International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(4): 11-18

Received: 03-05-2017
Accepted: 04-06-2017

Thaneshwar Kumar
Ph.D Scholar, Department of Soil Sciences & Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

K Tedia
Principal Scientist, Department of Soil Sciences & Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Vinay Samadhiya
Scientist, Department of Soil Sciences & Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Rahul Kumar
Research Scholar, Department of Soil Sciences & Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Correspondence
Thaneshwar Kumar
Ph.D Scholar, Department of Soil Sciences & Agricultural Chemistry, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Review on effect of fly ash on heavy metals status of soil and plants

Thaneshwar Kumar, K Tedia, Vinay Samadhiya and Rahul Kumar

Abstract
Uninterrupted generation of fly ash by the coal based thermal power plants and its dumping has lead to steady encroachment of useful land in India. The deleterious effects of fly ash on the nearby environment are inevitable due to its fine texture and presence of toxic metals. Agriculture application is one of the several options available for the disposal of fly ash, a hazardous solid waste generated from coal based thermal power plants. Fly ash contains both micro- and macro nutrients useful for plant growth. However, it also contains toxic heavy metals which can move to the plants and accumulate resulting in toxicity to plants and animals. Accumulation of metals in plant parts having secondary metabolites, which is responsible for a particular pharmacological activity. The issue of heavy metal pollution is very much concerned because of their toxicity for plant, animal and human beings and their lack of biodegradability. Excess concentrations of heavy metals have adverse effects on plant metabolic activities hence affect the food production, quantitatively and qualitatively. Heavy metal when reaches human tissues through various absorption pathways such as direct ingestion, dermal contact, diet through the soil–food chain, inhalation and oral intake may seriously affect their health. Prolonged exposure to heavy metals such as cadmium, copper, lead, nickel, and zinc can cause deleterious health effects in humans. This article attempts to highlight the use of fly ash bearing heavy metals and their problems.

Keyword: Fly ash, metals, toxicity, macro and micro nutrients

1. Introduction
Coal occupies an important position in the Indian energy sector since India has vast reserves of thermal grade coal. Coal is the most abundant and widely spread fossil energy resource in the world (Benito, *et al*., 2001) [5]. Among the total power generated annually in India, about 70% is produced by thermal power plants. The majority of thermal power plants (about 84%) are running on coal with 70 billion tons of coal reserve, while the remaining 13% run on gas and 3% on oil. About 112 million tons of fly ash is being generated annually in India by thermal power plants as a byproduct of coal combustion (Chandra and Chandra, 2005) [8].
Fly ash quality depends on coal type, coal particle fineness, percentage of ash in coal, combustion technique, air/fuel ratio, and boiler type (Dhadse *et al*., 2008) [11]. In India, studies have been carried out toward management of fly ash disposal and utilization (Kumar *et al., 2003*) [21] (Sarkar**,** 2001) [33]. Fly ash is utilized in cement and construction. However, the rate of production is greater than consumption. The unused fly ash is disposed into holding ponds, lagoons, landfills and slag heaps. Disposal of huge amounts of fly ash in landfills, and surface impoundments or its reuse in construction materials is of environmental concern (Piekos and Paslawska 1998) [29].
The disposal of fly ash is considered a potential source of contamination due to the enrichment and surface association of trace elements in the ash particles (Choi *et al.*,2002) [10]. The elements Mn, Ba, V, Co, Cr, Ni, Ln, Ga, Nd, As, Sb, Sn, Br, Zn, Se, Pb, Hg, and S in coal are volatile to a significant extent in the combustion process. However, the elements Mg, Na, K, Mo, Ce, Rb, Cs, and Nb appear to have smaller fractions volatilized during combustion, whereas Si, Fe, Ca, Sr, La, Sm, Eu, Tb, Py, Yb, Y, Se, Zr, Ta, Na, Ag, and Zn are either not volatilized or show only minor trends related to the geochemistry of mineral matter (Iyer, 2002) [19]. During transport, disposal, and storage phases, the residues from coal combustion are subjected to leaching effects of rain and part of the undesirable components in the ashes may pollute both ground and surface waters (Benito *et al.*,2001) [5]. These solid residues (fly ash) can be leached in higher concentrations than drinking water standards and can cause contamination in drinking water sources. Fly ash contains trace amounts of toxic metals that

may have negative effects on human health and on plants (Mehara *et al.*, 1998) [22].

Environmental pollution due to toxic heavy metals has increased exponentially in the past few years and reached alarming levels in terms of its effects on living creatures. Heavy metal ions do not degrade into harmless end products (Gupta *et al*., 2001) [16] therefore they are difficult to degrade biologically. Heavy metal contamination exists in ecosystem largely due to refining ores, mining operations, sludge disposal, metal plating, fly ash incinerators, processing of radioactive materials, paints, alloys, batteries, pesticides and preservatives (Ahalya *et al*, 2005) [2]. Heavy metals such as Pb, Cd, Zn and Cu present in industrial wastewater, are non-biodegradable and their existence in receiving lakes and streams causes bioaccumulation in living organisms, which leads to several health problems in animals, plants and human beings (Mehmet *et al.*, 2006) [23]. These toxic metals enter the food chain and are concentrated in fish and other edible organisms and become difficult to track as they move up in tropic levels (Kalai and Canil 2000) [20] (Sankar *et al.*, 2006) [32]. Due to their bioaccumulation and biomagnifications in the food chain they accumulate in living tissues throughout the food chain and human receive the maximum toxic impact, since they are at the top of the food chain (Duruibe *et al.*, 2007) [12].

