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Effect of fly ash, organic manure and fertilizers on available heavy metals in rice-wheat cropping system in *Alfisols* and *Vertisols*

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Abstract
Field experiment was conducted under *Alfisols* at KVK, Farm Katghora, Korba and Vertisols at Instructional Farm Indira Gandhi Krishi Vishwavidyalaya, during 2011 and 2012. To assess the impact of different doses of fly ash alone or in combination with manure and fertilizers on available heavy metals in rice –wheat cropping system in *Alfisols* and Vertisols in the following treatments (i.e. T_1Control, T_2-10 t FA ha^{-1}, T_3-20 t FA ha^{-1} T_4-STCR (based fertilizer recommendation), T_5-75 % NPK ha^{-1}, T_6-100 % NPK (100:60:40), T_7-75 % NPK ha^{-1}+ 10 t FA ha^{-1}, T_8-75 %NPK ha^{-1} + 20 t FA ha^{-1}, T_9-100 % NPK ha^{-1}+ 10 t FA ha^{-1}, T_{10}-100 % NPK ha^{-1} + 20 t FA ha^{-1}, T_{11}-75 % NPK ha^{-1}+ 5 t FYM ha^{-1}, T_{12}-100 % NPK ha^{-1} +5 t FYM ha^{-1}, T_{13}- 75 % NPK ha^{-1} + 5 t FYM +10 t FA, T_{14}- 75 % NPK ha^{-1} + 5 t FYM +20 t FA ha^{-1}, T_{15}-100 % NPK ha^{-1} +5 t FYM+10 t FA ha^{-1} and T_{16}- 100 % NPK ha^{-1} +5 t FYM+20 t FA ha^{-1}) under Split Plot Design with factorial arrangment of crop and soil in main plot and treatment in sub plot. The available soil Cd, Ni, Cr and Pb significantly increased due to addition of fly ash in *Alfisols* and Vertisols in rice-wheat cropping system. The higher available Cd, Ni and Cr content in soil was recorded in *Alfisols* under both the crops in treatment T_{16} and interaction of soil x crop x treatment was non-significant. The available Pb content in soil influenced due to addition of fly ash, interaction between rice × *Vertisol* × treatment and rice × *Alfisol* × treatment, T_{16} recorded significantly highest available lead content in soil among all the treatments. It was at par with treatment, T_{14} and T_{10} in rice × *Vertisol* × treatment and T_{14} in rice x *Alfisol* × treatment. In case of wheat × *Vertisol* × treatments and wheat × *Alfisol* × treatment, T_{16} recorded higher available lead content in soil. It was at par with T_{15} in wheat × *Vertisol* × treatment and T_{15} and T_{14} in wheat × *Alfisol* × treatment. The lowest available lead content was recorded in T_1.

Keywords: Fly ash, Available micro nutrients, rice-wheat cropping system

Introduction
Eleven major Thermal Power Plants in Chhattisgarh which produces fly ash to the tone of about 26880 metric tons per day i.e. nearly 9.7 million tons of fly ash annually, out of which the four major Thermal Power Plants in Korba district alone generate about 24000 metric tons per day. This is nearly 90% of the total ash generated in the state and about 8.7% of the total ash generated in the country.

It is having excellent physico-chemical properties. The particle size distribution of fly ash is similar to silt or silt loam soil. It contains 35% sand, 55% silt, 10% clay with 13g kg^{-1} organic carbon, pH ranged from 4.5 to 12.0 depending on the silica-content of parental coal. Total N, P and K_2O content is 0.3% 1.5%, 0.09% respectively. Total Fe_2O_3 9%, Al_2O_3 2.3%, CaO 1.6% and SiO_2 73% (Maiti *et al.* 1990) [1]. Rautaray *et al.* (2003) [3] reported that fly ash contains high concentration of mineral matters such as Cu, Zn, Cd, Ni, Cr along with low nitrogen and phosphorous content and pH ranged from 4.5-12.0 depending upon the S- content of partial coal.

