Environment Protection Engineering

Vol. 16 1990 No. 2

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THERMAL POWER PLANT WASTES AND THEIR MANAGEMENT A CASE STUDY

The problem of pollution caused by coal-fired thermal power plants is still of importance because of the tremendous growth in use of electrical energy. The wastewaters of a typical coal fired power plant include cooling tower blowdown, wastewaters from ash handling system, boiler blowdown, regenerate wastes, floor and yard drains, coal pile run off, etc. The solid waste is the fly ash. The present communication deals with the physico-chemical characteristics of fly ash pond effluent and the fly ash and their effects on certain chemical properties of soil, seed germination pattern and the growth of some crop plants. The plants selected for these studies were as follows: for fly ash pond effluent – kidney bean (*Phaseolus aureus*) and lady's finger (*Abelmoschus esculentus*), whereas for the fly ash – wheat (*Triticum aestivum*) and pea (*Pisum sativum*).

1. INTRODUCTION

The problem of pollution caused by thermal power plants is still of importance because of the tremendous growth in use of electric energy and ultimately increase in coal fired electricity generating stations. The wastewaters discharged by a typical coal fired thermal power plant include cooling tower blowdown, wastewaters from ash handling system, boiler blowdown, regenerate wastes, floor and yard drains, coal pile run off, etc.

Impacts of power plants on striped bass (*Morono saxatilis*) living in the Hudson river have been studied by CAMPBELL et al. [5] who found it to be affected by thermal pollution. PRESTON [13] has found that discharge of heated water into river was harmful for fish and their eggs. SIMPSON [15] observed insignificant change in numbers of copepods after their passage through the cooling system. However, significant changes were recorded for copepod nauplii and bivalve larvae (decreased)

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and barnacle nauplii (increased). ENRIGHT [9] has demonstrated the destruction of a large number of planktonic larvae from the cooling systems of power plant.

The river water is generally used for flushing pulverised fuel ash for pumping it into the ash ponds. As the fly ash settles rapidly after entering the pond, the major dissolution of salts from the ash occurs. The concentrations obtained will, however, depend on the time of contact in the pipeline and in the ash pond and also on the quantity of the element present in the fly ash, its immediate availability and its rate of release (BROWN and RAY) [4]). DRESSEN et al. [8] have observed the elevation of the level of trace metals in the effluents of the power plants as compared to the intake waters. CHU et al. [6] have characterised the concentrations of heavy metals in ash pond effluents and leachates from coal fired plants. KEITH et al. [11] and CONNOR et al. [7] have reported the concentrations of As, Co, F, Sb, Se, Sr, U and V in soils and plants around power plants in Wyoming and New Mexico. Increased concentrations of Zn, Pb, Cu and Cd were monitored in the soil around the power plant (WIERSMA and CROCKETT [20]).

AJMAL et al. [1] have reported high concentrations of heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Pb and Zn) in the cooling tower and machine washing effluents from coal fired thermal power plant. Recently, AJMAL and KHAN [2] have studied the effects of cooling tower, machine washing and scrubber and bottom ash effluents on certain properties of soil, germination pattern and growth of pea (*Pisum sativum*) and wheat (*Triticum aestivum*) crop plants. They found that use of undiluted effluents caused 100% germination of both crops when they were irrigated with cooling tower effluent. The germination was restricted to 90% for the two crops when they were irrigated with the machine wasching effluents, to 80% and 70% for pea and wheat, respectively, when they were irrigated with scrubber and bottom ash effluent.

The present paper deals with the physico-chemical characteristics of fly ash pond effluent, the fly ash and their effects on certain chemical properties of soil, seed germination pattern and the growth of some crop plants. The plants selected for these studies were: kidney bean (*Phaseolus aureus*) and lady's finger (*Abelmoschus esculentus*) for fly ash pond effluent and wheat (*Triticum aestivum*) and pea (*Pisum sativum*) for the fly ash.

