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Trace Elements in Sediments, Water, and American Coots (*Fulica americana*) at a Coal-fired Power Plant in Texas, 1979-1982

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Because of increased demand for electricity and dwindling supplies of natural gas and petroleum, electric power companies are turning to alternate energy sources as boiler fuels. A large part of the demand will have to be met with coal-fired plants. Even though coal is a plentiful fuel, its combustion has the potential for significantly impacting fish and wildlife and their habitats (Cherry and Guthrie 1977; Dvorak and Lewis 1978); a major problem is the storage and disposal of fly ash containing toxic heavy metals and other harmful substances.

Central Power and Light Company (CPL) completed Unit-1 construction of a two-unit, coal-fired plant in eastern Goliad County near Fannin, Texas, in October 1980. Unit-1 consumes about 30,000 tons of low-grade bituminous coal per week with an ash content of 9.1%. The fly ash is precipitated from the flue gas and hydraulically sluiced to a 77-ha settling basin (ash pond). Before plant operation began, we observed that waterfowl, shorebirds, and other aquatic birds were attracted to the ash pond as a resting and feeding site. Analysis of the coal for trace elements by CPL indicated concentrations of certain toxic metals such as nickel, copper, cadmium, lead, and mercury, among others. Even if initially present in low concentrations, these elements have the potential of accumulating to toxic levels in the sediments of the ash pond. Waterbirds could either ingest sediments or contaminated organisms during their feeding process with detrimental effects. Laboratory studies have demonstrated adverse effects in waterbirds fed diets containing sublethal concentrations of heavy metals (Heinz 1974; Heinz and Locke 1976; White et al. 1978; White and Dieter 1978; Cain and Pafford 1981).

This study was conducted to determine the temporal accumulation of trace element concentrations in water, sediments, and waterbirds at a coal-fired power plant ash pond and to document aquatic bird use of the ash pond.

MATERIALS AND METHODS

Five sampling stations for water and sediments were established at the ash pond in April 1980 with baseline samples collected before the plant became operational. Thereafter, water and sediment samples were collected at 6-month intervals for 2 years after the plant began functioning in October 1980. Sediment samples were collected by pushing inverted chemically cleaned 250-ml glass jars into the substrate until they were full. Water samples were collected by filling chemically cleaned 500-ml glass bottles just below the water surface. Samples were refrigerated before being shipped to the Patuxent Wildlife Research Center (PWRC) for elemental analysis. Baseline samples of American coots (Fulica americana) were collected with steel shot during March, October, and November 1979 at the ash pond and at a control site (Port Mansfield, Texas). Subsequent samples were obtained at approximately 6-month intervals in March and October. We believe that coots were a good representative species since they utilized the most extensive habitat and feeding niche of 14 waterfowl species studied in south Texas (White and James 1978). Livers, kidneys, and femurs of coots were dissected and shipped frozen to PWRC for elmental analysis. Livers were analyzed for cadmium, copper, mercury, molybdenum, nickel, and zinc; kidneys for arsenic and selenium; and femurs for lead.

Coot tissues were analyzed for elements as described by Haseltine et al. (1981), except that a Perkin-Elmer model 5000 atomic absorption spectrophotometer was used. Soil samples were dried overnight at 80^{o} C. Twenty ml 3:1 hydrochloric acid:nitric acid were added to a 1-g portion and the sample was digested over a hot plate for 4 hr. The digestate was filtered and diluted to 25 ml with distilled deionized water and analyzed for elements as in Haseltine et al. (1981). Water samples were acidified by adding 5 ml concentrated nitric acid per 50 ml water and allowed to sit overnight. A 50-g portion was taken for mercury analysis. For other elements in water, 5 ml concentrated nitric acid were added to a 50-g portion and evaporated slowly on a hot plate to 10 ml; the sample then was diluted to 50 ml with distilled deionized water and analyzed for elements as in Haseltine et al. (1981). All mercury water portions were digested and analyzed as described by Haseltine et al. (1980). Limits of quantification ranged from 0.1-0.2 ppm for tissues, 0.02-7 ppm for sediments, and 0.1-5 ppb for water.