Materials and methods
The experiments were conducted in *Alfisols* and Vertisols at KVK, Katghora, Korba and Instructional farm IGKV, Raipur respectively. Rice and wheat crops were taken as test crops with sixteen treatments under Split Plot Design with factorial arrangment of crop and soil in main plot and treatment in sub plot. The Heavy metals, i.e. Cd and Ni were extracted by using 0.005 M diethylenetriamine penta acetic acid (DTPA), 0.01 M calcium chloride dihydrate and 0.1 M triethanol amine (TEA) buffered at pH 7.3 and Cr and Pb was extracted by using 0.05M

EDTA at 7 pH. The concentrations of the nutrients in the filtrate were analyzed by atomic absorption spectrophotometer (Lindsay and Norvell, 1978) [2].

Results and Discussion

Available cadmium in soil

Table 1 show that available cadmium in soil was significantly influenced due to addition of fly ash in rice-wheat cropping system in *Alfisol* and *Vertisol*. The higher available cadmium was recorded in both the crops under *Alfisol* during 2011.Where as in case of pooled data higher cadmium content was recorded in *Alfisol* for both crops.

Table 2 shows that the treatment, T_{16} recorded highest available cadmium in 2011, 2012 and pooled data. It was at par with treatment, T_{15} T_{10}, T_{13}, T_{14}, T_9 and T_8 in 2011, treatment T_{15}, T_{10}, T_9, T_{13} and T_{14} in 2012 and treatment T_{15}, T_{10}, T_{14}, T_{13} and T_9 in pooled data. The lowest available cadmium content was recorded in treatment, T_1. The interaction of crop × soil × treatments was non-significant.

Available nickel in soil

Table 1 show that available nickel content in soil was significantly influenced due to addition of fly ash in rice-wheat cropping system in *Alfisol* and *Vertisol*. The higher available nickel content was recorded in rice under *Alfisol* during 2011, 2012 and pooled data

Table 3 shows that the treatment, T_{16} recorded highest available nickel content in 2011, 2012 and pooled data. It was at par with treatment, T_{15}, T_{14} and T_{10} in 2011 and T_{14} T_{15} in 2012 and T_{15} and T_{14} in pooled data. The lowest available nickel content was recorded in treatment, T_1. The interaction of crop × soil × treatments was non-significant.

Table 1: Effect of fly ash alone or in combination with organic manure and fertilizers on available cadmium and nickel in soil in rice-wheat cropping system in *Alfisol* and *Vertisol* at harvest.

Particular	Available Cadmium (mg kg^{-1})						Available Nickel (mg kg^{-1})					
	2011		2012		Pooled		2011		2012		Pooled	
	Vertisol	*Alfisol*	*Vertisol*	*Alfisol*	*Vertisol*	*Alfisol*	*Vertisol*	*Alfisol*	*Vertisol*	*Alfisol*	*Vertisol*	*Alfisol*
Rice	0.083	0.091	0.086	0.094	0.084	0.092	0.080	0.096	0.075	0.111	0.077	0.104
Wheat	0.088	0.093	0.083	0.090	0.085	0.092	0.081	0.093	0.076	0.090	0.079	0.091
	SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%
A	0.002	N/A	0.001	N/A	0.001	N/A	0.001	N/A	0.001	0.004	0.001	0.003
B	0.002	0.006	0.001	0.005	0.001	0.004	0.001	0.005	0.001	0.004	0.001	0.003
A×B	0.002	N/A	0.002	N/A	0.002	N/A	0.002	N/A	0.002	0.006	0.001	0.004

Table 2: Effect of fly ash alone or in combination with organic manure and fertilizers on available cadmium in rice-wheat cropping system in *Alfisol* and *Vertisol* at harvest.