Fly ash utilization and disposal

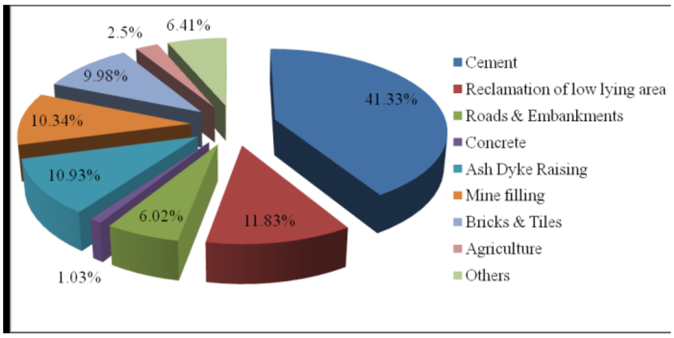

Fig 1: Fly ash utilization in Indian scenario, in different sectors/industries in the year 2012-2013. Modified from Central Electricity Authority, 2012 [7]

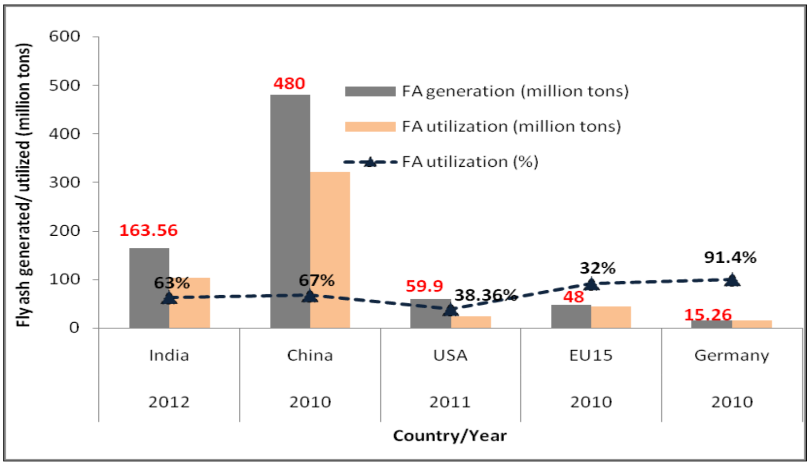

Fig 2: Fly ash generation and utilization in different countries in the world. Modified from Ram and Masto, 2014 [30].

2. Heavy metals: some general information

The term ‘‘heavy metals’’ refers to any metallic element which has a high density, specific gravity or atomic weights between 63.5 and 200.6 and is toxic or poisonous even at low concentration (Hutton and Symon 1986) [18] (Hawkes 1997) [17]. However, chemical properties of the heavy metals are far more important as compared to their density. Heavy metals include lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), iron (Fe), copper (Cu), zinc (Zn), chromium (Cr), iron (Fe), arsenic (As), silver (Ag) and the platinum group elements as reported by Duruibe, *et al.*, 2007 [12]. Heavy metals occur as natural constituents of the earth crust as their ores in different chemical forms, from where they are recovered as minerals and are persistent environmental pollutants. They enter the body system through food, air and water and bio-accumulate over a period of time disrupting the health system of human beings, plants and animals. Ferner 2001 [15] and Young 2005 [36] studies Certain heavy metals like Fe, Cu, Zn, Ca and Mg are nutritionally essential for a healthy life, but large amounts of any of these may cause acute poisoning, whereas some others like As, Cd, Pb and Hg are of no known bio-importance in human biochemistry and physiology and their consumption even at very low concentrations can be toxic. Chronic heavy metal in toxications damage central nervous system, lungs, kidneys, liver, the cardiovascular and gastrointestinal (GI) systems, endocrine glands and bones and may increase the risk of some cancers. Heavy metals can be emitted into the environment by natural and anthropogenic pollutants like industrial wastewaters from mining, metal processing, pharmaceuticals, tanneries, pesticides, rubber and plastics, organic chemicals, lumber and wood products. Therefore to avoid health hazards it is essential to remove these toxic heavy metals from waste waters before their disposal.

Definition

"A metal of relatively high density (Specific gravity greater than about 5) or of high relative atomic weight (especially one i.e poisonous) one mercury or lead." It has been includes density, atomic weight, atomic number, or periodic table position. Density criteria range from above 3.5 g/cm^3 to above 7 g/cm^3. Atomic weight definitions start at greater than sodium (22.98) to greater than 40. Atomic numbers of heavy metals are generally given as greater than 20 sometimes this is capped at 92 (uranium). Heavy metals as all the metals in groups 3 to 16 that are in periods 4 and greater. The term "heavy metals" was in use as far back as 1817, divided the elements into nonmetals, light metals and heavy metals. Light metals had densities of 0.860–5.0 gm/cm3; heavy metals 5.308–22.000. Adverse effects of the heavy metals "arsenic, lead, copper, zinc, iron and manganese" in drinking water.

