Indian J.Sci.Res. 13 (2): 15-20, 2017
ISSN: 0976-2876 (Print)
ISSN: 2250-0138 (Online)

IMPACT OF COAL FLY ASH AS SOIL AMENDMENT ON PHYSICO-CHEMICAL PROPERTIES OF SOIL

SONAL MISHRA[a1], S.V.K. PRASAD[b] AND V.K. KANUNGO[c]

[a]Department of Botany, Govt. Digvijay Autonomous, P. G. College Rajnandgaon, Chhattisgarh, India

[b]Principal, Govt. College, Pakhanjur, Chattisgarh, India

[c]Department of Botany,Govt. N.P.G. College of Science, Raipur, Chhattisgarh, India

ABSTRACT

In the last few decades the main focus of the world is on alternate source of energy in the same reference the coal has become the prime source of energy especially country like India where plenty of coal reserves are found. In India the thermal power plants covers more than 80% of total power production. This coal combustion produces lots of byproduct whose management and disposal had become a unsolved problem hence it is the need of the time that different method must be discovered in order for its proper disposal or its utilization for alternate purposes. Various studies had shown that fly ash can be used as a good soil amendment as it contains essential macro and micro nutrients. In the present study physico-chemical characters of the soil such as bulk density, particle density, porosity, percent solids, water holding capacity, pH, total dissolved salts, electrical conductivity were studied under the influence of coal fly ash for the experiments various levels of coal fly ash were taken 0%(Control), 5%, 10%, 15%, 20%, 25%, 30%, 50%, 75%, 100% and changes in physical, chemical and structural properties were observed. This investigation explores the potential of fly ash to be used as amelioration agent for agricultural purposes.

KEYWORDS: Coal Fly Ash, Macro and Micronutrients, Soil Amendment, Physico-Chemical Properties

The most important ill effect of Industrialization all over the world is production of huge quantities of Industrial waste and byproducts this has arise a challenges infront of environmentalist and scientists for safe disposal and proper management of these byproducts. In India to achieve the national goal of energy independence, the amount of coal consumption is expected to increase rapidly. India where agriculture is the main occupation millions of acres of agricultural land is occupied by fly ash lagoons, In India we generate more than 100 million tonnes of fly ash every year. Karla *et al* (1998) has documented that it will cross the 140 million tonnes by the year 2020.

Fly ash is disposed either by wet or dry method. In wet method the fly ash is washed out with water in artificial lagoons and is called Pond Ash, while in dry method it is dumped in landfills and fly ash basins. Both of these methods leads to degradation of soil and are harmful to human health (Page *et al* 1979). Both the methods of disposal are very costly so there is an argent need for the techniques for safe and profitable utilization of fly ash.

Therefore agricultural utilization and waste area management techniques have emerged as prime utilization methods for solving fly ash problems (Vijayan and Behera 1999). Field and green house experiments have proved that it can be used in growing agricultural crops (Gupta *et al* 2002). Fly ash addition can improve nutritional status of soil and can neutralize the soil reaction to a level suitable for plant culture (Mollinear and Street 1982).

Fly ash the fine residue captured from flue exhausts when coal is burnt in power stations may be used as an amendment to enhance water and nutrient retention in soil (Pathan *et al* 2003). Fly ash improves the physico-chemical properties of soil such as pH, nutrient availability, porosity, texture, water holding capacity (Singh *et al* 1994, Khan *et al* 1996, Khan *et al* 1997, He et al 1999, Grewal *et al* 2001). Fly ash formulated compost and other agro-industrial waste have to be recycled in soil through integrated nutrient management approach (Gu *et al* 2013). Fly ash based fertility but also mobilizes macro and micronutrients in the soil (Buddhe *et al* 2014).

MATERIALS AND METHODS

Fly Ash Treatment

Fly ash used in the experiment was collected from ACC cement factory, Jamul, Bhilai, C.G. Top soil taken from 25 cm of agricultural field of Raipur, C.G. The fly ash and the field soil both were sun dried for 7 days and mixed together in different proportion i.e. 0%(Control), 5%, 10%, 15%, 20%, 25%, 30%, 50%, 75%, 100% . Clay pots of 24 cm diameter were filled with the flyash –

[1]Corresponding author

soil mixture and named as T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10} respectively. Three replicates are used for each treatment.

