 52.2, df = 3,7, p < 0.1$; $F_2 = 76.7, df = 3,7, p < 0.1$).

CONCLUSION

This work concludes that with earthworm inoculation the pH declined whereas the P, N, K and OC enhanced. Thus, it may be said that earthworms ameliorated the nutrient profile of the FA amended soil helping to increase its usability percent in agricultural prospects with higher efficiency at lower concentration of FA(5%) amendment.

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