Table 1: Main Properties of Heavy Metals

Property	Copper (Cu)	Zinc (Zn)	Lead (Pb)	Cadmium (Cd)
Atomic number	29	30	46	48
Atomic mass, (g/ mol)	63.54	65.39	207.2	112.41
Density, (g.cm-^{3})	8.96	7.133	11.35	8.65
Melting point, (K)	1356.6	692.73	600.65	594.1
Boiling point, (K)	2840	1180	2013	1038
Electronic shell	[Ar] $4s^1$ $3d^{10}$	[Ar] $4s^2$ $3d^{10}$	[Xe] $4f^{14}5d^{10}6s^{2}6p^2$	[Kr] $4d^{10}$ $5s^2$
Specific gravity	8.96	7.133	11.35	8.65

Table 2: Available concentration of metals (mg kg^{-1}) in fly ash, obtained by extracting with various reagents by different workers. The concentrations are compared to soluble threshold limit concentration.

Metals (mg kg^{-1})	Extractant used				STLC	
	Deionized water/Distilled water	0.05M DTPA-$CaCl_2$	1N HNO_3	Mehlic h I	Acetic Acid+ NaOH (TCLP)	
Sample: solution (w/v)	1:10	1:2	1:10	1:4	1:20	1:20
pH	5.8 –6.3	7.3	3.5 - 4	2.5	4.93	4.93
Period of extraction	6h	2h	2h	4h	18h	18h
Fe	0.01-1.7	8.2 –21.9	22.8	161	5.4 - 8.2	NA
B	0.1 –1.1	25	4	3	2.9	NA
Mn	0.03-0.13	0.41–3.5	23.1	19	2.1	NA
Co	0.02-0.06	<0.05	1.9	1.07	0.11	80
Cu	0.01- 0.02	0.85–6.2	4.5	11	0.48	25
Zn	0.02-4.8	1.2	7.4	4.6	2.4	250
Ni	0.01	0.09- 0.56	1.4	2.3	0.25	20
Se	0.1	1.1	0.84	0.35	0.12	0.3 - 1
As	0.1	0.6 - 4.7	0.91	16	0.29	0.3 - 5
Cd	0.01–0.71	0.14-0.34	0.14	0.12	0.02	0.3 - 1
Cr	0.03–0.86	0.94–2.1	1.6	1.3	0.05	5
Hg	BDL	0.04	0.07	0.07	0.08	0.2
Pb	0.07-1.10	0.38–1.8	2.2	<0.1	0.004	0.3 - 5
Ba	0.04	0.2-15	0.2-15	0.63	1.7	100
Ag	BDL	NA	NA	<0.25	BDL	5

3. Properties of fly ash

Szponder and Trybalski 2009a [33] reported that fly ash is inorganic residue from coal combustion in power boilers. FA has a high morphological, phase and chemical composition diversity depending on the use of different methods of combustion (conventional and fluidized bed boilers), the composition of fuels (bituminous coal, lignite, and biomass), a high dispersion of minerals in fuels and the dynamics of thermal processes. There are three basic groups of FA – silicate fly ash (sFA), aluminium fly ash (aFA) and calcium fly ash (cFA).

Physical Properties

Generally, fly ash is light gray to black in colour (depending on the amount of unburned carbon and organic matter residue). Some time it can be light brown to dark brown in colour (mostly from brown coal and biomass combustion). FA (fly ash) consists of fine, glassy particles, which range in particle size from 0.01 to 100 µm. Their composition is dominated by spherical grains (mineral or amorphous), either solid (pirospheres), hallow (cenospheres) or filled with smaller amorphous particles (plerospheres). These grains appear individually, or in the form of aggregates. In addition, there is a large group of irregular, highly porous, rounded or sharp-edged grains in FA (carbon residue and soot). FA has low bulk density, high surface area and light texture (Ahmaruzzaman, 2010) [3].

Table 3: Physical properties of fly ash

	Fly ash
Particle diameter	0.01 - 100 µm
Texture	Silt loam
Specific surface area	2500 to 4000 cm^{2}g^{-1}
Specific gravity	1.6 - 2.6 g cm^{-3}
Bulk density	0.9 - 1.3 g cm^{-3}
Water holding capacity	40 –60 %
Color	White/yellow-orange/black

Source: El-Mogazi *et al.*, 1988 [13].

Chemical Properties

The major chemical components of FA include oxides of silicon, aluminum, iron and calcium (95-99%). In addition, FA contains secondary components in the form of oxides of Ti, P, Mg, S, Na and K (0.5-3.5%) and unburned carbon (roasting loss). This waste also contains trace elements like Mn, B, Ba, Cu, Sr, Ni, Cr, Zn, Cd, Co, Mo, V, Se, Pb, As, etc. (0.1-0.3%) and radioactive elements like 40K, 226Ra i 232Th. The pH of FA is usually in the range from 4.5 to 12.0, depending on the sulfur content in coal and on combustion and desulphurization technology. Wastes in which the ratio of Ca to S is lower than 2.5 are acidic in nature, and those with a ratio higher than 2.5 are alkaline (Szponder and Trybalski 2009b) [34], (Pandey and Singh 2010) [27], (Feng 2006) [14].