Physico-Chemical Analysis

Physico-chemical properties of coal fly ash depends on the origin and the composition of coal used for combustion (Capp 1978). The physical, chemical and mineralogical characterization of fly ash depends on a variety of factors such as parent coal composition, condition for combustion, the efficiency and type of emission control devices and disposal methods (Adrino *et al* 1980). Fly ash is the mixture of fine powdered ferroaluminosilicates material with Al, Ca, Fe, Na and Si as the predominant elements (Tripathi *et al* 2013).(Table,1)

Mostly fly ash particles are of silt sizes ranges from 2-50 microns. Fly ash is comprised primarily of fine sand and silt sized particles therefore if applied at sufficient rate it can be used to change the soil texture (Adrino *et al* 1980, Aitken *et al* 1984, Gangloff *et al* 2000).

Various elements that constitute fly ash are Si, Ca, Mg, Na, K, Cd, Pb, Co, Cu, Mo, Ni, Zn, B, F and Al thus fly ash contains mostly all the elements required for plant growth and metabolism with the exception of nitrogen and available phosphorus (Plank and Martens 1974, El-Mogazi *et al* 1988, Singh and Yunus 2000). The pH of fly ash vary from 4,5 to 12.0 depending largely on S content of the parent coal (Plank and Martens 1974). The analysis of physico-chemical properties such as texture, bulk density, particle density, pH, electrical conductivity, porosity, water holding capacity were done by the dried soil collected from each experiment pots.(Table,2)

Texture

Particle size distribution was assessed by using method of Misra et al (1970). The sand, silt and clay were weighed separately and their proportions were calculated. Soil texture was determined by using Palmer and Troeh (1977) soil texture triangle.

pH, Electrical Conductivity and Total Dissolved Salts

Methods given by APHA, AWWA, WEF (1992) were used to determine these parameters. Various instruments used for it were systronic digital pH meter, electrical conductivity analyzer and value of electrical conductivity was calculated in $mScm^{-1}$ and digital salinity meter was used to calculate total dissolved salts and values were expressed in $mgkg^{-1}$.

Percentage porosity and percentage solids

Porosity and soil solids in samples of various treatments were calculated by method given by Misra *et al* (1970).

Bulk density and particle density

Bulk density and particle density for soil samples of various treatments were determined by following the methods given by Black and Hartage (1986) and value are expressed in $gmcm^{-3}$.

Water holding capacity

Water holding capacity was determined by following the method of Pandaya *et al* (1968) and value are calculated in %.

RESULTS AND DISCUSSION

Impact of coal fly ash on physico-chemical properties soil was studied from the soil with different treatments from T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8, T_9, T_{10}. Results are compiled in table 1 and 2.

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

S.No.	Parameters	Soil	Fly ash
1	Texture	Silty clayey	Clayey
2	Bulk density	1.49	1.06
3	Particle density	2.80	2.18
4	Water holding capacity	42.73	60.36
5	pH	6.97	6.15
6	Electrical conductivity(mS/cm^{-1})	0.19	0.62
7	Total dissolved salts	115.40	387.60
8	Porosity (%)	52.46	57.30
9	Solids (%)	48.90	45.82

Table 2: Effect of coal fly ash treatment on physico-chemical properties of soil

S. No	Treatment	% FA	Texture	pH	EC ($mScm^{-1}$)	TDS ($mgkg^{-1}$)	BD (gm cm^{-3})	PD (gm cm^{-3})	Porosity (%)	Solids (%)	WHC (%)
1	Control T_1	0	Silty clayey	6.97	0.19	115.40	1.49	2.80	52.46	48.90	42.73
2	T_2	5	Silty clayey	6.92	0.21	128.18	1.46	2.76	52.85	48.81	43.45
3	T_3	10	Silty clayey	6.88	0.23	142.22	1.44	2.71	53.14	48.79	44.12
4	T_4	15	Silty clayey	6.84	0.26	158.41	1.41	2.68	53.52	48.64	45.33
5	T_5	20	Silty clayey	6.79	0.28	169.30	1.38	2.63	53.76	48.37	46.70
6	T_6	25	Silty clayey	6.73	0.30	183.45	1.36	2.59	54.08	47.64	47.25
7	T_7	30	Clayey	6.69	0.34	195.70	1.33	2.55	54.64	47.90	48.61
8	T_8	50	Clayey	6.54	0.41	252.5	1.29	2.47	55.82	46.74	51.42
9	T_9	75	Clayey	6.33	0.53	321.55	1.18	2.33	56.32	46.15	54.89
10	T_{10}	100	Clayey	6.15	0.62	387.60	1.06	2.18	57.30	45.82	60.36
Mean				6.684	0.337	205.431	1.34	2.57	54.389	47.776	48.486
SD				0.267	0.142	88.849	0.133	0.195	1.605	1.156	5.606
SE				0.084	0.045	28.099	0.042	0.062	0.507	0.365	1.772