Treatments			Available Cadmium (mg kg^{-1})					
			2011		2012		Pooled	
T_1	-	Control	0.063d		0.060e		0.062f	
T_2	-	10 t FA ha^{-1}	0.076c		0.076c		0.076d	
T_3	-	20 t FA ha^{-1}	0.084c		0.087b		0.085c	
T_4	-	STCR	0.068d		0.088b		0.088c	
T_5	-	75%NPK ha^{-1}	0.088b		0.072d		0.070e	
T_6	-	100% NPK ha^{-1}	0.080c		0.087b		0.083c	
T_7	-	75%NPK ha^{-1}+10 t FA ha^{-1}	0.086b		0.081c		0.083c	
T_8	-	75%NPK ha^{-1}+20 t FA ha^{-1}	0.095a		0.088b		0.091b	
T_9	-	100%NPK ha^{-1}+10 t FA ha^{-1}	0.098a		0.101a		0.100a	
T_{10}	-	100%NPK ha^{-1}+20 t FA ha^{-1}	0.103a		0.101a		0.102a	
T_{11}	-	75% NPK ha^{-1}+5 t FYM ha^{-1}	0.077c		0.078c		0.078d	
T_{12}	-	100%NPK ha^{-1}+5 t FYM ha^{-1}	0.092b		0.090b		0.091b	
T_{13}	-	75%NPK ha^{-1}+5 t FYM+10 t FA ha^{-1}	0.101a		0.099a		0.100a	
T_{14}	-	75%NPK ha^{-1}+5 t FYM+20 t FA ha^{-1}	0.100a		0.099a		0.100a	
T_{15}	-	100%NPKha^{-1}+5 t FYM+10 t FA ha^{-1}	0.103a		0.102a		0.102a	
T_{16}	-	100%NPK ha^{-1}+5 t FYM+20 t FA ha^{-1}	0.106a		0.107a		0.106a	
			SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%
C			0.003	0.009	0.003	0.009	0.002	0.007
A×C			0.005	N/A	0.004	N/A	0.003	N/A
B×C			0.005	0.013	0.004	0.012	0.003	0.009

Table 3: Effect of fly ash alone or in combination with organic manure and fertilizers on available nickel in rice-wheat cropping system in *Alfisol* and *Vertisol* at harvest

Treatments			Available Nickel(mg kg^{-1})		
			2011	2012	Pooled
T_1	-	Control	0.076^{c}	0.068^{e}	0.072^{d}
T_2	-	10 t FA ha^{-1}	0.077^{c}	0.074^{d}	0.075^{d}
T_3	-	20 t FA ha^{-1}	0.087^{b}	0.084^{c}	0.085^{c}
T_4	-	STCR	0.088^{b}	0.082^{c}	0.085^{c}
T_5	-	75%NPK ha^{-1}	0.073^{c}	0.067^{e}	0.070^{e}
T_6	-	100% NPK ha^{-1}	0.089^{b}	0.083^{c}	0.086^{c}
T_7	-	75%NPK ha^{-1}+10 t FA ha^{-1}	0.087^{b}	0.084^{c}	0.085^{c}
T_8	-	75%NPK ha^{-1}+20 t FA ha^{-1}	0.090^{b}	0.095^{b}	0.093^{b}

T_9	-	100%NPK ha^{-1}+10 t FA ha^{-1}	0.088^b		0.090^b		0.089^b	
T_{10}	-	100%NPK ha^{-1}+20 t FA ha^{-1}	0.093^a		0.097^b		0.095^b	
T_{11}	-	75% NPK ha^{-1}+5 t FYM ha^{-1}	0.082^b		0.081^c		0.081^c	
T_{12}	-	100%NPK ha^{-1}+5 t FYM ha^{-1}	0.086^b		0.092^b		0.089^b	
T_{13}	-	75%NPK ha^{-1}+5 t FYM+10 t FA ha^{-1}	0.088^b		0.093^b		0.091^c	
T_{14}	-	75%NPK ha^{-1}+5 t FYM+20 t FA ha^{-1}	0.093^a		0.104^a		0.099^a	
T_{15}	-	100%NPKha^{-1}+5 t FYM+10 t FA ha^{-1}	0.100^a		0.103^a		0.101^a	
T_{16}	-	100%NPK ha^{-1}+5 t FYM+20 t FA ha^{-1}	0.106^a		0.111^a		0.108^a	
			SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%
C			0.004	0.010	0.003	0.009	0.003	0.007
A×C			0.005	0.014	0.005	0.013	0.004	0.010
B×C			0.005	0.014	0.005	0.013	0.004	0.010

Available chromium in soil

Table 4 shows that available chromium content in soil significantly increased due to addition of fly ash in rice-wheat cropping system in *Alfisol* and *Vertisol.* The higher available chromium content was recorded in wheat under *Alfisol* during 2011 and 2012 and pooled data.

Table 5 shows that the treatment, T_{16} recorded highest available chromium in 2011, 2012 and pooled data. It was at par with treatment, T_{12}, T_{15}, and T_{14} in 2011 and T_{15} in 2012 and pooled data. The lowest available chromium was recorded in treatment, T_1.