Mineralogical Properties

In its mineralogical structure, FA contains primarily amorphous substances in the form of silicon-aluminium glass (80%). It contains also a few crystalline phases such as gypsum ($CaSO_4.2H_2O$), mullite ($3Al_2O_3.2SiO_2$), quartz (SiO_2), magnetite (Fe_3O_4), anhydrite ($CaSO_4$), ettringete ($3CaO.\ Al_2O_33CaSO_4.32H_2O$), opaline SiO_2, hematite (Fe_2O_3), lime (CaO), chlorite, feldspar, and spinel ($FeAl_2O_4$) (Ahmaruzzaman, 2010) [3], (Szponder and Trybalski, 2009b) [34].

Classification of fly ash

Coal combustion based power plants generated fly ash typically falls within the American Society for Testing and Materials (ASTM) fly ash classes C and F (Page *et al.*, 1979) [26]. The difference between Class F and Class C fly ash is given in Table 4.

Table 4: Differences between class F and class C fly ash.

Class F	Class C
Class F fly ash produces by burning of harder anthracite and bituminous coal.	Class C fly ash produces by burning of younger lignite or sub bituminous coal.
This class of fly ash contains less than 20% of lime.	This class of fly ash contains more than 20% of lime.
Alkali and sulfate contents are generally lower in class F.	Alkali and sulfate contents are generally higher in class C.
The quantities of Si, Fe & K oxides are higher in Class F.	The quantities of Si, Fe & K oxides are higher in class C.
The CaO, MgO, SO_3 & Na_2O quantities are lower in Class F.	While CaO, MgO, SO_3 & Na_2O quantities are higher in Class C
Class F fly ash has been rarely cemetitious when mixed with water.	Class C fly ash usually has cementitious properties in addition to pozzolanic properties

Generation of fly ash

In thermal power plant, Fly ash is generated when coal is fed to a series of mills that pulverize the coal to a very fine powder. This powder is then fed into a boiler which combusts the coal to produce heat. In general, three types of coal-fired boiler furnaces used in the thermal power plant. They are referred to as dry-bottom boilers, wet-bottom boilers, and cyclone furnaces. In them dry-bottom furnace is most commonly used (Oram 2009) [25].

Fly ash is generated by burning of pulverized coal in the boiler furnace and carried by flue gas, passed in super heater from there it goes to the reheater, economizer and air pre-heater one by one. Finally reached in to electrostatic precipitator. The path followed by flue gas is given in Fig. 3

Furnace
↓
Superheater
↓
Reheater
↓
Economizer
↓
Air pre
↓
Heater
↓
Electrostatic precipitator
↓
Fly ash

Fig 3: Pathway of fly ash generation

Table 5: Ranges in elemental composition of fly ash, soil, farm yard manure, plants in India and worldwide along with maximum allowable concentrations (MAC) for trace metals in soils and plants

Metals (mg kg^{-1})	Soil[a]	Fly ah				FYM[d]	MAC	Plants[f]	MAC for plants[f]
		Range[a]	India[b]		Worldwide				
			Total	Available					
Fe	7-550	10-290	68	10-15	0.31-36.6	3040	-	-	-
Al	40 - 300	1-17.3	4.8-312	0.1-822	0.5-108.5	-	-	-	-
Ca	7-500	1.1-222	0.029-34	460-4400	1.84-86.4	-	-	-	-
Mg	0.6-6	0.4-76	0.017-1.4	0.8-179	0.02-11.5	-	-	-	-
K	0.4-30	1.5-35	10.8	32-8900	24.5	-	-	-	-
B	2-100	10-618	17-38	0.5–3	0.4-50	52	-	-	-
Mn	100-4000	58-3000	500-739	0.9–19	100-679	53.1	1500-3000	20-1000	300-500
P	0.05-2	0.4–8	10.8	6.2	2.1	24	-	-	-
Co	1-40	7-520	21.1-58	0.05–0.15	7-26	0.85	20-50	0.02-1	15-50
Cu	2-100	14-2800	40-80	0.5–11	19-57	44.1	60-150	5-20	2 –100
Zn	10 - 300	10-3500	52–203	0.4–4.6	39-167	24.7	100-300	1-400	100-400
Mo	0.2-5.0	7- 160	4.0 - 33.3	0.1–0.6	3-4.2	4.5	4-40	0.03-5	10-50
Ni	10 - 1000	6-4300	50-204.8	0.15 –3	15-88	39.4	20-60	0.02-5	10-100
Se	0.1-2	0.2-134	0.6-2.6	0.1–0.4	8-10	0.56	3–10	0.001-2	5-30
As	0.1-40	2-6300	1-4	0.1-16	20.4	0.62	15-20	0.02-7	5–20
Cd	0.01–0.5	0.7-130	5-43	0.03–0.07	0.03-1.3	<0.002	1-5	0.1–2.4	5-30
Cr	5-3000	10-1000	38.2-330	0.3–1.3	15-148	<0.002	3–25	0.03-14	5–30
Hg	Up to 1	0.02 - 1.0	BDL	BDL	0.18-0.4	<0.001	0.5 - 5	0.005 –0.17	1 - 3
Pb	2-100	3-5000	20-70	<0.1	16-97	<0.002	20-300	0.2-20	30-300

FYM: farmyard manure; BDL: below detection limit,

Source: ([a]Page *et. al.*, 1979) [26], ([b]Pandey *et. al.*, 2009) [28]., ([d] Tripathi *et. al.*, 2004) [35]., ([f]Alloway, 2013) [4].