EC= Electrical conductivity, TDS= Total dissolved salts, BD= Bulk density, PD= Particle density, WHC= Water holding capacity

Texture

The addition of appropriate quantity of fly ash can alter the soil texture of sandy and clayey soil to loamy soil (Fail and Wochock 1977). Texture describes the size of particles which are grouped according to their sizes in to clay, silt and sand. Pure soil used in the experiment shows silty clayey texture and pure fly ash was clayey. In the experiment data shows that the percentage of clay content was increased while the percentage of silt and sand had decreased shows gradual transformation from silty clayey to clayey with increase in level of fly ash.

pH

Fly ash has high salinity and alkalinity (pH ranges from 8.5 to 12.5) when dissolved in water (Carlson and Adrino 1993, Singh and Yunus 2000) while some acidic fly ash (pH ranges from 6-6.7) is derived from high sulphur coal and conditions of combustion and final handling (Davison et al 1974, Khan et al 1996). Coal fly ash can change soil pH in both directions that is increase or decrease depending on fly ash characters and its weathering, acidic fly ash decrease soil pH while alkaline fly ash can raise pH of acidic soils (Pathan et al 2003, Skousen et al 2013). The maximum pH 6.97 was found in treatment T_1 and minimum pH 6.15 in treatment T_{10}. Fly ash decreases pH progressively with increase of fly ash incorporation.

Electrical Conductivity

Fly ash added to soil increases the electrical conductivity by increasing the levels of soluble major and minor inorganic constituents (Adrino et al 1980, El-Mogazi et al 1988). In this experiment the electrical conductivity varies from 0.19 $mScm^{-1}$ for treatment T_1 to 0.62 $mScm^{-1}$ for treatment T_{10}, thus electrical conductivity shows continuous increases with increase of fly ash incorporation.

Total Dissolved Salts

Total dissolved salts (TDS) is a measure of total salt materials present in water certain level of these ions are necessary in soil water for plant life. These salts get dissolved in water forming positive and negative charged ions. In the present study the TDS varied from 115.40 $mgkg^{-1}$ for treatment T_1 and 387.60 $mgkg^{-1}$ for treatment T_{10} showing continuous increases with elevated amount of fly ash addition.

Percentage Porosity and Percentage Solids

Incorporation of fly ash to soil results in addition of fine sized particles leading to increase total porosity (Aitken et al 1984, Pathan et al 2001). The percentage porosity is inversely proportional to percentage solids (Khan and Khan 1996, Siddiqui and Singh 2005). The finding of this experiment shows the percentage porosity increases and percentage solids decreases with increasing amount of fly ash incorporation. The maximum porosity was found in treatment T_{10} 57.30 and minimum in treatment T_1 52.46 while the minimum percentage solids was for treatment T_{10} 45.82 and maximum for treatment T_1 48.90.

Bulk Density and Particle Density

Bulk density and particle density has a strong negative correlation with increasing levels of fly ash (Khandkar et al 1999). The bulk density of soil decreases with increasing amount of fly ash due to increased proportion of clay particles (Karla et al 2003, Pathan et al 2003). The maximum bulk density was found for treatment T_1 1.49 gcm^{-3} and minimum for treatment T_{10} 1.06 gcm^{-3} while maximum particle density was found for T_1 2.80 gcm^{-3} and minimum for treatment T_{10} 2.18 gcm^{-3}.

Water Holding Capacity

Gradual increase in fly ash levels reported to increase the water holding capacity of soil (Khan and Khan 1996). Fly ash application increases the plant available water content and water holding capacity of soil (Adriano and Weber 2001). The experiment shows gradual increase in water holding capacity with increasing amount of fly ash in soil. The peak value was observed in treatment T_{10} was 60.36 and minimum in treatment T_1 42.73. This happens due to change in particle size distribution and increase in porosity (Sharma et al 1990, Mishra et al 2007).