2. MATERIALS AND METHODS

The 530 MW Kasimpur coal fired thermal power plant is situated in the Aligarh district in Uttar Pradesh, 14 km away from the Aligarh Muslim University, on the bank of the Upper Ganga Canal. The power plant takes water from the canal and discharges its wastes into it. The fly ash pond effluent was collected from the fly ash pond by means of polyethylene containers and then its physico-chemical characteristics were determined using a Hach model DR-EL/4 spectrophotometer and the standard methods [16]. The fly ash was also collected near the coal fired plant. Its pH and electrical conductivity were measured and the content of organic matter and phosphorus determined. The concentrations of sodium, potassium, calcium, cadmium, copper, iron, manganese, lead and zinc in the fly ash pond effluent and fly ash were determined by atomic absorption spectrophotometer (IL751 Atomic Absorption/Emission spectrophotometer) (PARKER [12]).

IRRIGATION PATTERN OF THE FERTILE SOIL WITH FLY ASH POND EFFLUENT

Powdered soil (1 kg) was placed in each of earthen pots (15 cm diameter) and these were surface irrigated daily for 6 weeks with 150 cm^3 of solution containing different amounts of fly ash pond effluents in tap water (100%, 75%, 50%, 0%). Ten seeds of both kidney bean and lady's finger were sown in different pots after surface sterilization. One set of earthen pots was kept without seeds and irrigated as indicated above in order to monitor the effluent effects on the soil without plants. Each treatment was replicated four times. After six weeks of irrigation, the changes in the soil properties were determined using standard methods. The growth of the two crop plants irrigated with various concentrations of the effluent was also monitored. At the end of the sixth week, the shoot length and dry weight were determined.

IRRIGATION PATTERN OF DIFFERENT PERCENTAGES OF FLY ASH WITH TAP WATER

One kg of fly ash of different percentages, i.e. 100%, 80%, 60%, 20% and control (original soil), was kept in each of the earthen pots. Ten seeds of both wheat and pea were sown in each pot. The pots were daily irrigated for 6 weeks with 150 cm^3 of tap water. One set of the pots was filled with fly ash of the percentages indicated above and kept without seeds in order to monitor the fly ash effects on soil without plants. Each treatment was replicated four times. After six weeks of irrigation, the changes in the soil properties were determined using standard methods. The shoot length and dry weight of plants were measured after six weeks of irrigation.

3. RESULTS AND DISCUSSION

The physico-chemical properties of the fly ash pond effluent are presented in table 1. The effluent was found to be alkaline in nature (pH = 8.13). Considerable amounts of chlorides and sulphates were present in the effluent. The BOD and COD were found to be high in fly ash pond effluent. The concentrations of sodium, potassium, calcium, iron and zinc were considerably high, whereas cadmium, copper, manganese and lead were present in low concentrations in both fly ash pond effluent and fly ash.

The analiysis of the original soil has been given in table 2. The effects of undiluted and diluted fly ash pond effluents on certain properties of soil with and without

Table 1

Physico-chemical properties of fly ash pond effluent from Kasimpur coal fired thermal power plant, Aligarh

Properties	Fly ash pond effluent
Colour	greyish
Temperature (°C)	27
Total solids	1630
Suspended solids	996
Dissolved solids	542
Turbidity (FTU)	120
pH	8.13
Electrical conductivity (microohm$^{-1}\cdot$cm^{-1})	343.5
Dissolved oxygen (DO)	5.6
Biochemical oxygen demand (BOD)	35.0
Chemical oxygen demand (COD)	62.0
Ammonia-nitrogen	0.3
Nitrate-nitrogen	1.8
Nitrite-nitrogen	ND
Chloride	8.0
Sulphate	26.0
Total hardness	170.0
Total alkalinity	32.0
Total phosphorus	0.85
Sodium	9.57
Potassium	11.25
Calcium	27.0
Cadmium	0.04
Copper	0.07
Iron	7.95
Manganese	1.00
Lead	0.02
Zinc	2.08

All parameters except colour, pH, temperature, turbidity and electrical conductivity are expressed in mg/dm^3.

crops are given in tables 2 and 3. A slight upward change was noted in the cases of all parameters (pH, electrical conductivity, water-soluble salts, organic matter, Na, K, Ca, Cd, Cu, Fe, Mn, Pb and Zn) when the soil was irrigated with tap water (control).