4. Available lead in soil

Table 4 shows that available lead in soil was significantly influenced due to addition of fly ash in rice-wheat cropping system in *Alfisol* and *Vertisol.* The higher available lead content was recorded in rice under *Alfisol* during 2012, and pooled data.

Interaction between crop × soil × treatments reveals (Table 6) that, rice × *Vertisol* × treatment and rice × *Alfisol* × treatment, T_{16} recorded significantly highest available lead content in soil among all the treatments. It was at par with treatment, T_{14} and T_{10} in rice × *Vertisol* × treatment and T_{14} in rice x *Alfisol* × treatment. In case of wheat × *Vertisol* × treatments and wheat × *Alfisol* × treatment, T_{16} recorded higher available lead content in soil. It was at par with T_{15} in wheat × *Vertisol* × treatment and T_{15} and T_{14} in wheat × *Alfisol* × treatment. The lowest available lead content was recorded in T_1.

The heavy metals Cd, Ni, Cr and Pb content in soil statistically increased significantly with application of fly ash alone or in combination with organic manure and fertilizer as compared to control. It is attributed to the pH decrease due to application of fly ash and organic matter the results of the study are in conformity as reported earlier by Sharma *et al.* (1989) [4]. Although fly ash increases heavy metal content of soil, they are not in available form. The results also supported by Rautaray *et al*. (2003) [3] and Yeledhalli *et al.* (2009) [5], reported that fly ash contains high concentration of mineral matters such as Cu, Zn, Cd, Ni, Cr along with low nitrogen and phosphorous content and pH ranged from 4.5-12.0 depending upon the S- content of partial coal. Application of higher dose @ 40 t ha^{-1} increased the concentration of heavy metals and radinucleocides in edible parts viz, sunflower, groundnut and maize grown on *Alfisols* and Vertisols. However, combined application of fly ash and FYM did not increase the heavy metal elements and radio nucleocides activity in seeds and stover of crops. The levels of radio nucleocides and heavy metal elements in soils and crop produce are well within the permissible limit.

Table 4: Effect of fly ash alone or in combination with organic manure and fertilizers on available chromium and lead in soil in rice-wheat cropping system in *Alfisol* and *Vertisol* at harvest.

Particular	Available Chromium (mg kg^{-1})						Available Lead (mg kg^{-1})					
	2011		2012		Pooled		2011		2012		Pooled	
	Vertisol	*Alfisol*	*Vertisol*	*Alfisol*	*Vertisol*	*Alfisol*	*Vertisol*	*Alfisol*	*Vertisol*	*Alfisol*	*Vertisol*	*Alfisol*
Rice	0.121	0.210	0.118	0.215	0.119	0.213	0.101	0.119	0.106	0.128	0.104	0.123
Wheat	0.124	0.214	0.127	0.225	0.125	0.219	0.107	0.119	0.109	0.122	0.108	0.121
	SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%
A	0.002	N/A	0.001	0.005	0.001	0.003	0.001	N/A	0.001	N/A	0.003	N/A
B	0.002	0.006	0.001	0.005	0.001	0.003	0.001	0.004	0.001	0.002	0.000	0.002
A×B	0.002	0.008	0.002	N/A	0.001	N/A	0.001	N/A	0.001	0.003	0.001	0.002

Table 5: Effect of fly ash alone or in combination with organic manure and fertilizers on available chromium in rice-wheat cropping system in *Alfisol* and *Vertisol* at harvest.

Treatments			Available Chromium (mg kg^{-1})		
			2011	2012	Pooled
T_1	-	Control	0.133^g	0.128	0.131
T_2	-	10 t FA ha^{-1}	0.159^d	0.163^c	0.161
T_3	-	20 t FA ha^{-1}	0.171^b	0.176^b	0.173^b
T_4	-	STCR	0.156^d	0.166^c	0.161
T_5	-	75%NPK ha^{-1}	0.143^f	0.146^d	0.145
T_6	-	100% NPK ha^{-1}	0.147^e	0.149^d	0.148
T_7	-	75%NPK ha^{-1}+10 t FA ha^{-1}	0.163^c	0.169^c	0.166^c
T_8	-	75%NPK ha^{-1}+20 t FA ha^{-1}	0.168^c	0.181^b	0.175^b
T_9	-	100%NPK ha^{-1}+10 t FA ha^{-1}	0.177^b	0.182^b	0.179^b
T_{10}	-	100%NPK ha^{-1}+20 t FA ha^{-1}	0.180^a	0.178^b	0.179^b
T_{11}	-	75% NPK ha^{-1}+5 t FYM ha^{-1}	0.171^b	0.163^c	0.167^c