CONCLUSION

Due to rapid industrialization the demand for energy had also touched the hike to meet this demand for energy the pressure had increases on power plant to increase their power generating capacity in the same concern the dependency on coal for power generation and problem for disposal of fly ash will continue to rise along with other environmental problems. To use fly ash as an amendment is a welcomed step to reduce its disposal problems on the other hand it is beneficial as it contains almost all the essential macro and micronutrients P, K, Mg, S and Fe, Mn, Zn, Cu, B and Mo, inturn it improves soil quality, fertility and increases the productivity thus indirectly helps to improves the economy in India. As the major determinant of the productivity is the nutritional status of soil but in the absence of a well-planned strategy in our country for its disposal we are facing serious health, ecological and economical hazards. The outcome of the study revealed that fly ash can be effectively used as soil amendment and fertilizer resulting in the increase of soil fertility. It utilization also solve the dumping problems of fly ash and will help in planning future strategies for its utilization.

REFERENCES

Adriano D.C. and Weber J.T., 2001. Influence of fly ash on soil physical properties and Turfgrass establishment. J. Environ. Qual., **30**:596-601.

Adriano D.C., Page A.L., Elseewi A.A., Chang A.C. and Straughan I., 1980. Utilization and disposal of fly ash and other coal residues in terrestrial ecosystem: a review. J. Environ. Qual., **9**:333-344.

Aitken R.L., Campbell D.J. and Bell L.C., 1984. Properties of Australian fly ash relevant to their agronomic utilization. Aust. J. Soil Res., **22**: 443-453.

APHA, AWWA and WPCF, 1992. Standard methods for the examination of water and waste water, 18th ed. American Public Health Association, Washington D.C.

Blake G.R. and Hartage K.H., 1986. Bulk density and Particle density. In A. Klute (ed.) Methods of soil analysis. Part I. 2nd ed. Agron. Monogr.9. ASA and SSSA, Madison, WI. 365-382.

Buddhe S.T., Thakre M.G. and Chaudari P.R., 2014. Application of magnetized fly ash based soil conditioner for the improvement of soil fertility and paddy productivity. American J. of Engineering Research, **3**(6):298-304.

Capp J.P., 1978. Power plant flyash utilization for land reclamation in the eastern United states. In : Schaller, F.W and Sutton, P (eds). Reclamation of drastically disturbed Lands. Soil Sci. Soc. Of America. Madison WI, 339.

Carlson C.L. and Adriano D.C., 1993. Environmental impacts of coal combustion residues. J. Envion. Qual., **22**:227-247.

Davison R.L., Natusch D.F.S., Wallace J.R. and Evans C.A., 1974. Trace elements in fly ash : Dependence of concentration on particle size. Environ. Sci. Technol., **8**: 1107-1113.

El-Mogazi D., Lisk D.J. and Weinstin L.H., 1988. A review of physical, chemical and biological properties of fly ash and effects on agricultural ecosystem. Sci. Total Environ., **74**:1-37.

Fail J.L. and Wochok Z.S., 1977. Soyabean growth on fly ash amended strip mine spoils. Plant and Soil, **48**:473-484.

Gangloff W.J., Ghodrati M., Sims J.T. and Vasilas B.L., 2000. Impact of fly ash amendment and incorporation method on hydraulic properties of sandy soil, Water, Air and Soil Pollut., **119**:231-245.

Grewal K.S., Yadav P.S., Metha S.C. and Oswal M.C., 2001. Direct and residual effect of fly ash application to soil on crop yields and soil properties. Crop. Res. Hicar., **21**:50-65.

Gu H., Li F.P., Guan X, Xu Y.L., Liu Y.J. and Chen X.T., 2013. Effect of fly ash an heavy metal uptake of rice growing on multi-metal contaminated acidicsoil. Advan. Mat. Reser., **680**: 94-99.

Gupta D.K., Rai U.N., Tripathi R.D. and Inouhe M., 2002. Impacts of fly ash on soil and plant responces. J. Pl. Res., **115**:401-409.

He Z.L., Baligar V.C., Martens D.C., Ritchey K.D and Elarshidi M.A., 1999. Relationship of rye grass growth to extractable phosphorus in acidic soil amended with phosphate rock, coal combustion byproduct, limestone and cellulose. Communications in soil science and plant Analysis, **30**:457-470.

Karla N., Jain M.C., Joshi H.C., Chaudhary R., Harit R.C., Vasta B.K., Sharma S.K. and Kumar V., 1998. Fly as as a soil conditioner and fertilizer. Bioresource Technology. **64**:163-167.