A marked increase in the organic matter, phosphorus and ammonia-nitrogen contents of the pot soil has been observed, when it was irrigated with undiluted effluent followed by 75% and 50% effluent. The concentration of water-soluble salts increased with the increasing effluent concentration as did the electrical conductivity and the pH of the soil. Similarly, the highest increase in the total metal concentrations (sodium, potassium, calcium, cadmium, copper, iron, manganese, lead and zinc) was found, when the soil was supplemented with 100% effluent followed by 75% and 50% effluents.

The soil in the pots without plants irrigated with the various effluent concentrations was found to contain higher amounts of water-soluble salts, ammonia-nitrogen, phosphorus and total metal contents (Na, K, Ca, Cd, Cu, Fe, Mn, Pb and Zn) than the soils supporting the crop plants, showing thereby the uptake of the nutrients by the plants from the soils (RAJANNAN and OBLISAMY [14], THABARAJ et al. [17]. The uptake of the nutrients by the kidney bean plants were found to be greater than that of lady's finger plants.

The effects of different percentages of fly ash, i.e. 100%, 80%, 60%, 40%, 20% and control (original soil), on certain chemical properties of soil with and without crops have been shown in tables 4 and 5. A slight upward change was found in the case of pH, electrical conductivity, organic matter and total metals (sodium, potassium, calcium, iron and zinc) when the soils were irrigated with tap water. No significant change was observed in the contents of cadmium, copper, manganese and lead.

Evidently, the ash raised the concentrations of organic matter and total metals (cadmium, copper, iron, manganese, lead and zinc) in the different fly ash–soil mixtures after irrigation with tap water. The organic matter as well as metal contents in the fly ash were responsible for these changes. The pH and electrical conductivity of the irrigated fly ash–soil mixtures showed an upward trend, whereas sodium, potassium and calcium showed a downward trend after receiving irrigated water (tap water).

The organic matter and total metal contents were lower in the different fly ash–soil mixtures supporting crop plants as compared with those without crop plant after irrigation with tap water, indicating the uptake of metals by the crop plants from the fly ash–soil mixtures. It is clear from the data given in table 5 that the concentrations of metals in the fly ash–soil mixtures supporting pea plants were lower as compared to the fly ash–soil mixtures supporting wheat plants, showing thereby that pea plant took up more metals from the fly ash–soil mixtures than the wheat plants during their growth.

The effects of the various concentrations of the fly ash pond effluent on the germination and growth of the two crops, kidney bean (*Phaseolus aureaus*) and lady's finger (*Abelmoschus esculentus*), are presented in table 6. The germination in the pots irrigated with water (control) was 100% (all the seeds germinated) for both the crops. The germination of the kidney bean and lady's finger seeds was limited to 80% and 90% respectively, when 100% effluent was used for irrigation. The germination was also delayed in the soils irrigated with 100%, 75% and 50% effluent as compared to the soil irrigated with water (control). The delay in germination may be attributed to the considerable effluent salinity (THAKRE et al. [18]). The germination is known to be more susceptible to the soil-water relationship than to the growth at later stages when plants may cope with adverse conditions. During germination, seeds take up water which is used to hydrolyse the stored food materials and to activate the enzymes. As water absorption takes place by osmosis, the salt content outside the seeds may act as a limiting factor which may be the reason for the germination delay (TRUOG [19]).