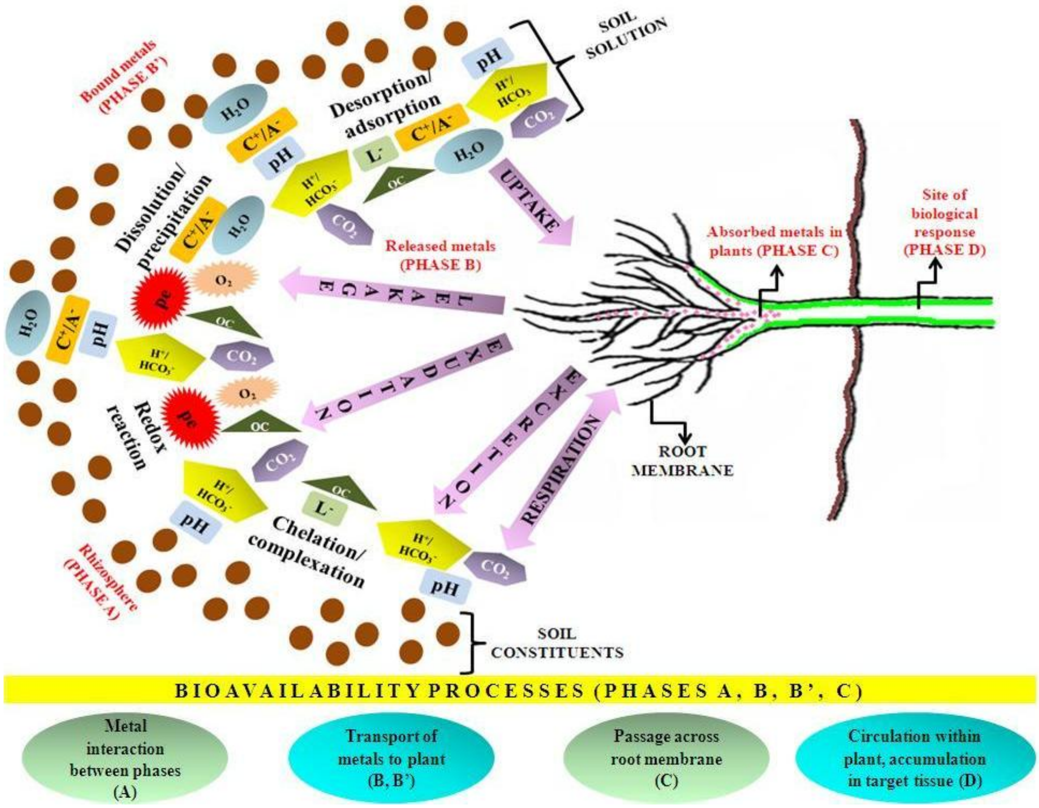

Fig 4: Bioavailability processes for metals in the rhizosphere of plants, emphasizing the mechanisms in soil solution interface. Legends: OC = organic carbon; C+ = cation; A+ = anion; L- = ligand; pe = redox potential. Modified from ***Source*:** Adriano *et al*., 2004 [1].

4. Metal accumulation in soil and plants

Mishra, 2009 [24] studied accumulation of Al, Cu, Cr and Pb (Table 7) in soil and plant materials of rice grown in fly ash applied soil. Metal content in soil as well as plant materials increased with increase application of ash. Al, Cu, Cr and Pb contents (mg/Kg) were 9.9, 81.0, 89.0 and16.0 in soil with 20 tons/ha fly ash against 0.6, 5.0, 3.6 and 5.0 mg/kg respectively in control soil (with no ash application). In control field metals accumulation was negligible with 0.1 and 0.3 for Al, 1.3 and1.0 for Cu, 0.8 and1.6 for Cr and 3.0 and 2.0 for Pb respectively with no accumulation in grains. However, at 20 tons/ha application higher accumulation of all the four metals were recorded even in the grains. A bioconcentration factor of more than 1 indicates biomagnification. Only Al showed a BCF of more than 1 in grain only. A BCF of less than 1 for all other metals in plant samples indicate lower mobility of Cu, Cr and Pb. from soil to plants. In general the accumulation of metals was in the order of root>shoot>grain.