T_{12}	-	100%NPK ha^{-1}+5 t FYM ha^{-1}	0.182[a]		0.176[b]		0.179[b]	
T_{13}	-	75%NPK ha^{-1}+5 t FYM+10 t FA ha^{-1}	0.174[b]		0.179[b]		0.177[b]	
T_{14}	-	75%NPK ha^{-1}+5 t FYM+20 t FA ha^{-1}	0.181[a]		0.185[b]		0.183[b]	
T_{15}	-	100%NPKha^{-1}+5 t FYM+10 t FA ha^{-1}	0.181[a]		0.193[a]		0.187[a]	
T_{16}	-	100%NPK ha^{-1}+5 t FYM+20 t FA ha^{-1}	0.191[a]		0.203[a]		0.197[a]	
			SEm±	CD at 5%	SEm±	CD at 5%	SEm±	CD at 5%
C			0.004	0.011	0.004	0.012	0.003	0.008
A×C			0.005	N/A	0.006	0.017	0.004	N/A
B×C			0.005	N/A	0.006	0.017	0.004	0.011

Table 6: Effect of fly ash alone or in combination with organic manure and fertilizers on available lead content in rice-wheat cropping system in *Alfisol* and *Vertisol* at harvest.

Treatments			Available lead (mg kg^{-1})			
			Rice		Wheat	
			Vertisol	***Alfisol***	***Vertisol***	***Alfisol***
T_1	-	Control	0.083[e]	0.105[e]	0.077[h]	0.105[d]
T_2	-	10 t FA ha^{-1}	0.093[d]	0.123[b]	0.083[h]	0.123[b]
T_3	-	20 t FA ha^{-1}	0.100[c]	0.133[b]	0.098[g]	0.132[a]
T_4	-	STCR	0.092[d]	0.107[e]	0.090[g]	0.117[c]
T_5	-	75%NPK ha^{-1}	0.075[f]	0.095[e]	0.077[h]	0.098[e]
T_6	-	100% NPK ha^{-1}	0.092[d]	0.108[e]	0.087[h]	0.108[d]
T_7	-	75%NPK ha^{-1}+10 t FA ha^{-1}	0.092[d]	0.115[d]	0.093[g]	0.118[c]
T_8	-	75%NPK ha^{-1}+20 t FA ha^{-1}	0.103[c]	0.122[b]	0.113[e]	0.123[b]
T_9	-	100%NPK ha^{-1}+10 t FA ha^{-1}	0.112[b]	0.128[c]	0.102[f]	0.125[b]
T_{10}	-	100%NPK ha^{-1}+20 t FA ha^{-1}	0.122[a]	0.135[b]	0.122[d]	0.128[b]
T_{11}	-	75% NPK ha^{-1}+5 t FYM ha^{-1}	0.095[d]	0.110[d]	0.105[f]	0.105[d]
T_{12}	-	100%NPK ha^{-1}+5 t FYM ha^{-1}	0.113[b]	0.125[c]	0.122[d]	0.112[c]
T_{13}	-	75%NPK ha^{-1}+5 t FYM+10 t FA ha^{-1}	0.112[b]	0.137[b]	0.128[c]	0.130[b]
T_{14}	-	75%NPK ha^{-1}+5 t FYM+20 t FA ha^{-1}	0.125[a]	0.143[a]	0.135[b]	0.132[a]
T_{15}	-	100%NPKha^{-1}+5 t FYM+10 t FA ha^{-1}	0.118[b]	0.137[b]	0.142[a]	0.132[a]
T_{16}	-	100%NPK ha^{-1}+5 t FYM+20 t FA ha^{-1}	0.132[a]	0.150[a]	0.153[a]	0.143[a]
SEm±			0.004			
CD at 5% level			0.012			

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