Table 2

Effects of different dilution of fly ash pond effluent on certain chemical properties and total metals in pot soil without plants (data represent the mean of four replications)

Treatment	Water soluble salts (meq/kg of soil)	pH	Electrical conductivity (microohm^{-1} $\cdot$ cm^{-1})	Ammonia nitrogen (%)	Organic matter (%)	P (mg/kg of soil)	Na (mg/kg of soil)
Original soil	46.35	7.72	546.0	0.037	0.20	117.0	32.50
Control (water)	47.91	7.85	656.0	0.038	0.23	124.0	33.85
	(2.50)	(0.05)	(5.0)	(0.004)	(0.07)	(2.30)	(1.50)
50% effluent	59.30	8.20	729.0	0.042	0.29	147.0	52.80
	(2.10)	(0.15)	(10.0)	(0.005)	(0.03)	(4.25)	(1.70)
75% effluent	67.15	8.35	810.0	0.050	0.38	163.0	59.38
	(1.58)	(0.26)	(10.0)	(0.003)	(0.05)	(3.50)	(1.18)
100% effluent	74.60	8.74	870.0	0.060	0.48	178.0	71.66
	(2.20)	(0.22)	(15.0)	(0.006)	(0.06)	(2.50)	(1.60)

Treatment	K (mg/kg of soil)	Ca	Cd	Cu	Fe	Mn	Pb	Zn
Original soil	340.0	135.30	0.28	4.72	350.0	115.0	2.45	18.25
Control (water)	342.0	139.50	0.29	5.35	355.0	116.80	2.49	19.00
	(3.60)	(0.50)	(0.80)	(0.30)	(1.60)	(0.70)	(0.20)	(0.80)
50% effluent	360.0	150.50	0.64	6.75	373.0	133.60	2.55	24.00
	(2.40)	(0.75)	(0.05)	(0.10)	(2.50)	(0.50)	(0.60)	(0.69)
75% effluent	374.80	168.35	0.86	7.10	382.0	145.10	2.63	25.75
	(3.15)	(0.30)	(0.20)	(0.30)	(2.10)	(1.05)	(0.65)	(1.20)
100% effluent	392.60	189.32	1.18	7.74	400.56	158.36	2.90	28.50
	(2.86)	(0.45)	(0.4)	(0.60)	(1.80)	(0.60)	(0.50)	(0.90)

Standard deviations are given in parentheses.

The 100% fly ash pond effluent reduced the growth of both crop plants; however, the shoot length of both the crops were found to be maximum in pots irrigated with 75% effluent. BERNSTEIN and HAYWARD [3] have pointed out that the increased accumulation of soluble salts and hence the increased osmotic pressure are related to the degree of growth inhibition. HAYWARD and WADLEIGH [10] have also supported the view that reduced water availability induced by high osmotic pressure of the root medium was the factor restricting the growth of the plants. The uptake of metals by the plants may be other reason for the growth inhibition noted in this study.

Table 3

Effects of different dilutions of fly ash pond effluent on certain chemical properties and total metals in pot soil supporting different crops (data represent the mean of four replications)

Treatment	Water soluble salts (meq/kg)		pH		Electrical conductivity (microohm$^{-1}\cdot$cm^{-1})	
	KBC	LFC	KBC	LFC	KBC	LFC
Control (water)	45.30	44.36	7.75	7.80	610.0	618.0
	(1.50)	(1.30)	(0.10)	(0.15)	(10.0)	(10.0)
50% effluent	53.16	55.40	8.00	0.10	689.0	696.0
	(2.10)	(1.80)	(0.15)	(0.05)	(5.0)	(10.0)
75% effluent	61.52	63.70	8.20	8.20	755.0	770.0
	(1.70)	(1.90)	(0.15)	(0.10)	(15.0)	(15.0)
100% effluent	69.25	70.65	8.55	8.45	825.0	890.0
	(2.10)	(2.15)	(0.20)	(0.25)	(10.0)	(15.0)