Biweekly mid-morning censuses were conducted throughout the study period to document aquatic bird use and abundance at the ash pond. All birds observed were identified to species, counted, and their activities noted (either resting or feeding).

RESULTS AND DISCUSSION

Element geometric mean concentrations (ppb, wet weight) in water samples were very low for all collection periods and some elements in water appeared to increase over time (Table 1). Statistical comparisons were not possible because numerous samples were lost during the shipping and analytical processes. Also, there was unexplained extreme variation in element concentrations at collection stations among periods, e.g., at 1½

Table 1. Element concentrations (ppb, wet weight) in water samples

Collection Period	n	Pb	Cu	Zn	Ni	Cd	Hg	Mo	As	Se
Pre-Startup (1 year)	3	0.9[1] (2)[2] ND[3]-1.8[4]	0.7 (1) ND-4.4	53.2 (3) 18.7-96.8	ND	ND	0.4 (1) ND-1.4	5.9 (1) ND-33.3	6.1 (3) 4.9-7.3	0.7 (1) ND-1.2
Post-Startup (6 months)	5	4.1 (5) 1.4-12.1	ND	37.9 (5) 34.1-45.4	ND	0.2 (4) ND-0.9	1.0 (5) 0.5-2.9	4.5 (2) ND-13	6.5 (5) 2.4-2.9	0.6 (5) ND-1.7
Post-Startup (1 year)	2	2.5 (1) ND-25	6.3 (1) ND-157	25.0 (2) 9.4-66.6	28.7 (1) ND-329	1.0 (1) ND-18	0.3 (1) ND-0.6	ND	5.4 (1) ND-58.6	1.7 (1) ND-5.7
Post-Startup (1½ years)	4	4.9 (2) ND-21.2	0.9 (1) ND-53.4	82.8 (4) 94-1084	ND	0.5 (3) ND-2.6	0.4 (2) ND-0.7	5.0 (2) ND-13.8	1.6 (3) ND-14.6	0.8 (1) ND-3.6
Post-Startup (2 years)	2	1.3 (1) ND-6.4	ND	6.6 (2) 4.6-9.4	ND	ND	0.3 (1) ND-0.6	ND	5.9 (2) 2.3-15.4	2.3 (1) ND-10.5

[1]Geometric mean; ½ detection limit used for ND values in calculating geometric means
[2]Number of samples with detectable residues
[3]ND=not detected at limits of quantification
[4]Extreme values

years post-startup the highest value for zinc was 1,084 ppb, but 6 months later it was only 9.4 ppb (Table 1). Element concentrations in water that we detected were hundreds of times less than those reported for a similar study (Cherry and Guthrie 1977).

Element concentrations in sediment samples were much higher than in water and also appeared to increase temporally, e.g., molybdenum was not detected in pre-startup samples, but was present one year after startup at a geometric mean level of 24.4 ppm (dry weight), ranging up to 143 ppm (Table 2). However, except for molybdenum (ANOVA, $F= 5.43$, $df= 1$ and 15, $P<0.05$), there was no significant difference ($P>0.05$) in geometric means of pre-startup sediment samples ($n= 5$) and post-startup combined samples ($n= 12$), probably because of the extreme unexplained variation in values for each element (Table 2).

Elements did not accumulate to alarming concentrations in American coots collected at the ash pond after plant startup and there was no predictable pattern of residue accumulation in tissues over time (Tables 3 and 4). For most collections, element geometric means were similar for ash pond and control site samples. Although some elements were statistically higher in power plant coots than controls, e.g., copper at 1-year post-startup (9.4 ppm) vs. control site (5.2 ppm), the overall concentrations were below known-effect levels in birds (Gasaway and Buss 1972; Wood and Worden 1973; Heinz 1974; Longcore et al. 1974; Ort and Latshaw 1978; White et al. 1978; White et al. 1980; Cain and Pafford 1981) and are probably biologically insignificant.