Karla N., Jain M.C., Josshi H.C., Chaudhary R., Kumar S., Pathak H., Sharma S.K., Kumar V., Kumar R., Harit R.C., Khan S.A. and Hussin M.Z., 2003. Soil properties and crop productivity as influenced by fly ash incorporation in soil. Environ. Monitoring Assessment. **87**: 93-109.

Khan M.R. and Khan M.W., 1996. The effect of fly ash on plant growth and yield of tomato, Environ. Pollut., **92**:105-111.

Khan M.R., Khan M.W. and Singh K., 1997. Management of root knot disease of tomato by the application of fly ash in soil. Pl. Pathol., **46**:33-43.

Khan S., Beghum T. and Singh J., 1996. Effect of fly ash on physicochemical properties and nutrient status of soil. Ind. J. Environ. Health. **38**:41-46.

Khandkar U.R., Gangwar M.S. and Srivastava P.C., 1999. Effect of fly ash waste on some properties of an acid soil, elemental composition and yields of crops. Pollut. Res., **18**: 101-107.

Mishra M., Sahu R.K and Pandy R.N., 2007. Growth, yield, metabolism and elemental status of rice (*Oryza sativa*) grown in fly ash amendment soil. Ecotoxicology. **16**:272-278.

Misra K.C., Rao D.N., Ambasht R.S., Mukherjee K.L., Dwivedi R.S. and Ananthkrishnan P.V., 1970. Ecology Study of Ecosystem, AHW Heelar & Co (P) Ltd. Allahabad.

Mollinear A.M. and Street J.J., 1982. Effect of fly ash and lime on growth and composition of corn (*Zea maize* L.) on acid sandy soil. Proceedings of soil and crop science. Society Of Florida. **41**:217-220.

Page A.L., Elseewi A.A and Straughan I., 1979. Physical and chemical properties of fly ash from coal fired power plants with reference to environmental impects. Residue Rev. **7**1:83-120.

Palmer R.G. and Troeh F.R., 1977. Introductory Soil Science Laboratory Manual. Iowa State University Press, Ames, Iowa, USA.

Pandeya S.C., Puri G.S. and Singh J.S., 1968. Research methods in plant ecology. Asia Publishing House, Bombay.

Pathan S.M., Aylmore L.A.G. and Colme T.D., 2001. Fly ash amendment of sandy soils to improve water and nutrient use efficiency in turf culture. Int. Turfgrass Soc. Res. Journal **9**:33-39.

Pathan S.M., Aylmore L.A.G. and Colmer T.D., 2003. Properties of several fly ash materials in relation to use as soil amendments. J. Environ. Qual. **32**:687-693.

Plank C.O. and Martens D.C. 1974. Boron availability as influenced by application of fly ash to soil. Soil Science Society of America Proceedings. **38**: 974-977.

Sharma B.M., Aggarwal R.K. and Kumar P., 1990. Water retention and nutrient availability in fly ash amended desert sandy soil: A study in vitro. Arid Soil Res. Rehab. **4**:53-58.

Siddiqui Z.A. and Singh L.P., 2005. Effect of fly ash, *Pseudomonas striata* and *Rhizobium* on the reproduction of nematode meloidogyne incognita and on the growth and transpiration of pea. J. Environ. Biol. **26**:117-122.

Singh N. and Yunus M., 2000. Environmental impact of fly ash. In: Iqbal, M., Srivastava, P.S. and Siddiqui, T.O.(eds.) Environmental Hazards: Plant and People. CBS. New Delhi. 60-79.

Singh N., Singh S.N., Yunus M. and Ahmad K.J., 1994. Growth response and element accumulation in *Beta vulgaris* L. raised in fly ash amended soil. Ecotoxicology. **3**:287-298.

Skousen J, Yang J.E., Lee J.S. and Ziemkiewicz P., 2013. Review of fly ash as a soil amendment. J. Geosystem Engineering. **16**(3): 249-256.

Tripathi B. and Ali Jawaid S.M., 2013, Environmental Impacts and Utilization of Pond Ash, IJBSTR RESEARCH PAPER VOL 1 [ISSUE 9], pp1-4. R&D and technology development/ application in Fly Ash area, 2012, Submission of R&D Proposals, Government of India, Ministry of Science & Technology, Department of Science & Technology FLY ASH UNIT (FAU), Technology Bhawan, Room No.17 B,New Mehrauli Road,New Delhi.

Vijiyan V. and Behera S.N., 1999. Study of heavy metals in wheat and paddy grains. International J. of PIXE. **9**: 365-371.