Treatment	Ammonia nitrogen (%)		Organic matter (%)		P (mg/kg of soil)		Na (mg/kg of soil)	
	KBC	LFC	KBC	LFC	KBC	LFC	KBC	LFC
Control (water)	0.035	0.035	0.20	0.20	118.0	120.0	27.30	27.80
	(0.005)	(0.003)	(0.06)	(0.07)	(1.50)	(1.70)	(1.10)	(1.15)
50% effluent	0.040	0.39	0.24	0.26	139.0	142.0	45.0	46.50
	(0.006)	(0.008)	(0.03)	(0.02)	(1.20)	(1.65)	(0.80)	(1.10)
75% effluent	0.046	0.047	0.33	0.35	155.0	156.8	51.45	53.0
	(0.002)	(0.005	(0.04)	(0.06)	(1.70)	(1.90)	(1.18)	(0.95)
100% effluent	0.05	0.056	0.42	0.43	171.5	173.0	65.60	67.0
	(0.006)	(0.005)	(0.09)	(0.05)	(2.15)	(1.60)	(1.30)	(1.20)

Treatment	K (mg/kg of soil)		Ca (mg/kg of soil)		Cd (mg/kg of soil)		Cu (mg/kg of soil)	
	KBC	LFC	KBC	LFC	KBC	LFC	KBC	LFC
Control (water)	328.0	334.0	124.0	125.50	0.25	0.26	4.80	4.10
	(1.90)	(2.30)	(0.80)	0.85	(0.06)	(0.04)	(0.12)	(0.18)
50% effluent	345.0	347.0	139.40	141.60	0.58	0.60	5.45	5.90
	(2.60)	(1.10)	(0.80)	(0.03)	(0.05)	(0.15)	(0.31)	
75% effluent	361.0	366.0	157.52	159.0	0.82	0.84	5.20	5.66
	(1.65)	(1.30)	(0.65)	(0.60)	(0.10)	(0.25)	(0.28)	(0.50)
100% effluent	379.0	382.0	180.36	183.0	1.10	1.13	5.75	6.00
	(2.50)	(2.15)	(0.90)	(1.10)	(0.05)	(0.06)	(0.34)	(0.33)

Table 3 continued

Treatment	Fe (mg/kg of soil)		Mn (mg/kg of soil)		Pb (mg/kg of soil)		Zn (mg/kg of soil)	
	KBC	LFC	KBC	LFC	KBC	LFC	KBC	LFC
Control (water)	349.0 (2.05)	350.0 (2.10)	114.0 (1.20)	115.8 (1.60)	2.38 (0.08)	2.40 (0.21)	18.0 (0.30)	18.4 (0.42)
50% effluent	365.0 (1.75)	358.0 (1.60)	129.40 (0.80)	130.65 (1.25)	2.45 (0.09)	2.46 (0.31)	22.6 (0.36)	22.9 (0.56)
75% effluent	371.0 (1.80)	374.0 (1.40)	139.75 (1.30)	141.20 (1.15)	2.51 (0.20)	2.55 (0.06)	23.50 (0.44)	23.50 (0.40)
100% effluent	392.0 (2.10)	394.0 (2.30)	153.0 (2.20)	155.10 (1.90)	2.77 (0.30)	2.80 (0.12)	27.20 (1.00)	27.70 (0.70)

KBC – kidney bean crop, LFC – lady's finger crop. Standard deviations are given in parentheses.

Table 4

Effects of different percentages of fly ash on certain chemical properties of pot soil without plants