The power plant ash pond proved to be very attractive to aquatic birds. During biweekly censuses throughout the study period, we documented 114 species using the 77-ha pond as a resting and feeding site. The American coot was the most abundant species, with numbers varying from 20 to several hundred individuals. It also was the most regularly occurring species, averaging about 85%. Waterfowl (Anatidae) were the most frequent and abundant group of ash pond users. Thus, it is comforting to know that generally waterbirds were not exposed to harmful metal concentrations at the CPL site near Fannin, Texas. However, since contaminants may accumulate to elevated concentrations in sediments, water, and food organisms over a longer period of time than during this study, we recommend that additional sampling be done at the CPL site every 4 or 5 years for elemental analysis.

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Table 2. Element concentrations (ppm, dry weight) in sediment samples

Collection Period	n	Pb	Cu	Zn	Ni	Cd	Hg	Mo	As	Se
Pre-Startup (1 year)	5	1.5[1] (1)[2] ND[3]-7.8[4]	1.0 (4) ND-3.7	4.2 (4) ND-68	2.0 (2) ND-7.7	0.4 (3) ND-1.5	ND	ND	0.7 (5) 0.2-1.8	0.1 (1) ND-5
Post-Startup (1 year)	4	2.3 (1) ND-27.5	8.5 (4) 1-57	25 (4) 10.4-77.3	4.3 (2) ND-22.3	0.2 (1) ND-0.4	ND	24.4 (3) ND-143	3.8 (4) 1-23.9	1.6 (3) ND-244
Post-Startup (1½ years)	3	6.4 (2) ND-19.3	18.3 (3) 3.5-45.9	36.9 (3) 20.3-53.1	10.4 (3) 2.7-20.9	0.3 (2) ND-0.6	ND	28.0 (3) 15.3-102	5.9 (3) 1.1-22.9	1.3 (2) ND-213
Post-Startup (2 years)	5	3.6 (2) ND-37.3	1.1 (3) ND-23.7	11.4 (5) 1.6-49.4	4.6 (3) ND-21.5	0.1 (2) ND-0.3	ND	13.8 (4) ND-43.6	1.5 (4) 0.8-5.8	0.7 (4) ND-8.5

[1]Geometric mean; ½ detection limit used for ND values in calculating geometric means
[2]Number of samples with detectable residues
[3]ND=not detected at limits of quantification
[4]Extreme values