Table 6: Metal accumulation (mean ± SD in mg/Kg) in fly ash amended soil and plant materials of Rice during 120 d growth period (values in parentheses are of BCFs)

Elements	**Fly ash doses (%)**						***LSD***
(µg/0		**2**	**4**	**8**	**16**	**24**	
K	6622	8148	7186	6940	7475	7395	*ns*
Ca	16359 ab	17471 a	13701 b	14139 b	14854 ab	16917 a	$p < 0.05$
Mg	3325	3441	3296	3259	3324	3388	*ns*
Na	1155 d	1503 c	1390 cd	1692 c	2107 b	3095 a	$p < 0.01$
P	795	822	755	803	776	723	*ns*
S	1202 d	1396 d	1402 d	1796 c	2193 b	2771 a	$p < 0.01$
Fe	15847 b	17575 ab	17563 ab	17769 ab	18493 a	19788 a	$p < 0.05$
Mn	689	717	717	790	672	673	*ns*
Zn	77.72	76.86	73.06	76.10	81.95	79.63	*ns*
Cu	38.81	34.29	36.16	40.23	41.03	40.20	*ns*
B	26.77 e	47.88 d	58.33 d	80.41 c	123.47 b	222.20 a	$p < 0.01$
Mo	2.35 d	2.36 d	2.80 cd	3.51 c	5.78 b	15.23 a	$p < 0.01$
Ni	26.70	29.42	23.60	22.92	24.67	27.51	*ns*
Se	3.95	6.30	3.71	4.15	5.88	5.88	*ns*
Al	56	61	60	62	67	66	*ns*
Cd	0.734	0.606	0.534	0.530	0.623	0.567	*ns*
Cr	30.57	33.91	29.77	25.75	35.75	42.90	*ns*
Pb	22.15	22.11	21.92	21.46	21.85	22.92	*ns*

***Source*:** Cafer, *et al*., 2015 [6].

Table 7: The effect of fly ash on heavy metal content of the soil

Metal	Material	Control	10 ton/ha	20 ton/ha
Aluminium	Soil	0.6 ±0.16	3.7 ±0.95	9.9 ±1.45
	Root	0.1 ±0.03 (0.17)	2.6±0.56 (0.70)	30.7±2.5 (3.1)
	Shoot	0.3±0.025 (0.5)	2.6±0.56 (0.92)	14.3±2.5(1.4)
	Grain	-	-	50.0±6.5 (5.0)
Copper	Soil	5.1±1.4	4.4±0.95	81.6±7.5
	Root	1.3±0.05 (0.26)	3.6±0.79(0.82)	67.3±6.9 ((0.83)
	Shoot	1.1±0.005 (0.2)	1.9±0.23 (0.45)	52.3±4.7 (0.64)
	Grain	-	0.5±0.002 (0.11)	5.2±0.007 (0.06)
Chromium	Soil	3.6±0.8	9.5±1.59	89.5±10.5
	Root	0.8±0.19 (0.24)	3.6±0.85 (0.38)	56.3±7.5 (0.63)
	Shoot	1.6±0.06 (0.48)	2.7±0.85(0.28)	36.2±5.5(0.4)
	Grain	-	-	15.3±1.96(0.17)
Lead	Soil	5.1±1.3	10.6 ±1.9	16.1±2.5
	Root	3.2±0.07 (0.6)	8.5±1.43(0.8)	14.4±2.59 (0.875)
	Shoot	2.1±0.006(0.4)	6.4±1.03(0.6)	12.3±2.59 (0.75)
	Grain	-	1.0±0.005(0.1)	8.2±1.75(0.5)

Source: Mishra, 2009 [24].

Cafer, *et al*., 2015 [6]. Evaluated the effects of fly ashes on soil and corn plants (Tables 6 and 9). Results shows that fly ash treatments increased B, Na, Mg, P, S, K, Ca, Al, Cr, Mn, Fe, Cu, Zn, Se and Mo contents of soil. B ($P < 0.01$), Na ($P < 0.01$), S ($P < 0.01$), Ca ($P < 0.05$), Fe ($P < 0.05$) and Mo ($P < 0.01$) contents significantly increased with increasing fly ash doses. Increasing element contents are directly related to fly ash treatment doses. The highest increase was observed in pots containing 24% fly ash.

Table 9 shows that fly ash treatments also increased B, Na, Mg, P, S, Ca, Al, Fe, Cu, Se and Mo contents of plant roots. B ($P < 0.01$), Na ($P < 0.01$), Mg ($P < 0.01$), S ($P < 0.01$), Cu ($P < 0.01$), Cd ($P < 0.01$) and Mo ($P < 0.01$) contents significantly increased and increasing element contents were directly related to fly ash treatment doses. B, Na, P, S, Ca, Mn, Cu, Zn, Cd and Mo also increased with fly ash treatments on above-ground parts of plant.

Table 8: DTPA Extractable Heavy Metals in soil (0-15 cm) after crop harvest

Treatment	Pb (mg kg^{-1})	Cd (mg kg^{-1})	Cr (mg kg^{-1})
Control	0.08^{bc}	0.03	0.23^{ab}
Lime (L)	0.04^{c}	0.01	0.16^{cd}
Gypsum (G)	0.16^{a}	0.03	0.26^{a}
Fly ash (FA)	0.18^{a}	0.03	0.22^{ab}
L+FYM	0.04^{c}	0.01	0.19^{bcd}
G+FYM	0.18^{a}	0.03	0.23^{ab}
FA+FYM	0.18^{a}	0.03	0.23^{ab}
L+FA+FYM	0.08^{bc}	0.02	0.20^{bc}
CD(0.05)	0.04	0.01	0.05
CV (%)	10.55	14.70	12.64

Source: Chandrakar, *et al*., 2015 [9].