Parameters	Fly ash	% Fly ash mixed with soil					
		Control (soil)	20%	40%	60%	80%	100%
pH	8.20	7.80 (0.05)	8.00 (0.04)	8.25 (0.06)	8.40 (0.05)	8.50 (0.06)	8.80 (0.07)
Electrical conductivity ($\mu ohm^{-1} \cdot cm^{-1}$)	990.0	790.0 (1.22)	1052.0 (1.50)	1110.0 (1.30)	1180.0 (1.21)	1235.0 (1.40)	1360.0 (1.60)
Organic matter (%)	2.99	0.038 (0.005)	0.413 (0.007)	0.982 (0.006)	1.293 (0.009)	1.425 (0.007)	2.068 (0.009)
Phosphorus (mg/kg)	55.0	119.50 (0.70)	129.50 (0.50)	136.50 (0.50)	150.50 (0.80)	161.00 (0.70)	174.50 (0.60)
Sodium (mg/kg)	615.0 (2.90)	220.00 (2.70)	200.50 (3.00)	262.50 (2.10)	306.25 (2.70)	437.50 (2.50)	515.30
Potassium (mg/kg)	4475.0	804.00 (4.20)	775.00 (4.00)	1273.50 (6.00)	1554.50 (8.00)	2522.50 (7.50)	3779.50 (9.50)
Calcium (mg/kg)	42.47	62.00 (1.30)	55.30 (0.90)	68.00 (1.20)	80.62 (1.50)	88.76 (2.00)	98.40 (2.10)
Cadmium (mg/kg)	0.45	0.40 (0.01)	0.62 (0.01)	0.66 (0.02)	0.68 (0.01)	0.70 (0.03)	0.75 (0.01)
Copper (mg/kg)	16.20	8.42 (0.05)	9.65 (0.02)	11.22 (0.01)	12.25 (0.01)	14.50 (0.02)	18.32 (0.02)
Iron (mg/kg)	927.0	800.00 (4.50)	987.00 (2.60)	1120.00 (3.60)	1347.20 (4.80)	1490.50 (5.00)	1678.45 (6.60)
Manganese (mg/kg)	24.00	28.00 (0.10	29.55 (0.20)	32.05 (0.30)	34.20 (0.15)	35.00 (0.14)	37.02 (0.20)
Lead (mg/kg)	8.30	3.57 (0.03)	4.20 (0.02)	5.00 (0.01)	7.01 (0.01)	9.00 (0.02)	10.75 (0.01)
Zinc (mg/kg)	137.50	60.00 (2.00)	82.00 (1.70)	121.25 (1.30)	146.25 (1.20)	180.75 (1.60)	202.50 (1.55)

Data represent the mean of four replications. Standard deviations are given in parentheses.

Table 5

Effects of different percentages of fly ash on certain chemical properties of pot soil supporting plants

% Fly ash mixed with soil	pH		Electrical conductivity ($\mu ohm^{-1} \cdot cm^{-1}$)		Organic matter (%)		Phosphorus (mg/kg)		Sodium (mg/kg)	
	Wheat	Pea	Wheat	Pea	Wheat	Pea	Wheat	Pea	Wheat	Pea
Control (soil)	7.50 (0.02)	7.40 (0.02)	850.0 (2.10)	800.0 (2.00)	0.025 (0.002)	0.018 (0.001)	110.00 (0.90)	106.00 (1.00)	195.25 (1.40)	190.00 (1.30)
20% fly ash	7.90 (0.01)	7.75 (0.02)	970.0 (3.00)	902.0 (3.20)	0.336 (0.001)	0.320 (0.001)	115.70 (1.00)	110.00 (1.20)	190.75 (1.25)	183.40 (1.20)
40% fly ash	8.00 (0.03)	7.90 (0.01)	1005.0 (1.70)	995.0 (1.50)	0.775 (0.001)	0.750 (0.002)	126.00 (1.10)	118.20 (1.00)	255.40 (1.30)	252.00 (1.20)
60% fly ash	8.20 (0.01)	8.00 (0.03)	1075.0 (1.28)	1000.0 (1.20)	1.020 (0.003)	1.000 (0.002)	138.20 (1.20)	128.30 (1.10)	290.20 (1.30)	281.60 (1.25)
80% fly ash	8.30 (0.02)	8.10 (0.02)	1100.0 (4.00)	1037.0 (4.50)	1.210 (0.002)	1.189 (0.003)	153.00 (1.00)	142.50 (1.30)	411.00 (1.50)	404.80 (1.40)
100% fly ash	8.50 (0.01)	8.25 (0.02)	1190.0 (3.25)	1120.0 (2.30)	1.805 (0.001)	1.780 (0.002)	161.50 (1.30)	153.40 (1.20)	483.70 (1.50)	475.20 (1.30)