Table 3. Element concentrations (ppm, wet weight) in American coot livers

Collection Period	Location	n	Cu	Zn	Ni	Cd	Hg	Mo
Pre-Startup (1 year)	Power Plant	19	5.2[1a] (19)[2] 1.6-14[3]	40.2[a] (19) 20-87	0.14[a] (10) ND[4]-2.2	0.11[a] (12) ND-0.38	0.02[a] (11) ND-0.06	2.8[a] (19) 0.6-8.2
	Control Site	10	4.9[a] (10) 3-6	33.1[a] (10) 28-44	0.12[a] (5) ND-0.9	0.07[a] (2) ND-0.32	0.03[a] (6) ND-0.09	1.3[b] (10) 0.8-2
Post-Startup (6 months)	Power Plant	19	8.7[a] (19) 2.2-16	50.0[a] (19) 34-76	0.12[a] (11) ND-0.62	0.73[a] (19) 0.1-2.2	0.08[a] (17) ND-0.84	1.2[a] (18) ND-2.4
	Control Site	10	5.0[b] (10) 2.6-12	35.1[b] (10) 20-62	0.10[a] (5) ND-0.4	0.15[b] (7) ND-0.62	0.04[a] (9) ND-0.08	2.1[b] (10) 1.4-3.2
Post-Startup (1 year)	Power Plant	20	9.4[a] (20) 3.4-36	43.3[a] (20) 32-78	0.10[a] (9) ND-0.86	0.20[a] (16) ND-1.6	0.03[a] (14) ND-0.44	1.6[a] (20) 0.7-4.6
	Control Site	10	5.2[b] (10) 2.8-12	35.4[b] (10) 28-46	0.13[a] (7) ND-0.56	0.09[a] (1) ND-22	0.03[a] (8) ND-0.06	1.2[a] (10) 0.8-2.4
Post-Startup (1½ years)	Power Plant	20	7.7[a] (20) 3.6-19.9	36.4[a] (20) 23.9-59	0.24[a] (14) ND-4	0.21[a] (15) ND-1.1	0.02[a] (12) ND-0.06	2.04[a] (20) 0.9-5.9
	Control Site	10	6.7[a] (10) 3.1-11	34.8[a] (10) 22.4-51	0.22[a] (8) ND-0.75	0.27[a] (9) ND-0.51	0.01[a] (3) ND-0.03	2.8[a] (10) 1.2-6.2
Post-Startup (2 years)	Power Plant	20	8.7[a] (20) 5-23	67.7[a] (20) 47-90	0.06[a] (1) ND-0.57	0.23[a] (20) 0.11-0.51	0.05[a] (16) ND-0.26	2.5[a] (19) ND-15.5
	Control Site	10	8.9[a] (10) 4.2-14.6	68.3[a] (10) 56-77	0.07[a] (3) ND-0.75	0.20[a] (8) ND-0.42	0.08[a] (10) 0.06-0.86	1.8[a] (8) ND-3.3

[1]Geometric mean; ½ detection limit used for ND values in calculating geometric means
[2]Number of samples with detectable residues
[3]Extreme values
[4]ND=not detected at limits of quantification
[ab]Means for a collection period with different superscripts are significantly different (ANOVA, $P<0.05$)

Table 4. Element concentrations (ppm, wet weight) in American coot tissues; femurs were analyzed for Pb and kidneys for As and Se

Collection Period	Location	n	Pb	As	Se
Pre-Startup (1 year)	Power Plant	20	0.4^{1a} $(17)^{2}$ $ND^{3}-1.9^{4}$	0.05^{a} (5) ND-0.3	1.1^{a} (20) 0.1-1.8
	Control Site	10	0.3^{a} (5) ND-1.7	0.04^{a} (1) ND-0.6	1.0^{a} (10) 0.6-1.4
Post-Startup (6 months)	Power Plant	20	0.3^{a} (12) ND-2.6	0.05^{a} (4) ND-1.7	3.1^{a} (20) 2.1-4.8
	Control Site	10	1.0^{a} (10) 0.4-3.1	0.04^{a} (2) ND-0.07	2.0^{b} (10) 0.9-2.9
Post-Startup (1 year)	Power Plant	20	0.3^{a} (17) ND-2.2	0.05^{a} (8) ND-0.2	2.2^{a} (20) 1.3-5.5
	Control Site	10	0.2^{a} (8) ND-2.0	ND^{a}	2.2^{a} (10) 1.8-4.5
Post-Startup (1½ years)	Power Plant	20	0.2^{a} (10) ND-2.3	0.03^{a} (2) ND-0.09	2.3^{a} (20) 0.8-4.7
	Control Site	10	0.7^{b} (8) ND-5.5	0.03^{a} (1) ND-0.06	1.7^{b} (10) 1.2-2.2
Post-Startup (2 years)	Power Plant	20	0.6^{a} (18) ND-3.0	0.06^{a} (6) ND-0.5	2.9^{a} (20) 0.6-7.5
	Control Site	10	0.7^{a} (9) ND-2.8	ND^{a}	2.5^{a} (10) 1.3-3.9

[1]Geometric mean; ½ detection limit used for ND values in calculating geometric means
[2]Number of samples with detectable residues
[3]ND=not detected at limits of quantification
[4]Extreme values
[ab]Means for a collection period with different superscripts are significantly different (ANOVA, $P<0.05$)

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