Table 9: The effect of fly ash on heavy metal content of plant roots

Elements	Fly ash doses (%)						
(μg/₀)		2	4	8	16	24	*LSD*
K	34616	32871	32719	34181	35896	29823	*ns*
Ca	6355 b	5555 b	5484 b	6392 b	5836 b	12950 a	$p < 0.01$
Mg	2395 b	2269 b	2236 b	2300 b	2262 b	2897 a	$p < 0.01$
Na	7493 bc	5711 cd	4988 d	6488 bcd	8022 b	14474 a	$p < 0.01$
P	2562 b	2736 b	2897 b	2469 b	2610 b	2255 a	ns
S	3869 d	4240 cd	4546 c	4758 c	5658 b	7155 a	$p < 0.01$
Fe	2723	2999	3255	2584	2210	3308	*ns*
Mn	97	97	104	79	57	94	*ns*
Zn	58.02	47.66	44.56	52.56	50.20	56.81	*ns*
Cu	10.72 b	10.47 b	11.06 b	10.78 b	10.02 b	16.01 a	$p < 0.01$
B	4.12 b	17.96 b	7.91 b	22.67 b	69.08 b	261.10 a	$p < 0.01$
Mo	0.88 e	1.23 d	1.36 d	1.61 c	1.98 b	2.74 a	$p < 0.01$
Ni	13.52	16.94	11.18	13.97	9.62	12.40	*ns*
Se	0.24	1.11	0.12	0.69	0.51	1.45	*ns*
Al	497	620	608	552	512	599	*ns*
Cd	0.227 bc	0.180 c	0.189 c	0.258 bc	0.292 b	0.415 a	$p < 0.01$
Cr	5.11	5.86	5.38	4.70	4.06	4.92	*ns*
Pb	1.09	1.45	1.77	0.67	0.60	1.62	*ns*

Source: Cafer, *et al*., 2015 [6].

Conclusion

Environmental pollution generated by fly ash and industrial effluents is of special concern because they are posing a significant danger to human health and environment. Fly ash can be used in agriculture, because it has special physical and chemical properties. FA has a unique structure and contains almost all the nutrients necessary for proper plants growth and development. First of all, fly ash is used as a mineral fertilizer which improves the properties of soils. It can also be applied as an agent, which increases plant growth and amount of the obtained yields. Although fly ash application in agriculture has many benefits, there are some disadvantages connected with this application cause heavy metals and radionuclides contamination of soils and surface waters, soil salinity. In addition, there is also risk associated with lack of information on the long-term effects of fly ash application on soil quality and environment. Huge application should not be recommended for growing crops, it is desirable to monitor the heavy metal content regularly in plant components to ensure that it does not exceed the threshold value of human consumption. Therefore, it is necessary to continue research on this topic to clarify the effects of the fly ash addition to the soil on agricultural production and the environment.