% Fly ash mixed with soil	Potassium (mg/kg)		Calcium (mg/kg)		Cadmium (mg/kg)		Copper (mg/kg)	
	Wheat	Pea	Wheat	Pea	Wheat	Pea	Wheat	Pea
Control (soil)	789.80 (4.50)	780.00 (5.00)	57.00 (0.20)	54.30 (0.10)	0.35 (0.01)	0.34 (0.02)	7.20 (0.10)	7.00 (0.10)
20% fly ash	763.00 (5.80)	757.60 (4.70)	51.00 (0.22)	49.20 (0.20)	0.59 (0.02)	0.58 (0.03)	8.30 (0.12	7.85 (0.11)
40% fly ash	1256.00 (6.20)	1248.70 (6.90)	62.60 (0.20)	60.00 (0.25)	0.61 (0.01)	0.59 (0.02)	10.10 (0.10)	9.80 (0.10)
60% fly ash	1510.20 (6.20)	1500.00 (5.90)	76.20 (0.21)	72.10 (0.20)	0.63 (0.01)	0.60 (0.02)	11.20 (0.12)	10.75 (0.12)
80% fly ash	2490.00 (7.00)	2478.30 (6.30)	81.25 (0.23)	78.00 (0.23)	0.67 (0.02)	0.65 (0.02)	13.00 (0.13)	12.70 (0.12)
100% fly ash	37702.25 (7.50)	37695.00 (8.60)	90.50 (0.25)	86.60 (0.20)	0.71 (0.02)	0.70 (0.01)	16.90 (0.10)	16.00 (0.13)

Table 5 continued

% Fly ash mixed with soil	Iron (mg/kg)		Manganese (mg/kg)		Lead (mg/kg)		Zinc (mg/kg)	
	Wheat	Pea	Wheat	Pea	Wheat	Pea	Wheat	Pea
Control (soil)	979.00 (3.50)	970.00 (3.40)	26.50 (1.30)	25.26 (1.30)	2.80 (0.01)	2.50 (0.01)	55.00 (2.10)	53.00 (1.80)
20% fly ash	980.00 (2.90)	975.40 (2.10)	28.10 (1.20)	26.55 (1.20)	3.66 (0.02)	3.00 (0.03)	69.70 (2.00)	65.67 (1.90)
40% fly ash	1100.00 (5.90)	1092.00 (5.80)	30.00 (1.30)	28.00 (1.02)	4.10 (0.02)	3.75 (2.02)	109.00 (2.00)	101.74 (2.10)
60% fly ash	1311.00 (6.20)	1295.60 (6.50)	33.10 (1.25)	31.70 (1.21)	6.00 (0.02)	5.50 (0.03)	115.00 (2.30)	110.50 (2.00)
80% fly ash	1470.00 (6.50)	1442.20 (7.00)	33.70 (1.22)	32.00 (1.00)	8.02 (0.03)	7.46 (0.01)	130.00 (2.40)	120.00 (2.30)
100% fly ash	1659.20 (7.20)	1621.00 (6.80)	36.50 (1.22)	34.25 (1.31)	10.00 (0.02)	9.80 (0.03)	180.74 (2.50)	172.35 (2.30)

Standard deviations are given in parentheses. Data represent the mean of four replications.

Table 6

Effects of different dilutions of fly ash pond effluent on germination and growth of kidney bean and lady's finger plants

Treatment	Average time taken for germination (days)		Germination (%)		Average shoot length (cm)		Average dry weight of plants (g)	
	KBS	LFS	KBS	LFS	KBP	LFP	KBP	LFP
Control (water)	6	5	100	100	8.0	7.6	1.28	1.31
50% effluent	7	6	100	100	11.0	10.2	1.38	1.65
75% effluent	7	7	100	100	13.7	12.4	1.70	1.82
100% effluent	8	8	80	90	0.6	10.1	1.35	1.58

KBS – kidney bean seeds, LFS – lady's finger seeds, KBP – kidney bean plant, LFP – lady's finger plants.

The effects of different percentages of fly ash on germination and growth of two crops, pea (*Pisum sativum*) and wheat (*Triticum aestivum*), have been given in table 7. The germination of wheat and pea seeds was delayed and restricted to 80% and 90%, respectively, when 100% fly ash was used as compared to the control (original soil). The 100% fly ash reduced the growth of both the crop plants. The shoot length and dry weight were found to be maximum in both the plants grown in the 60% fly ash (60:40:fly ash:soil mixtures) after irrigation with tap water.

Table 7

Effect of different percentages of fly ash on germination and growth of crop plants

% Fly ash mixed with soil	Average time taken for germination (days)		Germination (%)		Average shoot length (cm)		Average dry weight of plants (g)	
	Wheat	Pea	Wheat	Pea	Wheat	Pea	Wheat	Pea
Control (soil)	6	6	100	100	27.6	18.2	0.28	0.30
20% fly ash	7	7	100	100	19.2	15.0	0.19	0.38
40% fly ash	7	7	100	100	21.2	16.1	0.22	0.46
60% fly ash	7	7	100	100	24.7	21.7	0.26	0.80
80% fly ash	7	8	100	90	18.0	17.0	0.15	0.35
100% fly ash	8	9	80	90	17.4	15.4	0.12	0.20

The low concentrations of the metals are growth-inducing, whereas in higher concentrations they inhibit germination and growth. 100% fly ash inhibits plant growth probably due to the fact that wheat and pea plants tolerated the heavy metals up to 60% fly ash, but higher concentration of these metals in 100% fly ash caused an adverse effect on the growth of both the plants.

ACKNOWLEDGEMENT

The authors would like to thank the Director, University Service and Instrumentation Centre, University of Roorkee, Roorkee, for providing instrumentation facilities.

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WYKORZYSTANIE ODPADÓW Z ELEKTROWNI CIEPLNEJ

Problem zanieczyszczania środowiska przez elektrownie cieplne opalane węglem jest ciągle aktualny ze względu na ogromny wzrost zużycia energii elektrycznej. Ścieki z typowej elektrowni opalanej węglem obejmują: spusty z chłodni kominowej, odpływy z systemu odpopielania, spusty z odmulania kotła, cieki kanalizacyjne, odpływy z hałd węglowych, ścieki z regeneracji i odpływy ze stawów sedymentacyjnych pulpy popiołowej. Odpadem stałym jest popiół lotny. W prezentowanej pracy przedstawiono fizykochemiczną charakterystykę popiołów lotnych z odpływów ze stawów sedymentacyjnych pulpy popiołowej oraz ich wpływ na wybrane własności chemiczne gleby, kiełkowanie nasion i wzrost wybranych roślin uprawnych. Wzrost roślin na podłożu z domieszką odpływów ze stawów sedymentacyjnych zbadano na przykładzie fasoli (*Phaseolus aureus*) i ketmi jadalnej (*Abelmoschus esculentus*), wpływ lotnych popiołów na rozwój roślin zbadano zaś na przykładzie pszenicy (*Triticum aestivum*) i grochu (*Pisum sativum*).

ИСПОЛЬЗОВАНИЕ ОТБРОСОВ ИЗ ТЕПЛОЭЛЕКТРОСТАНЦИИ

Вопрос загрязнения среды теплоэлектростанциями, отапливаемыми углем, все актуален из-за огромного роста потребления электроэнергии. Сточные воды из типичной электростанции, отапливаемой углем, охватывают: выпуски из башенного охладителя, отливы из системы

золоудаления, выпуски после продувки котла, канализационные сточные воды, отливы из угольных отвалов, сточные воды после восстановления и отливы седиментационных прудов зольной пульпы. Твердым отбросом является летучая зола. В настоящей работе представлена физико-химическая характеристика летучих зоч из отливов из седиментационных прудов зольной пульпы, а также их влияние на избранные химические свойства почвы, прорастание семен и рост избранных сельскохозяйственных культур. Рост культур на основании с добавлением отливов из седиментационных прудов исследован на примере фасоли (*Phaseolus aureus*) и бамии (*Abelmoschus esculentus*), следовательно влияние летучих зол на рост культур исследовали на примере пшеницы (*Triticum aestivum*) и гороха (*Pisum sativum*).