5. References

1. Adriano DC, Wenzel WW, Vangronsveld J, Bolan NS. Role of assisted natural remediation in environmental cleanup. – Geoderma. 2004; 122:121-142.
2. Ahalya N, Kanamadi RD, Ramachandra TV. Biosorption of chromium (VI) from aqueous solutions by the husk of Bengal gram (Cicer arientinum). Electron J Biotechnol. 2005; 8:45-49.
3. Ahmaruzzaman M. A review on the utilization of fly ash. Progress in Energy and Combustion Science. 2010; 36:327-363.
4. Alloway BJ. Heavy Metals in Soils: Trace Metals and Metalloids in Soils and their Bioavailability. - Springer, Netherlands. 2013; 20-26.
5. Benito Y, Ruiz M, Cosmen P, Merino JL. Study of leachates obtained from the disposal of fly ash from PFBC and AFBC processes. Chem. Eng. J. 2001; 84:167.
6. Cafer Türkmen, Uray Mücella Müftüoğlu, İsmet Uysalb. Effect of Fly Ash Applications on Heavy Metal Contents of Soil and Corn Plant (Zea mays L.). Turkish Journal of agricultural and natural sciences. 2015; 2(1):92-98.
7. CEA (Central Electricity Authority). Annual Report on Fly-ash utilization, Report on Fly Ash Generation at Coal/Lignite Based Thermal Power Stations and its Utilization in the Country for the Year 2011–12, New Delhi.
8. Chandra A, Chandra H. Impact of Indian and imported coal on Indian Thermal Power Plants. J. Sci. Ind. Res. 2005; 63:156.
9. Chandrakar Jena D, Dash AK, Jena SN, Panda N. Effect of fly ash on soil physico-chemical properties and maize yield in acidic Alfisol. International Research Journal of Natural and Applied Sciences. 2015; 2(7):48-62.
10. Choi S K, Lee S, Song Y K, Moon H S. Leaching characteristics of selected Korean fly ashes and its implications for the groundwater composition near the ash mound. Fuel. 2002; 81:1080.
11. Dhadse S, Kumari P, Bhagia I J. Fly ash characterization, utilization and Government initiatives in India- A review. J. Sci. Ind. Res. 2008; 67:11.
12. Duruibe JO, Ogwuegbu MDC Egwurugwu JN. Heavy metal pollution and human biotoxic effects. Int. J. Phys. Sci. 2007; 2(5):112-118.
13. El-Mogazi D, Lisk DJ, Weinstein H. A review of physical, chemical, and biological properties of fly ash- Science. 1988; 74:1-37.
14. Feng YJ, Li F, Wang XL, Liu X M, Zhang L N. Principal Chemical Properties of Artificial Soil Composed of Fly Ash and Furfural Residue. Pedosphere. 2006; 16(5):668-672.
15. Ferner DJ. Toxicity of heavy metals, eMed. J. 2001; 2(5):1-11.
16. Gupta VK, Gupta M, Sharma S. Process development for the removal of lead and chromium from aqueous solution using red mud –an aluminum industry waste, Water Res. 2001; 35(5):1125-1134.
17. Hawkes JS. Heavy Metals. J. chem. Edu. 1997; 74(11):1374-1381.
18. Hutton M, Symon C. The Quantities of Cadmium, Lead, Mercury and Arsenic Entering the U.K. Environment from Human Activities. Sci. Total Environ. 1986; 57:129-150.
19. Iyer R. The surface chemistry of leaching coal fly ash. J. Hazard. Material. 2002; B93:321.
20. Kalai H, Canil R. Elimination of Essential (Cu, Zn) and Non- Essential (Cd, Pb) Metals From Tissue of Freshwater Fish Tilapia Zilli. Turkish Journal of Zoology. 2000; 24:429-436.
21. Kumar V, Anandkumar R, Mathur M. Management of fly ash in India: a perspective. In: Proc 3rd Int.2003. Conf. on Fly Ash Utilization and Disposal, vol. 1 (Central Board of Irrigation).
22. Mehara A, Farago ME, Banerjee DK. Impact of fly ash from coal fired power stations in Delhi, with particular reference to metal contamination. Environ. Monit. Assess. 1998; 50:15.
23. Mehmet EA, Sukru D, Celalettin O, Mustafa K., Heavy metal adsorption by modified oak sawdust, J. of Hazard. Mater, In Press mineral processing. 2006; 4-6.
24. Mishra PC. Heavy metal accumulation in crops grown in fly ash amended soil. The Ecoscane. Special issue. 2009; 1:23-26.
25. Oram P. Flow behaviour of fly ash slurry. B. Tech thesis, National Institute of Technology, Rourkela, Orissa. Ostrava. 2009; 121-127.
26. Page AL, Elseewi AA, Straughan IR. Physical and chemical properties of flyash from coal-fired power plants with special reference to environmental impacts. Residue Reviews. 1979; 71:83-120.
27. Pandey VC, Singh N. Impact of fly ash incorporation in soil systems. Agriculture, Ecosystems and Environment. 2010; 136:16-27.
28. Pandey VC, Abhilash PC, Singh N. In phytoremediation, phytomanagement and biomass production. Journal of Environmental Management. 2009; 90:2943-2958.
29. Piekos R, Paslawska S. Leaching characteristics of fluoride from coal fly ash. Fluoride. 1998; 31:188.
30. Ram LC, Masto RE. Fly ash for soil amelioration: A review on the influence of ash blending with inorganic and organic amendments. - Earth Science Reviews. 2014; 128:52-74.
31. Sankar TV, Zynudheen AA, Anandan R, Viswanathan Nair PG. Distribution of organo chemical and heavy metal residues in fish and shellfish from Calicut regions, Kerala, India, chemosphere. 2006; 65:583-590.
32. Sarkar HS. Fly ash: A Global player in utilization games of multifarious areas. In: Proc 3rd Int. Conf. fly Ash Utilization and Disposal. 2001; 1(Central Board of Irrigation and Power, fly ash).
33. Szponder DK, Trybalski K. Identification of the fly ash properties by using different methods and equipments (Określanie właściwości popiołów lotnych przy użyciu różnych metod i urządzeń badawczych). Górnictwo i Geoinżynieria. 2009a; 33(4):287-298.
34. Szponder DK, Trybalski K. Influence of fly ash structure, phase and diversification of chemical composition on their utilization process. 13th Conference on Environment and mineral processing: 4.–6. 2009b; Ostrava, Czech Republic, Part I, VSB – Technical University of Ostrava, Faculty of Mining and Geology,

Institut of Environmental Engineering; Ostrava, 121 – 127.

35. Tripathi RD, Vajpayee P, Singh N, Rai UN, Kumar A, Ali M B, Kumar B *et al*. Efficacy amendments of var for-ash toxicity ameliorat growth performance and metal composition of *Cassia siamea* Lamk. – Chemosphere. 2004; 54:1581-1588.
36. Young RA. Toxicity Profiles: Toxicity Summary for Cadmium Risk Assessment Information System, RAIS, University of Tennessee.2005; Accessed 20/10/2012, Available:http//rais.ornl.gov/tox/profiles/ cadmium.shtml.